Management for Professionals

Ganesh Mahadevan
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Lean Management for Small and Medium Sized Enterprises

Adapting Operations to Changing Business Environment

Springer

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To our families…

Foreword

The upheavals across the world over the last three years are unprecedented. Just as the world started coming to grips with the COVID-19 pandemic, along came the Ukrainian conflict. We have seen entire industry segments almost wiped out due to a combination of lock-downs and international travel restrictions. Factories were shut down in different countries resulting in a huge shortage in key components that lead to even the mighty Toyota scaling down their own operations. The recent rise in fuel process is causing intense pressure on logistics, manufacturing and processing costs and thereby profitability margins. And yet at the same time, industry is also having to cope with dampened market demand.

The brunt of these disturbances has been borne by the Small and Medium Enterprises (SMEs) who do not have the large reserves needed to cushion such long term shocks. It is not easy to suspend operations for months together and still be able to pay off salaries, interest on loans and fixed costs. Several businesses have folded up or scaled down operations significantly. This does not augur well for the economy at large since it is a well proven fact that SMEs form the backbone of nation's economy and are a significant employer in most nations. So what can an SME do to survive in this environment and continue to grow in the long run?

In my opinion Lean remains the "Go-to" philosophy in these difficult times and it has never been more relevant than now. Two key characteristics of a Lean organization stand out as a beacon of hope – flexibility and productivity. Flexibility enables the organization to scale up and down rapidly to match the business demand and volatility in the external environment. Productivity makes us more efficient and cost competitive. Both these aspects lead towards long term growth and sustenance. Lean as a management philosophy has been around for over four decades. Numerous books, articles, and papers have been published and anyone can just Google to read and learn about Lean concepts, tools, and techniques. However, the actual rate of success in implementation remains a question mark. In the case of SMEs, rate of adoption itself has been negligible.

This book therefore has come out at exactly the right time and context. The authors seek to explain the reasons for Lean "hesitancy" and provide alternative approaches to break down the barriers to adoption. It addresses, how business owners and senior executives motivate themselves to invest resources in commencing the Lean journey. And having commenced, how does the organization sustain the practices to ensure long term business growth. The main body of this book lays out a comprehensive stage-by-stage methodology to implement a well-defined roadmap concluding with ways to sustain the improvements through culture building practices. The chapters are peppered with real life examples giving readers an insight into how Lean actually works and delivers results. A few features set this book apart from other books on Lean. It provides additional guidance on how Lean integrates with other management philosophies and technologies such as IoT. It discussed, how Lean helps cope with prevailing uncertainty. And most value adding are the case studies spanning diverse situations and industry sectors which are written from the first-hand experience of the authors.

Over a decade ago I had the good fortune of engaging with Ganesh Mahadevan, one of the co-authors, during the course of our SME Financing and Development project implemented by German Technical Cooperation (GTZ). He came out with a proposal to implement Lean in the pharmaceutical sector at a time when it was unknown to the entrepreneurs in this sector. The initial seminar to bring about awareness was well attended and three young second generation business owners signed up by committing to pay 50% of the consulting fees. Over the next six to nine months, I was able to witness first-hand, the transformation in their factories and processes leading to significant and ongoing business gains. More importantly, Lean was able to positively impact employees in the organization across the hierarchy right from top management to the plant operators. A decade later, all three businesses continue to grow. The most consistent adopter of the lot has now grown tenfold and has become a global exporter with multiple facilities.

The story I have shared above is a teaser of one of the several case studies that form the latter half of this book. Each case study shares a different perspective on the Lean implementation journey focusing on how to make Lean work across as diverse fields as a restaurant, an engineering job shop, high volume manufacturing set up, a warehouse and an agriculture based processing unit. There are learnings to be had by one and all whether you own a business, manage and run it or are an operating level executive.

I spent the intervening years since my first-hand experience of Lean at work as the Head of the National Institute – MSME, India's premier knowledge hub for the development and growth of SMEs. Government officials and SMEs from across the globe have participated in various NI-MSME programs covering organizational development, sustainability and growth. But the Lean intervention left an indelible mark on my mind and continued to remain at the top of my consciousness. And so it is with great happiness that I welcome the publication of this book. I urge all of you to read on…learn …and grow! Best wishes to authors and publishers.

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Preface

Lean is becoming an ever more relevant operational strategy in the post-COVID world due to the changing socio-economic scenario. Global recession and new work normal such as social distance are forcing organizations to look at ways to boost productivity, make processes fast, flexible, and Lean. A recent McKinsey report indicates that the COVID induced disruption may result in a 16% to 26% of global trade shift. The emerging economies in South and Southeast Asia and elsewhere are some of the beneficiaries of such shift. However, for the emerging economies to be competitive, they would need to embrace Lean concepts. SMEs from emerging economies have a great opportunity to move up to the next level both in terms of business growth as well as in becoming a part of the global supply chains.

Perspective of the book

Over the past two decades, Lean management has become one of the most talked-about management philosophies for business operations. There is a lot of literature in terms of books and articles, training material, and publicly available information on the internet. Millions of professionals world over are training themselves on Lean and its allied concepts. Yet, when it comes to actual implementation, there are more failures or sub-optimal implementations than there are successes. It is now an established fact that merely copying tools and techniques does not deliver the desired results. The ability to achieve improvements and sustain them depends on piercing through superficial facts and look in-depth at factors contributing to long-term successful implementations despite seemingly adverse circumstances. The failure to sustain is both due to a lack of appreciation of the Lean philosophy as also due to missing out on certain critical implementation nuances. The primary objective of this book is to bridge the gap of the unavailability of an implementation-oriented Lean management book, especially one that focuses on the needs of SMEs. Also, most books on Lean and its implementation are based on case studies and experiences of Japanese organizations, primarily Toyota, and of organizations in the Western world (USA and Europe). This is difficult to relate to for industries in developing economies where the economic, social, and cultural environments are different. Again, most literature especially the case examples are related to large organizations and therefore focus on aspects of organization culture, building Lean champions and teams and looking at long-term Lean and Continual Improvement (CI) interventions with a horizon of years. For SMEs the strategic focus is mostly on the here and now. They do not have the bandwidth of large teams or afford to employ Lean champions. This book is intended to bridge these shortcomings in the current body of Lean knowledge.

Diverse business situations such as meeting the demand fluctuations, designing a facility, or improving profit margin, etc. are included in the case studies from diverse industry sectors, to ensure that every reader finds a situation similar to his / her organizational situation. While the publicly available literature on Lean offers a large collection of tools and techniques, given each organization's unique context, the choice of the right sequence of tools differs. The book offers guidelines in terms of which solutions work in which context, backed by real cases, which is a big help to the resource constrained SMEs. This book is an equally good resource for the organizations that have already implemented Lean, as it provides realistic pointers about sustaining, tackling supply chain uncertainties and going beyond Lean by integrating emerging technologies and management principles. The following are the highlights of this book.

- Focusing on what Lean means as an operational strategy for the SMEs and how to deploy and make it a sustained success considering the socio, cultural, and economic factors unique to developing economies,
- Lean is all about the implementation and chapters are organized in terms of project life-cycle based flow rather than basis of Lean tools and techniques,
- Diverse real-life SME case studies from an emerging economy like India ranging from discrete to process manufacturing, products to services, and tactical to strategic implementations,
- Push Lean-driven results to new frontiers by integrating with other operations excellence initiatives such as sustainability, six sigma, Industry 4.0, theory of constraints (ToC), and time-driven activity-based costing (TdABC),
- Discuss the factors that support, or diffuse the Lean momentum based on interactions with owners and senior managers of SMEs who have implemented Lean, and
- Integrate supply chain resilience and Lean management, and present lessons on how to handle disruptions, a dire need of the hour for SMEs.

The philosophy of the book is distilled directly from the interactions with the original Kaizen Sensei. The application of well-proven Lean concepts in large automobile and engineering industries is adapted, tinkered and fine-tuned to suit the needs and constraints of SMEs. This unique blend stems from the authors' first-hand experience as well as access to work done by their organization at over 150 organizations across industry sectors ranging from SMEs to large multinationals across the world. Experience gained from multiple Lean transformations indicates that the key to success is in understanding and adapting the philosophy to the unique human and cultural aspects of each organization and region.

At the tactical level, the book guides the reader through practical approaches to deploying Lean. This includes how to set the context for Lean, diagnosing, and framing a Lean improvement roadmap, approaches to implement the roadmap, and what works best in which situation. (S) he will also learn from the failures and successes of organizations that have already undertaken the Lean journey in a variety of situations.

Organization of this book

The book consists of six modules organized along the typical Lean implementation life-cycle phases.

The first module of the book (Chaps. 1 and 2) covers introduction of Lean management to the reader with a brief background of Lean origination at Toyota, its spread through the rest of the world, and an overview of the current state of Lean across different industry sectors and sizes. The book then proceeds to set the context on the imperative of adapting Lean management in the current volatile environment – the value proposition of Lean implementation. The last chapter of the first module discusses the core principles of Lean and a conceptual Lean implementation framework incorporating the stages of stabilization, flow, pull and the ideal of single piece flow. A brief outline of the key Lean concepts, tools and techniques relevant to each stage is provided and then we end with the typical performance metrices used to measure the success of Lean.

Module-II (Chaps. 3 and 4)provides an overview of SMEs covering their role in economic development, challenges, constraints, government programs, and the ownership and management styles. Previously published literature on Lean implementation in SMEs from various sources is reviewed. Important findings such as identified barriers and enablers to Lean implementations are highlighted. Authors own experiences in terms of how to overcome financial and non-financial barriers are discussed to give the reader some creative ideas. This module concludes with a generic framework to implement Lean in SMEs, and discusses typical implementation model variants.

Module III (Chaps. 5–7) deals with the implementation of Lean and is as such the core of the book. The first step is to diagnose business operations under the Lean paradigm. Lean performance metrics such as quality, delivery, internal productivity metrics such as value-added ratio, people productivity, Overall Equipment Efficiency (OEE), etc., are introduced to the reader here. Key tools, benchmarks and techniques for diagnosing different industry sectors and their linkages to overall organizational financial performance is discussed. We move on next to the project planning stage in which the improvement roadmap is framed that maps business goals, improvement areas and priorities on to implementation schedule. The two key components of Lean, creating flow and enabling flow, are discussed with a detailed step by step practical approach for implementing them. Softer aspects such as the role of champion, communication, feedback loop, and experimentation in implementation effectiveness are discussed in this Module.

Module IV (Chaps. 8 and 9) looks at how organizations can stabilize improvements made in the implementation phase through the judicious use of standards, elements of Autonomous and Planned Maintenance and deploying organization wide 5S. Stabilization is the key to ensuring the gains from Lean are held over the long term. Data shows that over half of all Lean implementations do not sustain the momentum and fall back to old ways within two years of the original implementation. We track organizations through typical stages of Lean adoption and review the reasons for lack of sustenance based on direct feedback from a cross section of SME owners who have been on the Lean path. At the same time, we also look at possible ways in which SMEs can overcome some of these hurdles and develop a culture that not only sustains but also continuously improves its Lean status.

Lean is a journey towards perfection and is therefore an ongoing pursuit of excellence. Module V (Chaps. 10 and 11) provides guidance to the readers with suggestions on how other emerging management philosophies such as sustainability, Six Sigma, theory of constraints, Industry 4.0, and TdABC integrate with Lean principles and can be leveraged to achieve further improvements. The book demonstrates the synergies and necessity of such integrated approaches. Further, the module describes the increased relevance of Lean in the context of increased supply chain uncertainties. Lean is known to make processes fast, while being flexible and thereby enhance supply chain resilience. Solutions such as building redundant capacity adapted by larger enterprises may not be suitable options for SMEs. Hence, flexibility-based supply chain resilience solutions that fit the constraints of SMEs are proposed.

Throughout the book, caselets are provided to illustrate specific topics at relevant places. These caselets are derived from the larger stories of successful Lean implementations at a SMEs across a range of industry sectors to give readers a wide perspective on the nuances of Lean implementation. Having gone through various aspects of a Lean implementation project life cycle, readers will be able to appreciate and learn from the overall social-cultural-economical context of the complete case studies in Module VI. Range of business drivers and how Lean facilitated these drivers are discussed in these cases. Some examples are, how to grow rapidly, how to meet demand fluctuations, what is the best layout for a new facility, how to perk-up the eroding profit margins and how to build a motivated team – to name a few, are covered in detail.

Guide to the Case Studies Section

Over the last two decades, one of the authors has consulted for over a hundred organizations, mostly Small and Medium Enterprises, helping them improve their operational and business performance. These SMEs are from a diverse array of sectors, ranging in turnover from micro, small, medium to large, located across different regions of India, the Middle East and Southeast Asia and with varied management styles. The cases presented in this book have been carefully selected from among these so as to present the reader an experience of wide-ranging implementations.

The following table summarizes the contours of the seven case studies detailed in module VI, which will help the reader not only identify key take-aways but also navigate through the cases to dwell deeper into any particular context of interest. Each of these Lean stories is unique and throws light on different facets of implementation and sustenance of Lean.

Each case details key aspects of the Lean journey undertaken by the SME and showcases the application of relevant Lean tools and techniques in different situations. Readers are encouraged to refer to the appropriate section in the earlier modules to refresh themselves about these concepts, tools, and techniques when required.

Audience and Pathways

SMEs form the industrial backbone of the developing economies providing significant employment opportunities and are a vital link in supply chains. SME owners/entrepreneurs often hesitate to take the plunge into implementing Lean management concepts primarily due to lack of awareness of benefits and a wrong notion that implementation is either complicated or costly. Even those who are aware of general principles of Lean are unable to relate them to their context. This book is intended to be a practical guide on what to expect from Lean management and covers Lean implementation steps systematically and effectively in the given the backdrop of typical constraints of SMEs.

It details an approach that has been tested and fine-tuned at over a hundred organizations, mainly SMEs, across the emerging economies of India, Southeast Asia and the Middle East. The approach follows the typical flow of an implementation cycle and enables the reader to understand the imperative for Lean, how to diagnose current operations, how to plan and deploy Lean and shows a path for long-term sustenance. The overall focus of this book is therefore to bring about a 3600 perspective in Lean management implementation at SMEs, right from need identification through ongoing sustenance.

Senior executives responsible for large manufacturing units and corporate officers looking at driving Lean across the supply chain would also benefit from the book, given its implementation-oriented approach.

The primary audience for this book therefore are SME business owners, CEOs, plant / production managers and professionals engaged in operational excellence activities. This book would help them understand Lean philosophy and the business benefits of deploying Lean as an operational strategy. The secondary audience are researchers and students of operations management. Of special interest for them would be the enumeration of key aspects for success or failure of Lean interventions in SMEs and the use of different approaches to Lean implementation in different situations and industry sectors. How Lean fits in with other emerging

Table 1 Summary of full cases of lean implementation

Characteristic	Company						
	PAN seeds	Linkwell	Liberty	Toys manufacturer	Gubba	Pharma cluster	GSV
Industry	Agri products	Electronics	Services (hospitality)	Consumer manufacturing	Warehousing	Pharmaceutical	OEM manufacturing
Product(s)	Seeds	Energy meters	Restaurant services	Toys	Cold storage space	Bulk drugs and intermediates	Fabricated parts for motors
Revenue category	Medium	Medium	Micro	Small	Small	Small	Micro
Demand pattern	Seasonal: peaks twice a year	Regulatory product: contract-based and so fluctuates	Peaks at weekends and holidays	Generally, peaks in months leading to Christmas and new year	Inflow and outflow peaks at particular times of the year	Steady demand through the year	Linked to pump OEM which is again a seasonal industry
Customer	Dealers and distributors	Government organizations	Public	Global toy majors (export)	B2B (seed, pharma, and food industries)	Pharma majors	Pump OEMs
Management style	Mix of first and second generation	Professionally run with first-generation owner support	Run directly by first generation	Professional management (owners oversee finance and strategy)	Run directly by second generation	Mix of first and second generation	First-generation owner-driven
Workforce	Contract labour gangs + full-time supervisors	Mix of company employees and contracted workforce	Mix of full-time staff (chefs, etc.) and casual workers (housekeeping)	Mix of company employees and contracted workforce	Contract labour gangs + full-time supervisors	Full-time employees only	Full-time employees only
Supply chain	Farmer aggregators	Subcontractors [mported part suppliers	Local groceries	Component/RM suppliers	Only infrastructure suppliers	RM suppliers—local and import	Sheet metal suppliers
Trigger for lean	Systematic working	Low margins	Growth potential	Global customer pressure	To be world class	General curiosity	Rapidly rising demand

management philosophies and technological solutions such as ERP and industrial IoT, theory of constraints, Sustainability also provides useful directions to the academic and research community.

We hope readers find valuable take-aways from this book.

Secunderabad, India — Ganesh Mahadevan
Hyderabad, India — Kalyana C. Chejarla

Acknowledgements

The seeds for writing this book were planted when we were under “house arrest” as the COVID-19 pandemic first broke out. Two months of sitting at home would have been unbearable had we not chosen to spend this time in penning down case studies of significant recent work. Reading and rereading some of the best books on Lean and allied philosophies made us realize that we could still bring to the world, new aspects and ways of looking at Lean under different paradigms.

One of the highlights of this book is the varied and detailed stories of Lean at work in different industry sectors. This would not have been possible without the willingness of the industry owners and their plant managers to share their stories. We would like to thank Anshuman Marodia (Pan Seeds), Ms. Radha Rani and Mohan Rao (Linkwell), Vishal Lalwani (Liberty Exclusive), Kiran and Prashanth Gubba (Gubba Group), Chandrasekhar Reddy (GIZ), Srinivasan (Porus), Krishna Chaitanya (A.R. Lifesciences), Vamsi Krishna (Fine Group), and Manish Gupta (Rockwell) for allowing us to write about how Lean has worked at their respective organizations. We would also like to acknowledge Mr. Vijay Rangarajan (GSV Industries) for our case study from the Coimbatore Engineering Cluster Lean implementation program.

Implementing Lean successfully in MSMEs in a developing economy has its own set of challenges. The approach to changing the mindset is the key. I, Ganesh Mahadevan, have personally learned how to drive Lean on the gemba under my guru S. Dorairajan and through the teachings of Sensei (late) Dr. Gondhalekar (Dr. G), both founders of Kanzen Institute. I am indebted to them for providing me the opportunity to work with them and be able to develop this body of knowledge. A special mention to my father Dr. E.G. Mahadevan without whose constant prodding I would never have attempted to write a book and get it published.

And I, Prof. (Dr.) Kalyana C. Chejarla, am immensely thankful to all my colleagues and management at Institute of Management Technology (Hyderabad) for providing an extremely inspiring and intellectually stimulating academic environment, without which it would have been unthinkable for me to undertake such a writing project. Above all, I am especially grateful to almighty for whatever courage, intellect, and grit he graced upon me which is the true foundation of everything worthy that I have ever endeavoured.

Ganesh Mahadevan
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1 The Imperative of Lean Management

1.1 History of Lean Management

Two world events played a pivotal role in the development and adaption of Toyota Production System (TPS), a precursor to Lean management. First, the Second World War ravaged Japan, led to a period of economic distress that became a source for the creation of ingenious, innovative, humane, sustainable and in many ways, a common-sense approach to production by Toyota. For instance, general-purpose machinery, rather than the specialized large machinery favoured by the then mass manufacturers like Ford allowed production of smaller batches of larger varieties of components. Or, closer supplier-ties enabled just-in-time supplies and thereby enabling quicker product changeovers. Further, smaller families, smaller parking lots, and constrained budgets of customers have led Toyota to build smaller and fuel-efficient cars, as against the larger models prevalent in the western world. The goal was then to deliver small numbers of a variety of cars at low costs to the fragmented Japanese market post the devastation of the Second World War. Reduced purchasing power in the post-war years meant cars had to be affordable even for those few people who could still think of owning a car. At the same time, there needed to be some choice in terms of product to satisfy different needs. Hence, right from its origin, Toyota's manufacturing has been oriented to delivering what the customer wants in the shortest possible time and lowest cost without sacrificing process efficiencies. By 1970s, Toyota had established their own manufacturing philosophy and systems that collectively came to be known as the Toyota Production System (TPS) making Toyota one of the most productive automobile companies in the world. Up to this point in time, Toyota was still operating mainly in the Japanese and Asian markets, and TPS had not yet come into the sights of the western world.

Second, the decade-long oil embargo placed by OPEC countries on the western world starting 1973, led to accelerated adaption of Lean outside of Japan. The embargo induced hike of oil prices for an extended period of time dampened

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the demand for automobiles, especially the large gas guzzlers made by western manufacturers. This led to rise of demand for the relatively smaller and more fuel-efficient cars made by Toyota. The rest of the world started to take notice of Toyota, and by the 1980s, researchers and industrialists were realizing that Toyota continued to make profits while competitors in their own industry were struggling to contain losses. Toyota was open to visits by outsiders to their plants to study and understand TPS, and the resultant research gave birth to what was called Lean thinking. In the successive decades through 2000 and till date, hundreds of organizations have implemented TPS or Lean with different degrees of success. During the same period, Toyota has shot past to become the world's number one automotive manufacturer. The main reason for this differing degree of success from TPS in other organizations is that most of them have tried to implement specific concepts or individual tools, leaving out the larger spirit of TPS philosophy that includes elements of organizational culture, people management, and top management commitment. Fairly soon, the momentum lost steam in most of these firms, which then slipped back to the paths of least resistance. Organizations regressed to old ways of doing things, giving out excuses such as TPS is a Japanese thing or that it is suitable for low variety high volume business or meant only for automobile industry. TPS has sustained in those few organizations that have deeply internalized the philosophy into their organizational routines and made it as their own production system.

An understanding of the evolution of industrial production over the last hundred years or so would help us better appreciate the place of Lean in the current era. The developments can be grouped into four main eras which are detailed in the following sections. Readers can refer Samuel et al. (2015) for a table of specific events and developments related to Lean during the twentieth century.

1.1.1 Mass Production (1908–44)

Industrial scale (mass) manufacturing was pioneered by Henry Ford for the production of Model-T car through the world's one of the early "*moving assembly line*" method. Model-T, launched in 1908, had a successful run of about 19 years without any major changes either to the product or process resulting in a very low cost per car. Till then, most manufacturing was craft based and made using custom parts, resulting in high unit cost. Principles of assembly line production were extended to other industries as well, and functional managers and industrial engineers held the managerial control within organizations. Ford expanded to Europe with the assembly line production methods to avoid the substantial logistics costs (in exporting to Europe market). However, the management burden of a large vertically integrated firm could not provide enough leeway for Ford to drive product variety or component innovation.

Alfred Sloan's corporate structure design at General Motors, with individual divisions held accountable for financial performance from late 1920s, drove organizational efficiency and innovation. General managers with overall Strategic

Business Unit (SBU) responsibility were in their prime demand during this era. General Motors led the automobile world for 40 years till 1960s. Both Ford and Sloan systems are referred to as mass production systems, and both suffered from poor product quality. However, at this point in time, the Japanese products were also known to be of below par quality albeit at a higher cost.

1.1.2 Toyota Production System (1945–75)

Toyota Motor Company was formed in 1937 under the aegis of Kiichiro Toyoda, who started the company mostly with simple machinery. In 1950, Eiiji Toyoda, Kiichiro's cousin became the Managing Director of Toyota Manufacturing, and he travelled to USA and Germany to learn the prevailing production and management processes. He was keen to implement mass production concepts at Toyota, but found it infeasible due to the prevailing capital and market constraints in Japan. However, the delegation which included Taiichi Ohno learnt the notion of producing to takt time from their Germany visit (Holweg, 2007).

Ohno who is widely considered as the mastermind behind Toyota Production System (TPS) started his career as an engineer at the Toyoda automatic looms in 1932. It is here that the origins of TPS lay, where Ohno experimented with production autonomation (*Jidoka*) and learnt its benefits. An example of autonomation popularly cited in the literature is that of an automated loom, which stops production as soon as a thread breaks, instead of continuing to produce bad product automatically. Ohno moved to the automotive business in 1943. Autonomation was the underlying thread (no pun intended) throughout the development of TPS from 1945 to 75. The beginnings of TPS are traced to 1948, when Ohno started with just-in-time withdrawals and removed intermediate storages (Ohno & Bodek, 2019). While cell-based production was already in place, a visit to USA during 1956 prompted Ohno to devise Kanban replenishment throughout Toyota supply chain in the following years. The lot size reduction gained impetus when Shigeo Shingo, who was brought on board in 1955, developed a formal methodology to reduce changeover times of the large presses that were used for sheet metal stamped parts (Dillon & Shingo, 1985). The smaller lots across the supply chain then paved the way for yet another masterstroke, production levelling (*Heijunka*) by Ohno. *Hiejunka* helped Toyota to truly match supply with actual customer demand across models and variants.

American industry/government, as part of post-war support, sent quality gurus such as Deming to help Japanese industry improve its quality. Japanese industry, including Toyota, wholeheartedly welcomed and learnt from this intervention, so as to be competitive globally. TPS tools like error proofing (poka-yoke) and internal supplier and customer relationships with respect to product quality came out of this movement and served to strengthen the *Jidoka* pillar of TPS.

1.1.3 Foray of Lean into USA (1975–2000)

As stated before, a long oil embargo by OPEC on the western world led global automobile manufacturers to start looking closely at TPS as a means to bringing down the operating cost. Growing trade deficit, increasing logistics costs, and strengthening of Yen led Toyota and other Japanese manufacturers to set up both greenfield and brownfield plants in north America. One such notable brownfield venture was the New United Motor Manufacturing, Inc. (NUMMI) at Fremont, California, in collaboration with General Motors. In 1979, Massachusetts Institute of Technology and few other universities and industry sponsors created a research program called International Motor Vehicle Program (IMVP) with an intention to study the differences in production systems at various automobile factories around the world. This research was instrumental in disseminating the notion of TPS manufacturing as Lean manufacturing to the rest of the world via research articles (e.g. Krafcik, 1988), and the popular book "*The Machine That Changed the World*" (Womack et al., 2007, originally published in 1990). The idea behind phrasing TPS as "Lean" by the IMVP researchers is to reflect the fact that TPS uses much lesser resources (people, equipment, space, etc.,) than the mass-producing counterparts. Further, in 1996, Womack and Jones have packed the Lean concept, approach, and implementation in an action-oriented book titled, "*Lean Thinking*" a via set of diverse case studies.

During this period, many other books were written and a number of consultants also started to offer Lean implementation services. The adoption of Lean was faster in the USA, followed by Europe. Further, quality improvement programs in line with Deming's quality award in Japan such as Malcolm Baldrige National Quality Award (MBNQA) have heightened the necessity of improving production processes, especially in the USA. Womack and Jones (1996) document the successes of a few enterprises such as Wiremold, Lantech, Porsche, and Pratt & Whitney on account of Lean adoption in their organizations. Just-In-Time (JIT) was the foremost among the lot in terms of absorption, perhaps because of its highly visible effects. This also required manufacturers to take a closer look at their supplier relationships, resulting in lowering of manufacturing Lead times in the USA in the early 1990. However, this inventory reduction trend began reversing from late 1990s with a steady increase in inventories of manufacturers, retailers, and wholesalers, reflecting that the true root causes of higher levels of aggregate inventories were not yet mastered by majority of industrial supply chains.

As India opened up its economy to foreign investors in 1991, there was an influx of global automobile majors looking to source parts from low-cost Indian manufacturers. The quality standards forced progressive Indian organizations such as the TVS group to start looking to implement Lean under the guidance of Japanese *Sensei* (teacher).

1.1.4 Diffusion of Lean into Rest of the World (2000–2020)

The twenty-first century saw a lot of dissemination of Lean principles both to remaining geographies and to different industry verticals. The diffusion of Lean to the rest of the world and other sectors followed four different tracks (Samuel et al., 2015). They are Lean as a generic version of TPS, as process improvement toolkit, as an organizational ideology, and as an academic research area. The first track of diffusion took the form in which various authors, publishers, speakers, consultants, and other proponents of Lean wrapped the specifics of TPS (be it tools, culture, or philosophy) with an overarching and a generalized approach called Lean. Lean rubbed shoulders with its process improvement cousins such as Six Sigma, Theory of Constraints, Business Process Reengineering, etc., in its second track of diffusion. The third form of Lean diffusion has been broader in the sense that (a) it moved beyond the production floors into boardrooms as an organizational strategy or ideology, (b) service organizations have adopted Lean principles as ardently as manufacturing firms, and (c) the shift of perspective from cost reduction to value maximization among the adapters of Lean. The academic world contributed to final form of diffusion in the form of research specifically in the streams of operations management and organizational behaviour.

In their Shingo Research and Professional Publication award winning compendium, McKinsey & Company describes how companies from different sectors such as financial services (Ameritrade, RBS Citizens Financial Group, Axis Bank, etc.), public services (Swedish Migration Board), and Telecom (TDC) have implemented Lean principles to achieve superior organizational performances.[1]From its homestead of discrete manufacturing, Lean management has been adopted in process industries such as food, steel, pharmaceutical, textile, chemical, paper, and sugar (Panwar et al., 2015). In their study of Lean implementations in public sectors in 26 countries, (Lukrafka et al., 2020) note that the UK leads with 26 implementations followed by the USA with ten implementations. Europe, as a continent, leads with 48 implementations followed by Americas with 17 implementations. We discuss the adoption of Lean by SMEs in Chap. 3.

1.2 The Imperative

A Lean organization is characterized by its capability to satisfy customers on quality, delivery, and price, through fast and flexible processes that quickly respond to customer needs utilizing available resources effectively, thereby

[1] https://www.mckinsey.com/~/media/mckinsey/industries/consumer%20packaged%20goods/our%20insights/the%20consumer%20sector%20in%202030%20trends%20and%20questions%20to%20consider/2014_lean_management_enterprise_compendium.pdf.

incurring the lowest possible cost through operating a visually managed and self-regulating facility.

At the outset, Lean appears contrary to conventional operational strategy that typically pitches "*cost-to-serve*" and "*time-to-serve*" as conflicting objectives and that one should be optimized at the cost of another. Lean management shows us the way to improve on both the objectives, as we shall see in the coming chapters. In particular, the capability to reach higher levels of output not only without any capital investments but also at a much lower operating cost (materials, energy, manpower, etc.,) is highly attractive to the Small and Medium-sized enterprises (SME). The above stated definition of Lean can be distilled into the following two key elements.

- Flexibility of the value stream which is the set of processes that deliver the value in terms of product and/or service to the customer and
- Productivity of the resources used in delivering this value— man, material, energy, machinery, or infrastructure.

The important component of Lean management is the presence of a definite goal, utopian it may be, that provides unfaltering direction to the organization at all decision-making situations without any ambiguity. Managers and executives who embark on Lean transformation think about three fundamental business issues that should guide the entire organization. These are:

- *Purpose*: What customer problem will the enterprise solve to achieve its own purpose of prospering?
- *Process*: How will the organization assess the value stream(s) to make sure each step is valuable, capable, available, adequate, flexible, and that all steps flow in synchronous manner
- *People*: How can the organization ensure there is someone responsible for continually evaluating each value stream in terms of business purpose and Leanness? How can everyone touching the value stream be actively engaged in operating it correctly and continually improving it?

Lean management is a world view with a broader perspective involving the interests of stakeholders starting from customers all the way through to suppliers. Lean also takes a longer-term perspective as against short term, for example, in spending time and effort on root cause elimination, even at the cost of seemingly temporary revenue loss. This perspective always looks to improve business processes, develop standards, and implement systems keeping in mind the following realities that are an inherent part of the world we operate in.

- *Uncertainty of future:* Future is always uncertain, and the farther one looks at, more uncertain it becomes. Forecasts, howsoever sophisticated they are, do not reduce the uncertainty. Plans generated using the forecasts do not become a reality.

- *Process variability:* Processes are variable. Excess capacity or stock building does not reduce the variability, instead hides the immediate effect of it.
- *Everyone in the supply chain needs to make money*. Therefore, in the long run, it is both convenient and profitable to promote transparency, trust, and fair share among all the supply chain members.
- *Resources* is a broad term and includes space, people's effort, materials, machinery, and utilities. Organizations have a responsibility to acquire, use, and dispose these resources in the most efficient manner.
- *Genuine humility* leads to respect for everyone, customers, employees, and competitors, which then leads to accept and work with reality at all levels within the organization.
- *The only constant in the world is change*, and so create an organization that expects change and rapidly learns from it with improvement as the focus.
- *Organizations last longer than individual*. One needs to think beyond oneself and build a system that is self-perpetuating rather than one propelled by an individual or a team.

In the last three decades, many books, articles, and case studies have been written and published covering Lean philosophy, concepts, popular tools, and techniques and comparing Lean with other management methodologies such as TOC or Six Sigma. This book is not so much about hair-splitting definitions of Lean and allied terms, but about presenting solutions that SMEs can use. To that effect, we integrate relevant notions, principles from other management, and technological domains in various chapters and case studies. Lean management is not about east versus west or Toyota versus GM, or Lean versus some other management philosophy. In its true spirit, and the way we deal with it in this book is that, it is a culmination of learnings by and from a multitude of organizations that believe in providing a worthy goods/service to its customers over their lifetimes, by efficient and sustainable use of all the resources at its disposal and by endlessly enhancing the human learning and adaptation potential of its employees. It is a truism that profits (have to) follow.

1.3 Summary

This chapter traces the roots of Lean management to Toyota Production system which was developed in response to the resource-constrained environment in Japan, post-Second World War. As Toyota mastered the art of producing more, that accurately meets the needs of the customers using least resources, the western world plunged into resource-constrained environment in 1970s due to a prolonged oil embargo by OPEC. This paved way for the American companies to take a leaf from TPS handbook. The world industrial production systems have evolved from mass production to mass customization to today's technology led systems.

We looked at how Lean evolved through these systems and across geographies. Finally, we conclude by presenting how Lean maps to the current realities better than any other production system, and thus a clarion call for all firms, and especially SMEs to seriously consider Lean implementation.

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2 Lean Management Principles

2.1 Introduction

Lean management in its ideal form endeavours to develop a value delivery system that continuously learns and evolves, to get closer to the possibility of getting supply to exactly meet when, where, and how the demand occurs. As firms get closer to this ideal in execution, they will observe that some of the assumptions, especially related to forecasts, made in planning phase render themselves unnecessary. This will release the need for cushions in planning and make the firm more responsive to changing market needs, resulting in reducing reliance on forecasts. This creates a virtuous cycle (Fig. 2.1).

All the principles, tools, techniques, and other paraphernalia are created, modified, and dropped, if required, to support and sustain such a learning system. Clearly, the end goal (match demand with supply accurately) is worthy of pursuit, immutable, true north star, independent of the firms' managers, and timeless and provides an unambiguous direction whenever there is a decision dilemma. The ideal is tirelessly pursued by steadily taking steps towards it. No sooner than a firm achieves a milestone, there is a next milestone planned in the Lean direction at the firm. In fact, the true mark of a Lean organization is that it is a learning organization through cycles of continuous improvement (Mrugalska & Wyrwicka, 2017).

Despite being a logical, sustainable, common sense, and scientific approach, Lean is usually shadowed by the overhang of mass production and human inertia to change. A somewhat counter-intuitive (only because of our earlier conditioning) insights such as avoid/reduce batch production add to the mystery in the SME owner/manager's mind. The most unfortunate and yet very common shortfalls in the Lean implementations are the ones which were limited to some specific Lean tools, sans the philosophy/long-term direction. While Lean management does use a lot of tools, good Lean organizations are not fixated by tools themselves, for they are just what the name suggests, tools! A tool is needed in a certain context

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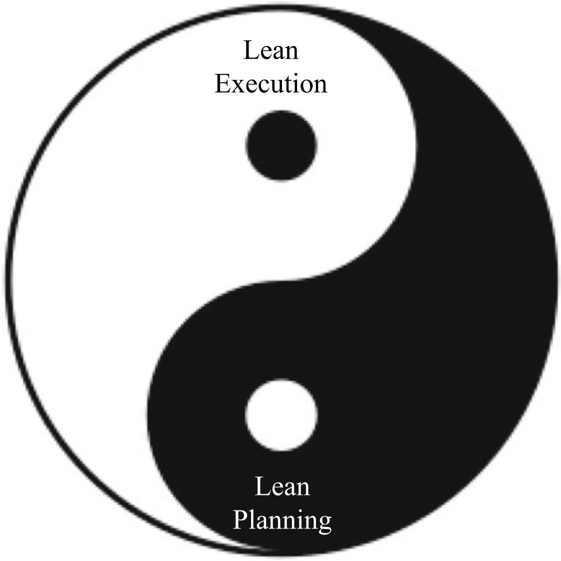
Fig. 2.1 Self-reinforcing virtuous cycle



and another one in another context. The smartness of the Lean organization lies in choosing/adapting or even creating the right tool in right context. Lean is a philosophy based on a paradigm—a way of looking at things. We provide an overview of the foundational concepts of the Lean paradigm in this chapter.

The pursuit of Lean management may be characterized into four distinct, progressively maturing stages. The role of a manager in Lean paradigm is that of a coach who helps the employees master the specific tools, but more importantly build, sustain, and live the learning culture. This chapter describes the foundational concepts behind the Lean management as appropriate for different maturity stages and point out corresponding tools and techniques. Further, the chapter concludes with a brief overview of performance improvements Lean enterprises worldwide have and continue to achieve, providing a financial motivation for an SME to adopt this path.

2.2 Lean Management Philosophy

In any organization, its working philosophy is embedded in its language, behaviour, communication, shared beliefs, routines, cadence, and career paths. The vision and mission statements alone cannot give the full picture. Different organizations will have different philosophies which explain their business procedures and in turn influence employee thinking patterns. Culture can be viewed as the explicit and implicit manifestation of organizational philosophy. Top-down approaches such as mass production assume that not only managers and senior executives know what is good for the organization in the long run, but they also know exactly how to execute these steps, which they instruct to their subordinates. These approaches rely on narrowly defined department-level economies of scale-based unit costs missing the non-value-added effort and time the product undergoes. Further, such approaches miss on the possibility of leveraging the ingenuity of operators at the floor in improving processes and thereby inculcating a sense of ownership in the success of the firm.

On the contrary, Lean management is a true long-term philosophy that is based on the following tenets:

- Profits and growth (long term/sustainable) are a result of continuously and efficiently matching demand with supply. Any other growth is unsustainable and, therefore, offers no lasting organizational learning,
- Buffers (capacity, inventory, and lead time) are a result of poor understanding and management of process and demand variation and not weapons to beat variation. Therefore, a right approach is to incrementally understand and control the variation, and critically question all buffers, and
- Finally, developing and adhering to the standards that reflect institutionalized and prevailing know-how (i.e. based on controlled experiments performed on the shop floor by the operators). The standards provide launch pad for next round of improvement initiatives and are readily changed as soon as an improved method is tested successfully.

This grass-roots-level fundamental understanding of how the organization makes money in the long run makes Lean organizations to have targets for efficient matching of supply with demand, rather than short-term (quarter to quarter) profits and growth. (Please see "Toyota Kata", by Mike Rother for details on how a seemingly harmless pursuit of short-term goals by a firm may put it on a path to its deterioration). Lean enterprises have targets for variability reduction and production cycle time matching to demand rate, rather than maintaining or even reducing buffer levels.

Lean management flourishes in a collectivistic set-up, which is free of individual agendas, idiosyncrasies, or fears. Lean management requires that not only every employee is treated with respect, but is truly considered as a source of human ingenuity to solve problems at the work area. It is universally accepted that in the long run, one man wanting to grow at the expense of others, or an organization wanting to grow at the expense of the customer (by making them pay for its own inefficiencies) is unsustainable. Clearly, sustaining and surviving in the long run requires not giving-in to short-term temptations such as quarterly sales goals and increase profitability by firing employees. Decision-making (especially in the context of improvement investments) according to Lean management philosophy is thus based on the following basic principles:

- Only customer defines/indicates the value of product/service.
- A decision should align with the long-run vision and yet be efficient in the short run in that order. This clearly implies that an efficient improvement proposal is rejected if it is not in alignment with the long-term vision.

- A decision should be based on the floor experimentation-led knowledge not on hunch, not on consultant recommendation, not on Sensei instruction, and not on automation company presentation.
- Between people and machines, people are a more valuable, learning, adaptive, and flexible resource, and thus the work allocation should reflect this understanding.
- Documenting the current state of learning in the form of a standardization document is a “must”, before undertaking any experimentation for improvement.
- Sunk costs (pre-existing capacity) do not justify creation of additional waste (maximizing utilization), e.g. inventory without orders.
- Supplier–customer relation should be established at the smallest of each handover. The objective of such unitary-level tight coupling is to ensure instantaneous transmission of feedback and implementation of corrective response.

2.3 Lean Management Maturity Phases

The end goal of Lean management is to create a supply system (production process) that can dance synchronously in lockstep with demand (of product). The variability in supply and demand needs to be understood, reduced, and responded. One major source of variability is a high time to respond, a.k.a lead time. Longer the time to respond, higher are the chances of a different reality emerging than what was planned and hence a higher variability. Lead time consists of information and material lead times. Taiichi Ohno had once famously said that the focus of the Toyota Production System (TPS) is to reduce the time it takes to meet a customer order from the time it is received. Lean’s foundation lies in TPS, and Lead time reduction is a primarily goal. Shorter the lead time, faster is the response to customer demand and more adaptable are the processes. The ideal state would be one where the lead time is a bare minimum or just equal to the sum of the processing times of all the processes required to make one unit of product.

Just as it takes time, practice, and a focused effort on the part of an amateur dancer to become a maestro, even firms need to approach this ideal (perfect matching of demand with supply) in a structured manner. Figure 2.2 presents a conceptual loop of four stages of improvement which are not necessarily sequential. While adopting Lean, one can enter anywhere in this loop and exit after any number of iterations, depending on the organizational need and strategy. An example of a single iteration would be one in which one may take up a project in flow/pull phases in order to demonstrate quick results to get the buy-in of relevant stakeholders, as we shall see in Chap. 4. Although achieving one-piece flow is the ideal, the recursive representation in Fig. 2.2 is to indicate that firms move on to other supplier–customer binary links in their value chain for Lean implementation. We describe these stages and provide an overview of the relevant tools/principles for each stage in the following subsections. Implementation details

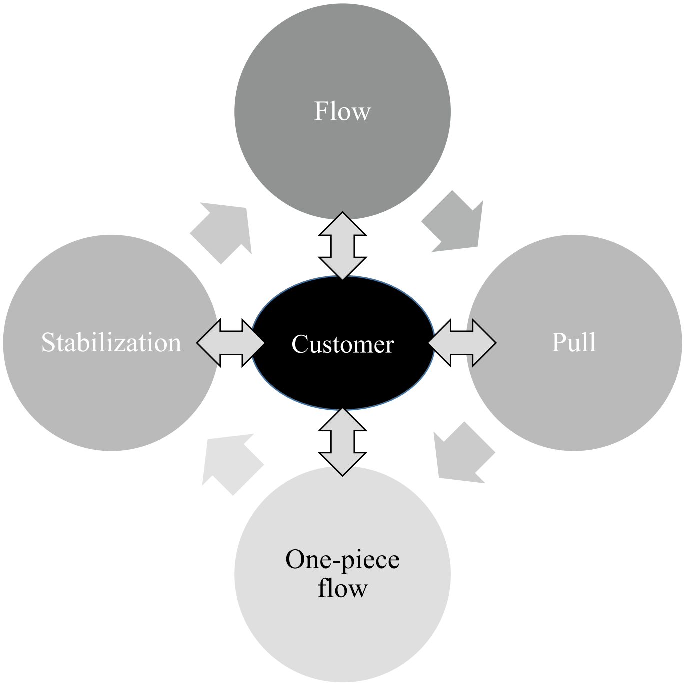


Fig. 2.2 Lean implementation maturity stages

of the tools/principles are described in Modules III and IV, which deal with the Lean implementation and stabilization, respectively.

The most important element of any of these improvement stages is their sole focus on customer perspective, i.e. improvement is done "*only when*" the initiative adds value to customer. This point cannot be overemphasized in the current environment, where a number of organizational capital investments are fancy and have a fragile customer basis. This emphasis on everything "revolving" around the customer is why we have placed customer in the centre of the loop. Pioneering Lean thinkers have established that, from a customer's perspective, there are three types of inefficiencies in any process that organizations have difficulty seeing, let alone eliminating. These three are popularly called 3Ms based on their Japanese names, viz. *Muda* (waste), *Mura* (unevenness), and *Muri* (overburden). 3Ms are explained in detail in later chapters. A lot of attention during Lean-based process improvements is given to the elimination or reduction of the 3Ms.

- *Flow:* The flow of material/work through the organization is unhindered, akin to the flow of a river, without any churning, reversal, or overflows.
- *Pull*: The trigger to perform action is initiated by the request/order from downstream customer (internal/external). In the absence of a signal from downstream, no action will be performed by the upstream. There may be some strategic inventories to help maintain flow.

- *One-piece flow*: The ideal state where a single piece is made at a time in response to each customer order just when it is needed. There is no batch production. Each process in the chain is working on one piece, and a maximum of one piece may wait its turn before any process.
- *Stabilization:* The organization has a complete grip on the quality of its product(s), by virtue of clearly defined processes, and their operating ranges, conditions, and capabilities.

2.3.1 Flow

Removal of obstacles to the smooth flow of the product through various production stages is usually the first step in most of the Lean implementations. Flow is the natural order of things—the best natural systems are designed on flow principles including all living systems such as human body. Streams and rivulets flow to the river and rivers flow to the sea—creating great natural wealth along their journey. Human body itself has multiple flows—air or breathing, food (digestion), water and blood (life), and brain (impulse). What would happen if any flow is constrained, blocked, or disrupted?

In business processes, typically, a product undergoes a series of sequential steps as it is converted from input (raw material) to finished item that is ready to be sold. In flow phase, firms would identify the impediments to flow and remove them gradually and steadily. Smooth flow is prevented whenever sequential processes operate at different rates. Flow is also blocked if large changeover/transfer times induce production/movement of big batches. Imagine the flow through a water pipe with different diameters at different cross sections. Conventional locally optimizing schedules result in inventory getting accumulated before processes with slower rates, and the equipment after such processes stays idle for want of input materials. Further, such a schedule results in long flow time for the products.

Before moving further, let us pause for a moment and ask ourselves the question—What should flow? The organization is in business to serve and satisfy its customers—it is customers who pay for enterprise' goods and services and keep the business profitable and sustainable. Customers pay for the specific product. Typically, the raw material gets converted in an incremental manner to the final product. Each step that changes the material in the direction specified by the customer is value adding through change in physical or inherent properties. And by corollary, any step (including waiting) that is not in the customer direction is a non-value-adding step, a waste. So, the product needs to flow through these value-adding steps, i.e. value should flow. A good way to visualize this would be to imagine oneself as a product moving through different production steps in your plant. If you are moving from first to the last step without ever stopping anywhere, then you have a perfectly smooth flow. Each place where you stop is an impediment to the flow, and since there is no value addition during waiting, it is considered as a waste. You will be surprised to see the number of places and the amount of time you will be waiting without value being added. Similarly, there are other inefficiencies (3Ms) as mentioned earlier which are impediments to flow. The objective of this stage is to identify, reduce, and eventually eliminate the 3Ms, as much as possible in structured and documented iterations. For a firm new to Lean, implementing this phase (flow) is the most involved, as it requires a number of behaviour altering changes at the shop floor. The following four principles help one to identify impediments and improve the flow of value through an enterprise.

2.3.1.1 Value Stream Mapping (VSM)

Value stream mapping is one of the key visual tools that helps chart the flow of material through the plant from material receipt to dispatch of final product. The information flows needed to ensure material flow are then depicted on the VSM making it an integrated view of the operations. Based on Toyota's Material and Information Flow diagram, Rother and Shook (Learning to See: Value Stream Mapping to Add Value and Eliminate *Muda*, Lean Enterprise Institute, 1999) have developed this tool. Drawing a VSM is a good first step in establishing a flow, because it offers a clear, unambiguous, comprehensive, and unanimous view of current flow and its obstacles. With the seemingly confusing product paths sorted out on paper, it is easy to identify the major impediments. These impediments are marked as clouds or improvement projects in star boxes and priorities assigned. It is also important to understand that true flow is said to occur, only when value is added. Hence, the VSM charts only the value-adding operations and gives a perspective on the mismatch of rates of different operations, thereby offering pointers to the true capacity of the system. The non-value-adding material flows pertaining to material handling, and transportation within the factory premises is separately depicted using a Spaghetti diagram or an arrow diagram (described in detail in Chap. 5). These bring to surface the causes for impediments to flow such as layout and process design issues.

Reasonable caution needs to be exercised while creating VSM, and yet there is no need for the team to go overboard in capturing the complete nitty–gritty of material flows. Likewise, the initial project priorities may have to change, if some initial improvements result in changing the process behaviour substantially, rendering either previously established improvement projects as irrelevant or by presenting completely new, unforeseen, and more critical impediments to flow. The firm should be prepared to step back and view at the whole VSM every now and then, critically reassess the priorities of projects.

2.3.1.2 Balance the Production Rate (Cycle Time) in Line with Takt Rate

Takt time is the inverse of desired production rate (cycle time) to meet the entire customer demand and can be calculated as the available time divided by the number of units to be produced (to meet the demand). If a factory needs to produce 960 units in an 8-h shift, the production rate is 120 units per hour, then the *takt* time is 30 s per unit and takt rate is 2 units/minute. Derived from a German word that means "metre", it is similar to the heart beat of a human being. When demand goes up, takt time or target time to produce will reduce and vice versa. One of the most common blocks to flow in most organizations is due to the differences in cycle times for different sequential steps in production. Cycle time is the amount of time taken by the specific operation to complete the processing of one unit of the product. Clearly, the cycle time of no process can be more than the takt time, else the factory would be unable to meet the customer demand on a consistent basis. Similarly, having cycle time for any of the process much lower than takt time implies idling of resources, an undesirable situation as well.

Detailed time and motion studies help managers to develop a thorough understanding of the work performed at a granular (task) level, both by machines and operators, and the dependencies. For various historical and convenience reasons, tasks are grouped into chunks at different work stations resulting in different production rates. According to balancing principle, tasks are redistributed and regrouped in a way that the time taken at all work stations is nearly equal to the *Takt* rate. Some of the useful solutions to balance the rates at different work stations are decoupling machine and operator work, ergonomic redesign of the workplace, elimination of uneven (*Mura*), strenuous (*Muri*), and wasteful motions, reduction of set-up time, and transfer batches (*Muda*). Work stations having longest cycle times are called constraints or bottlenecks and determine the overall capacity of the system. Upstream of the bottleneck, the production is pulled by the signal from bottleneck, and downstream production either flows or is pulled by customer signal.

2.3.1.3 Waste Elimination (*Muda*)

Anything that is not value adding from a customer perspective is a wasteful activity and prevents free flow of value. Such activities/processes should be reduced and eventually eliminated. Usually, customers value product features (such as safety, environment friendly, maintainability, ease of replacement), associated services (such as delivery, service, insurance, reminders), and the experience of purchase and post-purchase. It is worth the while of a Lean manager's time to dig deeper and evaluate whether and how different processes add value. In majority of the systems we observed, the value-added time was as low as 20% of the overall cycle time of the component. Understanding value and waste from a customer perspective within the manufacturing operations is the key. TPS has categorized the wastes into seven categories, viz. overproduction, storing in inventory, waiting, material transportation, human motion, overprocessing, and rework.

This *Muda* has a direct impact on the manufacturing lead time, the reduction of which is the primary goal of Lean. Figure 2.3 shows a typical production flow comprising both value adding and wasteful activities.

Now we minimize the waste activities and the time spent on them. Value-adding time remains the same. We can see that reducing the wastes even without any investments in speeding up or enhancing capacities of the actual value-adding operations can directly reduce the lead time and thereby increase capacity as shown in Fig. 2.4.

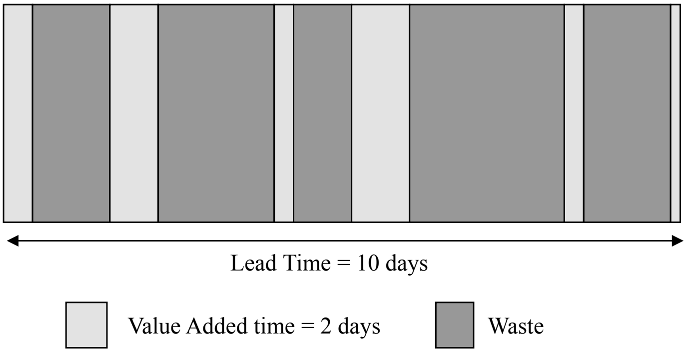
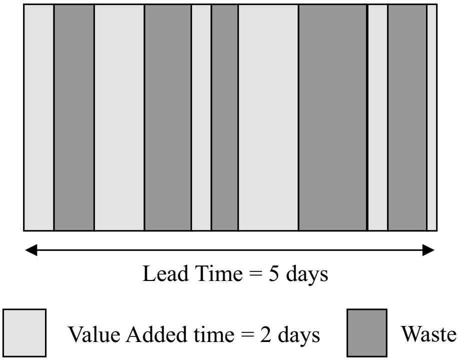


Fig. 2.3 Wastes contributing to higher lead time

Fig. 2.4 Reduction of wastes reducing the lead time



The benefit of capacity increase is only incidental. As per Womack and Jones (1996), every time an organization quarters its lead time, productivity goes up, and costs come down by 20%. It should be noted that, not all wastes are alike in terms of pursuit of their elimination. Context plays an important role in determining the priority. For example, in a capital intense industry, eliminating overproduction is less important than the waiting of the machine, whereas in an organization with mostly manual processes, the waiting time of operators may be used in some other productive tasks such as maintenance/process improvement, rendering overproduction as unnecessary.

2.3.1.4 Changeover Time Reduction—SMED

If any concept could be touted as the single most important thing to have helped establish TPS and implement flow at Toyota, it would be Single Minute Exchange of Dies (SMED). One of the main obstacles to flow was high changeover times between product types on many machines. TPS suggests a way of observing all the sub-tasks involved with a view to identify sub-tasks that can be done without having to stop the machine, or by someone other than operator, and any process/jig/fixture improvements that can reduce the remainder of the changeover times.

2.3.1.5 Visual Management (5S)

Visual tools play a very important role in Lean management on the floor monitoring, and control. Visual systems are designed to give immediate cues to operator and supervisor regarding the status of process. The 5S—sort, set in order, shine (and inspect), standardize, and sustain—are the classes of actions every operator undertakes around her immediate work area, every day, to inculcate the behaviour of observation, action, and visual management.

"*Sort*" requires that only the tools, materials, bins, and documents that are needed for value-adding work should be present at the workstation and the unwanted things removed and are disposed (after the review period). These required items are "*Set*" in clearly pre-defined places that enable ease of access to perform the work with minimum waste. The entire workplace is ensured to be clean, by "*Shining*" which also facilitates inspection for any abnormal conditions. The workplace processes are "*Standardized*" through documented SOPs and visual standards which help maintain the first 3S. Finally, the individual and the organizations are expected to reach a level of self-sustenance, where all the above practices are followed by each and every person on their own and it becomes a part of their conditioning.

2.3.2 Pull

Conventionally firms produce to forecast, because they have accepted that the lead times (consisting largely of non-value-adding times) are unchangeable. This requires various manufacturing resources in the plant to be scheduled (ahead of time) such that the product becomes available, when it is forecasted as required. In addition, generally each production resource is considered in isolation in the material requirement planning (MRP) systems to generate locally cost-optimal production batches. The production of different batch sizes at different production stages adds further to process variability and hence to lead time. Lean management overcomes this quandary by implementing a pull method for production.

Once the firm has achieved a good flow, by reducing and or eliminating as many wastes, and hence the lead time, it is ready to implement pull. Reduction of lead time paves way for pull because the downstream process (customer) does not have to wait too long to receive the input (as against picking from stock). Often TPS *Sensei* (teacher/master in Japanese) considers pull as a bridge to achieving the ideal state of one-piece flow. In the words of Rother and Shook (2003), "*Flow where you can, pull where you must*". By flow, here it is meant one-piece flow. In practice, pull loops become necessary in the value stream due to batching and differential rates of production in different product stages. Typically, pull loops proceed from customer end and move up the organizational processes until such point where it is difficult to distinguish the order-level activity. Following are some mechanisms to implement pull in organizations.

2.3.2.1 Pacemaker

Pacemaker is the last process in the value stream after which there exists only continuous flow till the finished good stage (Rother & Shook, 2003). As the name suggests, pacemaker determines rate at which the customer demand is met. Before the pacemaker, there can be a mix of flows, shared resources catering to multiple product groups, etc. Pull often begins from the pacemaker process. For example, in a typical assembled product such as automobile, white goods, pumps, or toys, the first operation in the *final assembly* line would be the pacemaker as after this there is only line flow. The continuous improvement endeavour of Lean organizations keeps pushing the pacemaker further up the supply chain. Further, recall that we defined a chain of clear binary supplier and customer relations throughout the supply chain using VSMs in the flow stage. We make use of these binary links to send the pull signal all the way to the most upstream supplier via each supplier in our VSM. The upstream supplier to each customer in the chain will only start producing when she receives the pull signal from the customer. The limitation to this is the fact that not all resources belong to a single supplier–customer lineage. There are usually some shared resources as part of most of process streams. Centralized planning is inevitable for such resources. For the resources prior to the pacemaker, pull is typically implemented using *Kanban* cards.

2.3.2.2 *Kanban*

Kanban is a visual signalling system that can be implemented by use of cards that are passed from downstream customer to supplier and vice versa. As observed previously in Takt rate Sect. 2.3.1.2, production upstream of pacemaker is pulled by *Kanban* signal from pacemaker, whereas downstream production is driven by customer orders. This is implemented for every binary customer–supplier relationship in the enterprise value chain. The literal meaning of the word *Kanban* in Japanese is signboard. As the name suggests, *Kanban* is the manifestation of pull implementation on the production floor using visual management (typically cards), i.e. the upstream producer will produce "***only***" when (s)he (or a machine with a sensor) "***sees***" a signal from the downstream customer. There are six inviolable rules that go with *Kanban* at TPS, to ensure that good material moves along with the cards, only when there is trigger. The number of cards in the system not only controls the extent of inventory, but also the extent of variability propagation up the supply chain, popularly known as the Bull-Whip effect. While organizations have developed a number of variants of *Kanban*, to suit specific contexts, including e-*Kanbans*, the fundamental pull principle remains intact. Given their specific purpose, *Kanban* is also classified as production, transport *Kanban.* Further, production *Kanban* is categorized into signal and production *Kanban*, depending on the presence of change-over time and transport *Kanban* is categorized into supplier and in-house *Kanban.*

2.3.2.3 Production Levelling (*Heijunka*)

Most organizations produce more than one model or a variant of product/service using common resources. Traditionally, it is viewed convenient to produce one model continuously and then switch over to another model and produce it continuously. Such uneven production in batches is an example of *Mura*. The problem with this approach is that sales happen at a different rate compared to production resulting in inventory holding or order backlog. All the associated problems due to excessive inventory such as feedback delay and lost/additional human effort follow. The solution is to create production runs such that in each run all models are produced in the same proportion as the overall sales proportion. The production run size is gradually reduced to minimum by continuously reducing changeover times (see SMED, Sect. 2.3.1.4), and transport batch is reduced by defining an appropriate material collection frequency (pitch). The important outcome of *Heijunka* is to define batches such that production effort is levelled throughout the time horizon. A side benefit of the ability to produce mixed lots is the embedded production flexibility to accommodate any model-mix changes in the demand. One of the common challenges to implement *Heijunka* comes from change resistance by employees, understandably so. We, humans, are conditioned such that we avoid change, if we can. Therefore, it requires conscious effort, coaching, and behavioural reinforcement to repeatedly change the models. Over a period of time, this flexibility becomes second nature of the employees at Lean organizations.

2.3.3 One-Piece Flow

This is the perfect or utopian phase of achieving make-to-order, yet with the efficiencies of mass manufacturing. Existing make-to-order systems mostly have unacceptably long lead times and are unable to scale up their business as a result. A single-piece flow (or 1×1 or continuous flow) means that in each operation of the chain of processes that are involved in the making of a product, only one unit of material is under process (value addition), and at the most, another unit is waiting before the operation. At its most perfectly synchronized level, this would be akin to the child game of passing the parcel or a set of labourers manually transporting bricks from stacking point to point of use in a construction site. Achieving single-piece flow means an excellent balance of cycle times among the connected operations and minimum disruption in the flow of work due to process instability, equipment breakdowns, and planning issues such as material availability. All the initiatives described in flow and pull sections must be at work such that they support a batch size of one, with minimal wastes. Further, the following initiatives help organizations to stay on course towards the Lean perfection manifested in the form of single-piece flow and waste elimination throughout the value chain.

2.3.3.1 *Kaizen*

Kaizen is a combination of two Japanese words: *Kai*—Change and *Zen*—For the better.[1] As the name suggests, *Kaizen* is an endeavour by everyone in the organization from top to bottom to continuously improve within their own sphere of work. While *Kaizen* is practised in general in a number of progressive organizations, the way it is implemented within TPS is quite purposeful. Rother (2019) in his book, "Toyota Kata: Managing People for Improvement, Adaptiveness, and Superior Results", does provide an in-depth account of how are target conditions determined, the steps to reach there, a cultural cushion that promotes taking smaller steps in the direction of target condition, and an overall organizational alignment towards this approach. So, *Kaizen* combined with *kata* (a way of keeping improvement steps in alignment with the target condition) to get to a target condition provides a powerful impetus and direction for organizations strive to achieve the Lean perfection.

2.3.3.2 Lean Enterprise

It is imperative that for Lean to truly work at an organization, and not backslide because its customers or suppliers continue to exhibit batch behaviour, Lean principles should be extended throughout the value chain, termed as Lean Enterprise by Womack and Jones (1994). They provide guidance on how the legally different enterprises in the value chains may still cooperate, enter into transparent agreements, and perform just transactions. An end goal of a Lean enterprise is that all wastes are eliminated throughout the value chain, entities are rewarded in proportion to their contribution to value, and there is no pushing of the product to end customer through meaningless discounts. Lean Enterprise is a powerful and an over encompassing notion, and organizations may implement the same in a step-wise manner by progressively convincing different entities in the value chain through demonstrated benefits.

2.3.4 Stabilization

Before the organization hopes to achieve quantity responsiveness, logic requires that it must ensure that the products/services it produces conform to the quality standards set as per customer expectations. The purpose of stabilization stage is twofold, ensures either lock-in of the previously achieved improvements or as a preliminary step to Lean, and stabilize the product quality. So, in stabilization phase, the focus is on minimizing the process variability, improving equipment effectiveness, achieving defect-free production, and ensuring that operators adhere to set operational procedures. Outcome of stabilization stage for a given process is that it is defect free and consistently produces at a predictable rate. This

[1] https://www.kaizen.com/what-is-kaizen.

stage is perfected by preventing defects, and this is achieved by following guiding principles.

2.3.4.1 Quality at Source

The empowerment of the operator to stop production as soon as a defect is spotted is achieved by pulling what is called an *andon* card (in an assembly line set-up). There are other digital and on the floor variants available for implementing *andon* mechanism. Stopping production in itself does not eliminate defects. The supervisor and the relevant operators immediately convene at the location where defect was found, root cause analysis performed, and the source of the error is fixed, before resuming production. Once this discipline is maintained (despite the temptation to put the defect away and keep producing), it is easy to see that the time lost in root cause analysis is gained quickly by avoiding potential and bigger losses of passing along the defect and the potential rework involved. This is the trigger to setting the virtuous cycle in motion. Fixing a defect at its root requires problem solving of higher order, forcing the operators develop a deeper understanding of the interactions between material, equipment, environment, and other relevant parameters.

2.3.4.2 Hundred Per Cent Inspection

All production at all processing stages is fully inspected to catch defects, if any, before being passed on to next stage. Deploying human resources for inspection is costly, demeaning to individuals, and above all is not completely fool proof. Efforts to automate inspection using simple solutions are called *Jidoka* or autonomation (automation with human mind) in TPS parlance. *Poka-yoke* or fool-proofing goes one step beyond and operationalizes various ingenious and cost-effective mechanisms to prevent errors in processing.

2.3.4.3 Total Productive Maintenance (TPM)

Equipment availability and reliability are enhanced by having the operators undertake routine checks, preventive maintenance routines, and change of consumables. TPM makes the operator more sensitive to any irregular behaviour of the equipment and prevent such abnormal symptom building into a more serious problem later. Equipment conditions impact the process and resultant quality much before they actually breakdown. TPM makes the production operator to take more accountability of the equipment they work on and hence take a good care of them. Chapter 8 details some useful practices related to autonomous maintenance (AM), planned maintenance (PM), and cleaning, lubrication, repair, and inspection (CLRI).

2.3.4.4 Standardize

Standardization of a work procedure is the documentation of current, proven best practice to operate the work station. This serves as the baseline to undertake new improvement projects, in order to achieve higher performance levels. Standardization refers to both the operating procedures and also the equipment condition.

Standardization is a necessary step in stabilization phase. A TPS practice called 5S (standing for sort, set in order, shine, standardize, sustain) is an excellent tool to institutionalize various improvements achieved through Lean initiatives within the organization. The 5S implementation needs to be strictly in the sequence as mentioned above for truly firming up the improvements. Typical implementations of 5S are stage-wise starting from 1S to all the way 5S, augmented by periodic audits to ensuring adherence.

2.4 Performance of Lean Enterprises

In this section, we present some of the published empirical research on the financial performance of firms that have implemented Lean vis-à-vis the firms that did not. Two trends are evident in the published results that Lean not only causes financial performance improvement, but also is self-perpetuating, i.e. it feeds on its success and delivers even better results every successive year.

Dieste et al., (2021) conducted a systematic literature review of 24 research articles published on the impact on financial performance due to Lean implementation. For the purpose of comparison, they grouped Lean initiatives into four bundles. They are "JIT" consisting of pull/*Kanban*, small lots of production, SMED, continuous flow production, and cellular layouts, "TQM" consisting of *Kaizen*, customer involvement, visual management, statistical process control, and 5S, "TPM" consisting of preventive and autonomous maintenance, and "HRM" consisting of multiskilled workforce, employee involvement, and Lean leadership. They found that JIT and TQM seem to enable a better financial performance, than TPM and HRM. Interestingly, they have also found evidence of unsatisfactory financial performance, where Lean was implemented half-heartedly. Similarly, Hofer et al. (2012) observed that a complete (internal and external oriented) Lean implementation gives higher performance benefits as against implementation of selective tools.

According to a research survey conducted by Arnaldo Camuffo in 2016[2] at 100 SMEs based in Italy who have seriously embarked on the Lean journey, the EBIDTA margin and ROIC have shown substantial and nonlinear improvements vis-a-vis their non-Lean counterparts. EBIDTA margin has increased to 11% in year 3 and to 54% by year 4. Likewise, ROIC has improved from 4% in year 1 to nearly 1.5 times by year 7. There was however a small dip in the initial year or so on EBIDTA margin, which is understandable since it takes that long for the new ways of operating (such as avoiding overproduction) to settle. In another study on North American SMEs, Olsen (2004) determined that not only the cash-to-cash cycle and RoE are better for Lean firms, but also synergistic in nature. Based on the survey findings from 187 manufacturing firms in Malaysia, Iranmanesh et al. (2019) observed that Lean culture of an organization has a positive effect

[2] https://planet-lean.com/financial-performance-sme-research/.

on the sustainability performance of an organization due to its process, equipment, and supplier relationship management practices. Boyd et al. (2006) used the Data Envelopment Analysis (DEA), a linear programming-based efficiency measurement tool that considers a range of inputs such as inventory, labour, and other assets, to produce outputs such as net sales, gross profit, EBIDTA, EBT, and net income. The authors applied this comprehensive measure to 18 manufacturing firms to conclude that the Lean management implementations help firms achieve superior technical efficiencies. Lastly, in a comprehensive study of the effect of Lean implementation at Delphi automotive, and Johnson Controls, both driven to Lean in the second wave by their mother companies, Kocakulah and Upson (2004) observe that driving culture change and supplier practices are the two main inertias preventing these companies achieve the desired levels on performance metrics such as inventory turns, quality performance, improved delivery, production lead times, conversion costs, product introduction times, smaller plants, and improved productivity. These authors also note that it takes a while for the network effects to show. After all, it took more than 50 years for the Lean leaders (Toyota) to achieve the current levels of performance.

2.5 Summary

In this chapter, we presented a comprehensive framework of Lean implementation with different maturity stages, namely flow, pull, and one-piece flow, and stabilization. Each stage and the interrelations among them was described from a conceptual standpoint. Relevant tools and techniques as appropriate for each of these four stages are introduced. A global review of performance improvement reported on account of Lean implementations by Small and Medium Enterprises is presented.

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Lean Management in Small and Medium Enterprises

3

3.1 Introduction

Exposure to constraints such as dependence on banks for capital, lack of stable demand, poor visibility to demand, presence of floating and relatively unskilled workforce, and far upstream positions in supply chains, make Small and Medium Enterprises (SMEs) particularly vulnerable to vagaries of social, economic, and political uncertainties. However, these very challenges make SMEs the natural candidates to pursue Lean practices. SMEs already have the favourable characteristics for Lean such as smaller, closer, and visible shop floors, fewer management layers, closer relationships among employees, higher product variety and the necessity to closely meet customer's needs, and make-to-order systems (Mrugalska & Wyrwicka, 2017). They also have unfavourable (to Lean) characteristics such as investment in terms of loss of production during training, owner's long-term ambiguous commitment to Lean, and the impatience for the success to solidify as a permanent culture (Djassemi, 2014). In our view, the favourable characteristics outweigh the unfavourable characteristics as visualized in Fig. 3.1.

Many SMEs implemented Lean management to overcome business environment challenges and to improve profitability. For example, Abdul-Nour et al. (1999) observe that some asset base is shifting from larger customer enterprises to smaller supplier SMEs, in order to reduce investment risk. Their research explores ways to reduce the break-even risk among SMEs using Lean techniques such as mixed-model scheduling (leading to improved basic, system, and aggregate flexibility), joining a JIT network, and continuous improvement.

And yet, most literature on Lean is about implementation at large enterprises. Approach to Lean implementation needs to be modified to suit the needs, constraints, and styles of SMEs. In this chapter, we review the literature on nuances of SME sector with a focus on identifying the barriers and enablers of Lean implementations. For implementing Lean management, SMEs need to overcome some unique challenges, which one may not be able to learn from the traditional

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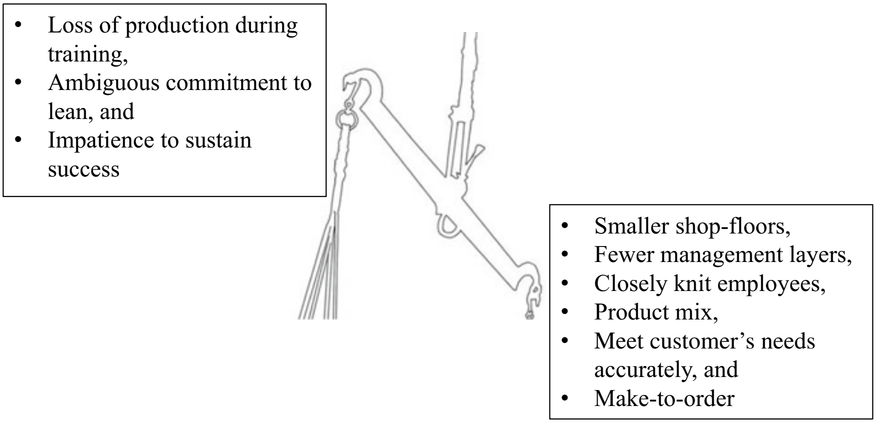

Fig. 3.1 Favourable and unfavourable (to Lean) characteristics of SMEs

Lean success stories of larger enterprises. This chapter concludes with a description of these challenges, laying a foundation for the rest of this book on Lean implementation at SMEs.

3.2 Overview of SMEs

What is an SME? Unfortunately, there is no common definition. Ayyagari et al. (2007) lists the definitions used by many countries for their SME sectors in order to collect, process, and publish the data on SMEs. Apart from a few quantitative measures, such as revenue and number of employees, there are a number of qualitative characteristics that define SMEs. Berisha and Pula (2015) have highlighted the qualitative differences between SMEs and large enterprises as shown in Table 3.1.

We describe the perspectives on economic role, unique constraints, barriers and enablers of Lean adoption, and growth culture with respect to SMEs in the following sub-sections.

3.2.1 Economic Role

SMEs form the backbone of most economies and are providers of large-scale employment. A thriving SME sector is a positive economic indicator. In their study involving 76 countries, Ayyagari et al. (2007) show that the organized SME sector gains importance as the countries become richer. They also observe that better business environment comprising healthy competition and a good credit eco-system contributes to the well-being of SME sector.

Table 3.1 Differences between SMEs and Large Enterprises (adopted from Berisha and Pula, 2015)

Category	SMEs	Large enterprises
Management	• Proprietor-entrepreneurship • Functions linked to personalities	• Manager-entrepreneurship • Division of labour by subject matters
Personnel	• Lack of university graduates • All-round knowledge	• Dominance of university graduates • Specialization
Organization	• Highly personalized contacts	• Highly formalized communication
Sales	• Comparative position not defined and uncertain	• Strong competitive position
Buyers' relationships	• Unstable	• Based on long-term contracts
Production	• Labour intensive	• Capital intensive, economies of scale
Research and development	• Following the market, intuitive approach	• Institutionalized
Finance	• Role of family funds, self-financing	• Diversified ownership structure, access to anonymous capital market

Considering the important role played by SME sector, and yet their limited access to capital, and advanced knowledge, many governments have come up with a number of support systems. Firstly, most governments have dedicated ministries or other bodies and also policies to support SMEs (viz., Small Business Services (UK); SME Promotion Office (Thailand), Small Business Administration (USA), Bureau of Small and Medium Business Development (Philippines), Ministry of Micro, Small and Medium Enterprises, India, etc. Stephen Ezell (2011)[1] observes that the national manufacturing support of the countries (Argentina, Australia, Austria, Canada, China, Germany, Japan, Korea, Spain, and United Kingdom, and the United States) for SMEs is shifting from continuous productivity improvement (Lean, quality, Six Sigma) to innovation and growth (Technology adoption, new age manufacturing, connecting SMEs). Babu et al. (2016) review the positive effects of various government support initiatives under the aegis of National Manufacturing Competitiveness Programme (NMCP) starting 2007 on the MSME sector in India. One of the nine components of NMCP is a Lean manufacturing scheme under which the government financially supports various SME clusters across the country in implementing Lean. Further, development of clusters fosters building horizontal alliances, shares common resources and achieves access to global value chains, in the presence of co-operative competition (Herr & Nettekoven, 2018).

[1] https://itif.org/publications/2011/09/14/international-benchmarking-countries%E2%80%99-policies-and-programs-supporting-sme.

Taiwanese PC cluster, Chilean salmon cluster, and Indian textile cluster are a few examples of clusters supported and developed by the respective governments.

Researchers also have recommended that governments should take active role in supporting SMEs. For example, Tambunan (2005) recommend that government policies should enable an effective market (domestic and global) linkage. Further, Lim and Kimura (2010) observe that increase in globalization is providing unprecedented opportunities for SMEs to participate in global value chains. They note that for SMEs to continue to flourish, policy measures to strengthen technological, human resources, and better access to finance must be taken by the respective governments.

3.2.2 Unique Constraints of SMEs

Shocks such as BREXIT, shifting orientation global value chains, COVID-induced recession, and supply disruptions, growing nationalism, and other environmental uncertainties cause strain especially on SME sector since most of them are at the upstream end of the supply chains, and by the time the true demand reaches them, they usually would have spent resources on production (based on forecast).

Naradda Gamage et al. (2020) observed that SMEs are increasingly affected by global challenges such as global market competition, global finance and economic crises, information communication technology, the emergence of multinational corporations, transnational corporations, consumer changes and especially their preferences, trade dumping, international terrorism, and religious conflicts and trade wars. According to them, some useful survival strategies that SMEs can adopt are-expanding dynamic capabilities, investing in research, technology innovations, new partnerships, getting into global supply chains, and skill development.

Table 3.2 summarizes the constraints and challenges faced by SMEs as documented in literature.

3.2.3 Growth Orientation

Herr and Nettekoven (2018) classify SMEs into three categories, namely those that start with an innovative combination of production factors—Schumpeterian SMEs (Joseph Schumpeter, 1934), those reacting to normal mismatch between supply and demand—normal SMEs, and those that start in response to lack of better economic opportunities—poverty-driven SMEs. Further, the authors note that the SMEs belonging to first two categories are open to innovation and are relatively fewer in numbers, more so in developing nations. Large number of SMEs, belonging to the last category, strive neither for innovation nor to become Lean.

Table 3.3 summarizes the unique characteristics of high growth SMEs.

Table 3.2 Challenges and constraints faced by SMEs

Researcher	Source	Constraints and challenges
Siegel et al. (2019)	45 published academic research articles	Manpower and financial constraints, poor management and leadership, lack of strategy, resistance to change, and improper project(s) selection
Beck (2007)	Enterprise Surveys database of the World Bank	Cost of finance, tax rates, macroeconomic stability, economic policy uncertainty, corruption, access to finance, anti-competitive/informal practices, tax administration, electricity, crime, theft, disorder, skills of available workers, legal system, customs and trade regulations, access to land, licensing and operating permits, labour regulations, transport, and telecommunications

Table 3.3 Unique characteristics of high growth SMEs

Researcher	Source	Constraints and challenges
Smallbone et al. (1995)	High growth SMEs in comparison with others	– Continuously expand the core product offerings to more value-added versions, thereby increasing wallet share of existing customers and acquiring newer customers – Added to employment, increased productivity, improved production processes, achieved growth organically, and – Increased bandwidth from management
Bigliardi et al. (2011)	Innovative SMEs in comparison with others	Enhance product offerings, improve process capability, and integrate innovation into the business strategies

3.2.4 Barriers and Enablers to Lean in SMEs

Common critical success factors (enablers) for Lean implementation as noted by a number of researchers are organizational learning, culture of innovation, leadership and constancy of purpose, processes and information-based management, customer focus, strategic direction and planning, training by an external consultant, top management support, communication, supplier relationship, linking Lean to business strategy, and customers (Achanga et al., 2006; Hu et al., 2015; Lande et al., 2016). Likewise, Thanki and Thakkar (2018) in their study of interdependence of critical success factors for Lean and green implementation among SMEs have found that effective leadership and management's customer focus, communication of goals, linking improvement initiatives with objectives, top management commitment, clear organization strategies and policies, and government support to be the driving CSFs.

Unique constraints faced by SMEs in their Lean adoption are lack of Lean knowledge across the organization, cost reduction through economies of scale mentality, poor (if any) linkages with suppliers and customers, external drive for Lean (typically by customers), lack of qualified staff, and lack of access to expertise (Matt & Rauch, 2013). Based on a detailed literature review and Lean experts' interviews, Belhadi and Touriki (2017) identify lack of management involvement, lack of adapted methodology of Lean implementation, short-term vision, fear and resistance to change, and lack of understanding of Lean as the top five barriers to Lean adaptation. Moreover, they also note that commitment and participation of management, adoption of simple measurement and KPIs, development of organizational learning culture, early deployment of Lean culture through training, and allocation of sufficient time and resources are the top five solutions to overcome the above barriers. Thanki and Thakkar (2014) identify inadequate Lean training and lack of Lean awareness programs for employees, poor application of statistical tools for process improvement, and uncertainty regarding the appropriate Lean tool as the barriers to adapt Lean among SMEs. Choi (1997), while discussing the efforts of seven small automotive parts suppliers to implement continuous improvement (CI), shows that only three had any degree of success. He identifies three major pitfalls for small- to medium-size companies when implementing Lean production: (a) alienation of line leaders, (b) treating CI simply as a problem-solving activity or as something to do when there was a spare moment, and (c) viewing CI as either a management program or a worker program.I am not able to locate where I picked this from. Perhaps the editor team can help me find the reference?Please ignore this comment. We mentioned this reference in the References list.

In their case study analysis involving a medium-sized Swedish enterprise, Assarlind and Aaboen (2014) have identified positive and negative forces that push forward or pull down an organization, respectively, in its Lean journey. According to them, it is equally important for an organization to weed out the negative forces as much as it is to strengthen the positive forces. Various frameworks are proposed for implementing and sustaining Lean such as tree of Lean implementation by Thanki and Thakkar (2011), Lean staircase by Hu et al. (2015), and a three-phased approach by Djassemi (2014). Hu et al. (2015) in their literature review covering over 100 Lean papers noted that most implementations are tool centric, and efficiency focussed, and are not driven by an effective long-term roadmap.

3.3 Resistances to Initiating Lean

It takes patience and trust-building with the SME owners and managers to elicit the exact challenges specific to their organization. During our numerous interactions with them, we were able to identify a few common resistances to initiating Lean. These resistances belong primarily to two categories, financial and non-financial, and we discuss them comprehensively here.

3.3.1 Financial Resistance

The foremost resistance put forth by SMEs to adopt Lean in their organizations is to do with the cost of the intervention. This resistance manifests in various questions such as—where would the funds come from, how to reduce the initial outlay, how soon would they recover the investment, how many times over the initial investment can be recovered etc,. Most SMEs operate with limited funds, generally internally generated or highly restrictive bank loans as the primary source of capital, and hence, this resistance is understandable. So, the SME owners' first lookout is at the payback of such an initiative. "If I invest *X* this year, how many times *X* will I realize and when". While it is easy enough for the SME owners to visualize the payback of hard assets such as machinery or people, it is difficult for the owners to visualize outcomes of an intangible (and typically ongoing) management approach such as Lean.

Further, a sustainable Lean intervention is more of a teaching and training exercise, which can be successful only with willing-to-learn students, and less of a consulting exercise in the conventional sense. Considering the all-pervading marketing glitz of making promises of quick fixes and magic pills by various solution providers including consulting and IT, it is a tough task for the Lean consultant to get the SME owner to understand that taking ownership of Lean is the only way to make it generate sustained benefits. Please see "Skin in the game" for our recent experience of this phenomenon.

Skin in the Game

A few years ago, we were referred to a defense electronics manufacturing unit where there was an urgent need to ramp up the output to meet customer demand. The owners, a technocrat couple, felt that they had implemented the best manufacturing system and technology. We noticed a typical batch type operations with a possibility of 50% increase in output through implementing basic Lean concepts. And we went ahead and put the same in our proposal to the client along with a reasonable fee structure considering their SME status. We included local references of our work.

After going through the proposal, the owners called us for a discussion. The gist of the discussion was that we should take only 25% of the fee for implementation and balance would be paid to us only on the basis of achieving the targets. We explained to them the Lean philosophy and how we would only be the guides to their internal team and that it is the internal team which would take ownership for the initiative and also credit for its results.

The next day we received a two-line email from the Managing Director. It said either accept their terms or forget the assignment. We thanked him for his time and wished them well for the future.

Lastly, many SMEs live from year to year; strategizing and planning five or ten years ahead is rare. When the business (planning) horizon itself is not very long, it becomes difficult for them to commit to a year-long Lean program. Few, if at all, SMEs do a structured budgeting exercise and use it for planned expenses. Absence of planned budget adds to the difficulty of raising funds, out of the blue, to pay for a Lean intervention.

3.3.2 Non-financial Resistance

After the financial resistance is softened or overcome (some ideas on how this is done are described in Chap. 4), a variety of non-financial obstacles begin to surface. Most common among them are described below.

3.3.2.1 Divergent Thinking

A lot of SMEs are family owned and are managed with fathers, uncles, sons, and daughters overseeing different aspects of the business. Often, the younger generation is enamoured by Lean, learning about it during their studies or from books or during business networking meetings. However, they find it difficult to get the buy-in of their "senior" family members who often hold the reins of major decision-making. Please see the box "Weaving strands together…or not".

Weaving Strands Together…or not

A former student of one of our consultants invited us to their manufacturing unit involved in making high strength plastic ropes. She was keen to have Lean implemented to increase their capacity in-line with their ambitious growth plans. We agreed to do a chargeable diagnostic visit. Once there, we met her brother who had been given charge of plant operations and their father who was the founder and overall boss.

The brother said he wanted the unit to have a world class look and feel through implementing Lean as it would attract more international buyers. The father did not set any goals but said he supports whatever his children do and he wanted them to take charge of the business.

We concluded the three-day diagnostic laying out a clear roadmap with the expected benefits. We even took up a couple of areas and demonstrated application of Lean techniques like flow and cycle time reduction and showed immediate results on a pilot basis.

But the implementation assignment never came through. We learnt later that the father was not convinced about Lean despite seeing the results.

3.3.2.2 Resource Time

After the financial and philosophical issues are ironed out, operational challenges are brought to the fore. Typically, SMEs are structured as flat organizations with just a couple of key people running the show. It is no surprise then that they are usually busy with routine work and time is at a premium. The minute Lean and its emphasis on involving all the people is laid out, and the management gets worried about their key resource time getting blocked. A frequently asked question which most Lean consultants would have heard many times over is “Can you deploy your people to run and implement the Lean program. Our people do not have the time”. However, this is not an option as the sustenance of the program depends only on the internal team taking ownership for the Lean initiative right from day one.

3.3.2.3 Employee Turnover

A closely related challenge is the continuity of employees with Lean knowledge within the enterprise. The salaries being conservative in SMEs, some employees (especially the good ones) are looking to gain some experience before moving on to a higher paying job or secure job with a better established companies. There is a genuine worry that having been trained on Lean, such employees become more marketable and may soon leave for better opportunities. Another continuity-related challenge especially in developing nations is the dependence of the SME on contractual “*migrant*” workforce to run their operations. In South Asian countries like India, these workers have unique vacation patterns that depend on myriad of factors such as monsoon, harvest season, festivals, and marriage functions, at their “*native*” states. It is quite normal to see a whole group of people absenting themselves for weeks at a time during such occasions leaving the SME struggling to run day-to-day production. Please see the box “People are the key”.

People Are the Key

We recently commenced an engagement at an engineered stone manufacturing unit located in a remote area. Within the first two months, half the supervisory staff had left, the engineer given role of Lean champion had to take over supervisory duties and was placed in the night shift. The plant manager went on a long leave of absence. One of the family members became plant manager. And Lean came to a grinding halt.

At this stage, the owners asked us the inevitable question "Can you deploy one of your people to continue Lean".

3.3.2.4 Trust

Openness to share information and data is another important barrier, especially in recipe-based industries such as food and pharmaceuticals. Hiring an outside Lean Sensei or consultant requires opening the shop floor and operational data to this external scrutiny. Family-owned SMEs are conservative by nature and are not comfortable with sharing the operational data or process knowledge with an outsider.

With these many barriers, both real and imaginary, in their minds, it is no wonder that most SMEs do not opt to even commence their Lean journey in spite of its widely known and proven benefits. We will present a few practical ways based on our experiences, to counter, soften, and overcome these resistances and make a start of Lean, in Chaps. 4 and 5.

3.4 Summary

This chapter discusses the unique characteristics of SMEs and their differences vis-à-vis larger enterprises. It surveys the state-of-the-art literature to present the economic role, unique constraints, and the growth pathways taken up by SMEs. Further, the literature review identifies the documented enablers and barriers, for Lean implementation at SMEs across the world. The chapter is concluded with the empirical findings from the authors from their various experiences in terms of financial and non-financial resistances posed by the SMEs to the idea of Lean implementation.

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4 Lean Implementation Methodology for SMEs

4.1 Introduction

Doing is the essence of Lean. This spirit is captured perfectly by former Toyota President Fuji Cho, when he stated

> We place the highest value on actual implementation and taking action. There are many things that one doesn't understand and therefore we ask them, why don't you just go ahead and take action; try to do something?…So by constant improvement, or should I say, the improvement based upon action, one can rise to the higher level of practice and knowledge.

The essence of a management philosophy such as Lean is that there are many possible approaches to implement. Organizations mistakenly viewing Lean as a collection of tools, tend to focus on implementing the tools with progressive difficulty in adaption. When Lean is seen as a philosophy, then there exists a logical progression of phases and the corresponding steps that ensure sustained results. Over the last three decades, organizations have undertaken the Lean journey through many different routes with differing degrees of success. Even within organizations that consider Lean as a philosophy, what succeeds at one organization may not work for another. This is due to the myriad of social, economic, and cultural diversities across the implementing organizations.

Hence, while implementing Lean, one has to follow a certain broad framework within which the concepts, tools, and techniques are defined. But, what to do when, where, and how is customized or fitted based on the specific needs and current status of the individual organization.

This book focuses on the needs of the Small and Medium Enterprises and standalone units. Many of them are family-managed businesses, and their unique features have been discussed in the previous chapter. In this chapter, we propose a methodology for implementing Lean at SMEs. A few outstanding organizations

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have gone through the entire journey and developed an internal culture of continual improvement. However, most SMEs find it difficult to envision the outcomes and are hesitant to commit resources to undertake this long journey at the outset. We propose various approaches that can give them a taste of Lean and whet their appetite for the long haul. These are based on our experience of over a hundred interventions during the past two decades.

4.2 Lean Implementation Methodology

Large organizations driven by strategy, foresight, and budgetary planning are able to initiate and embark on Lean journey in a planned-ahead manner. There are several case studies and books written about TPS and Lean at such organizations. Many of these organizations have their own internal teams often guided by external Lean *Sensei* as they walk along the Lean path. The overall methodology for implementing Lean is pretty much streamlined, and we have discussed this in an earlier chapter. The pyramid framework for Lean is founded on the principle of process stability. Lean begins with validating process stability against existing standards as the first step to ensuring processes are running in a stable and standardized manner. Implementation then follows the steps up the pyramid as shown in Fig. 4.1.

However, with SMEs, as we have discussed in the previous chapter, there are several barriers and constraints to adopting Lean. We saw that these include a number of financial as well as other factors. With their short-term planning horizons, financial constraints, and people stability issues, it is usually difficult to excite SME managements to take up Lean journey through the pyramid model. A Lean implementation methodology that shows some quick and substantial gains is more likely to motivate the SMEs to go in for the long haul.

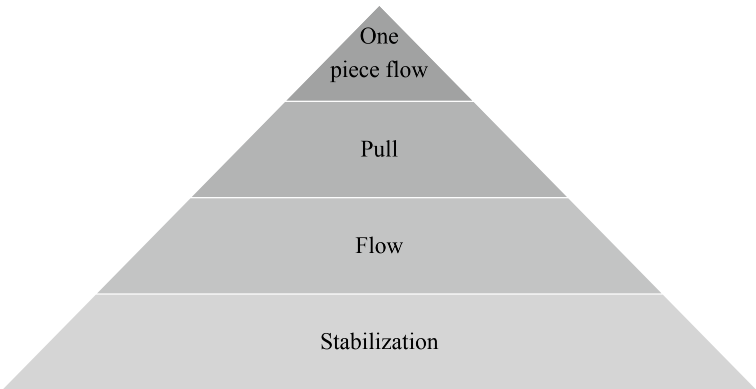

Fig. 4.1 Lean implementation pyramid at large enterprises

Wading through the various approaches that can be taken, we have been able to arrive at a broad methodology of the flow of activities for implementing Lean across organizations.

Learning from the Largest Formal Lean Manufacturing Program for SMEs

In 2008, the Government of India, unveiled a National Manufacturing Competitiveness Program (NMCP) with a separate track on implementing Lean manufacturing in MSMEs. There was a belief that Lean would help in improving profitability and growth of SMEs, but that they would need some support in getting access to reputed Lean *Sensei*. The program was designed using a broad 5-stage framework spread over a 12–18 month time frame. One of the authors has worked with three clusters comprising 29 SME organizations under this program and adapted the lean methodology to this framework:

- Stage 1 — Completion of Diagnostic Study Report (DSR) that includes current operations assessment and time bound targets for achieving improvements,
- Stages 2 and 3 — Applying Lean tools and techniques to improve processes as per roadmap,
- Stage 4 — Standardizing the improved processes,
- Stage 5 — Long-term sustenance which was aptly captured in the program guidelines stating "*However, it is required that the beneficiary units will follow the Lean Manufacturing techniques after the exit of Government of India program*".

Over a decade, this methodology has been rigorously applied across organizations of all sizes, industry sectors, and geographies and improvised with the learnings from each successive implementation. The version presented here in Table 4.1 has been validated over the past five years through multiple Lean interventions and depicts one complete cycle.

This methodology is a variation of the Lean implementation pyramid model discussed earlier. Firstly, process stabilization is now worked upon post-improvement Stages 2 and 3 which focus on flow and pull, respectively. The reasons for this fundamental change are: processes in most SMEs have a lot of inherent waste, and there is little point in stabilizing these only to alter them again in the next stage,

- Stabilization of processes needs patience and discipline, takes some time to get right, and may not lead to striking gains; SMEs may not have the inclination to invest resources,
- Stabilizing processes after improvement sets the ground for next iteration of improvement projects which are taken up by the sustenance team formed in Stage 5.

Table 4.1 Methodology for implementing Lean at SME

Timeline (months)	Stage	Focus areas	Key Lean tools & techniques	Expected outcomes
1	1.Diagnostic "Know Current State"	1. Understanding lean paradigms 2. Assessing current state vis-a-vis organizational goals 3. Identifying opportunities for improvement	• Value Stream Mapping (VSM) • Material Flow Diagrams • Measuring resource productivity • Overall Equipment Effectiveness (OEE)	• Know current capacity • Set Targets for key parameters – Productivity, Quality, Delivery, Cost • Lean Roadmap to enable operations to meet the set targets
2 to 4	2.Create Flow "Quick Wins"	1. Connect processes with each other 2. Improve material flow through value stream	• Takt time & Process Design • Layout design and implementation • Eliminate 3Ms (Muda, Muri and Mura) • Line Balancing	• At least 20% increase in throughput • Reduction in WIP and throughput time • Minimized material handling • Increased space utilization
5 to 8	3. Enable & support flow "Removing hurdles"	Debottlenecking Enabling conditions to ensure 24 x 7 flow 3. Implement Zero Defect Systems	• Workstation improvement • SMED - Reduce Changeover time • Problem-solving techniques • Jidoka and Error proofing • Pull Systems – KANBAN	• Increased output • Reduced rejection and improved FTR • Further reduction in WIP • Increased flexibility with shorter lead times
9 to 12	4. Standardize "Bringing stability"	1. Improve equipment and system reliability 2. Maintain improvements through standards	• Key elements of Total Productive Maintenance (TPM) – AM & PM • Workplace standards through 5 S • Visual SOP	• Increased equipment availability – further gain in output • Maintain the improved metrics • Self-managed "de-skilled" operations
13 to 18	5. Sustain "Eye on the future"	1.Install harmonized support systems (Synchronization) 2. Ensure continuity of Lean initiative	• Continual Improvement (CI) structuring • Lean (5S) assessments • Kaizen programs	• Internal trained resources to manage the CI journey • Foundation for Building Lean culture

Secondly, one-piece flow is not explicitly indicated in the methodology. It is expected that an organization reaching the sustenance stage will keep improving the flow towards the ideal of one-piece flow in later iterations.

Lean is all about flow. The originators at Toyota laid emphasis on achieving single-piece flow as the purest and ideal state of Lean. They also took the tough path of radically altering the processes to create this flow right at the outset and then overcoming the obstructions and constraints to this flow by solving the issues as and when they arose. Our methodology is a slightly diluted approach in the sense that it recommends creating flow wherever possible to make some quick gains. We then work to maintain this flow by solving the issues related to defects, line imbalances, changeovers or breakdowns, process variations, and administrative issues. At times, when the issue is not quickly surmountable and flow gets disrupted repeatedly, we may take a step back to define standard WIP inventory and institute pull-based schedules to maintain the overall system output in line with customer demand. But, we keep working in parallel to solve such issues permanently. Further we would need to synchronize our resources, be it man, material, or machine so that flow is smooth at all times.

Once issues have been solved and flow is streamlined, we write the improved method of operations into new standards and make them visual. Equipment standards for maintaining reliability and performance are also developed and implemented at this stage. This ensures a smooth operation day after day without any surprises or blockages.

In the last stage, we see how the internal team can take the learnings from one such cycle of Lean implementation and devise ways to repeat such a cycle again and again. Lean assessments are a powerful tool which can aid the Lean champions in ensuring this sustenance. Very few organizations have actually evolved to this level where Lean cycles are repeated year after year using such a framework. In those mature organizations such as Toyota, it is part of not only the organization's DNA but also of its value chain partners.

In the next few chapters, we will be going through each of the stages of this Lean implementation framework in detail with an emphasis on application in diverse industry situations. Here, we would only like to add that this "generic" methodology lays out the broad framework of a Lean implementation cycle spanning approximately 18 months. However, it is not meant to be rigid template to be adhered to at all times. As we go along, we will understand the nuances of using this methodology in different situations which are dependent on a combination of factors such as business maturity, industry sector, management outlook, and social and cultural factors. Let us first look at some ways to use this methodology to initiate Lean at SMEs.

4.3 Breaking Down the Barriers—Approaches to Initiating Lean

Over the past three decades, Lean implementation has been led or guided by experts who have learnt about it during the course of their employment in organizations like Toyota and its brethren. The automotive majors are the source of a bulk of Lean experts who have then become independent consultants or joined large global consulting companies that focus on big ticket clients. Their approach to lean implementation begins with a detailed current state assessment and framing a roadmap with defined goals. However, this step itself may take several weeks and involves a significant outlay by the client organization in terms of resource time and consulting fees. With so many barriers already in the minds of a typical SME, this approach has proven to be a non-starter. In this case, size does matter, and we need to tailor the shoe to the foot.

The surest way to begin is to try to give a taste of the good things to come. It is the initial sip of a good wine or coffee that slowly envelopes your senses and makes you eager to have the whole glass and more. Likewise, we need to begin with specific aspects of Lean that convince the management to invest in the initiative, while at the same time exciting the employees and make them want to be a part of the journey. We present a couple of approaches that have done just that.

4.3.1 Rapid Process Improvement Approach

The current state assessment and roadmap are no doubt a logical way to go. But, "how fast, can we move onto implementation, and show some results?", is a question asked by most SME prospects. Say, if within a week's time, we take up a couple of key areas identified during the assessment and rapidly improve them using appropriate Lean tools and show results; it is sure to catch the attention of the SME management. These "low hanging fruit" should culminate in quick wins within 3–4 days. Through this approach, the SME would not only have a broad roadmap for the Lean journey, but also would have already tasted the fruits of Lean implementation all within a week's time. Sounds great, does it not? Here is a case example of "The Cable Guys", a medium-sized organization in the UAE, where this approach worked.

The Cable Guys: How to Improve Within a Week!!

About a decade ago, the real estate market was booming in UAE, and TKB was well placed to supply a bulk of the cables required for the electricals of these new constructions. It was expected that the boom would last just a couple of years and TKB would need to move fast to take advantage of the situation. But, the management was in a dilemma as investing in new equipment could prove unproductive once the market starts slowing down. It was at this stage that the Lean consultants came in.

We met the top management and briefed them on Lean and its benefits. While they were aware about Lean through reading and hearing about it, very few organizations in UAE had attempted to deploy it. Hence, a lot of scepticism on the outcomes. We did not have a resident consulting team in the UAE and would have to travel there for this assignment. We then came up with this idea of a week's visit from Saturday to next Thursday (Friday being the weekly holiday in Middle East). During the first two days, we would do a Lean awareness session for the functional heads and key process leaders and involve them in a diagnostic exercise. The next three days, we would do improvements in a few identified bottleneck processes through cross-functional teams. On the last day, we would present the overall Lean roadmap, while the teams would present the results of the projects taken up. TKB's management agreed to this immediately; they would only have to commit time and resources for a week.

And it went to plan. Four teams were formed, one for each product family. Value stream maps were completed by each team and bottlenecks identified in two days. The diagnostic showed scope for improvement in reducing raw material inventory holding (44 days) and finished good inventories (23 days), copper wastage in drawing processes and increasing the extruder OEE from current level of 30%. Each team then took up one such area for improvement. Within a week, the teams have managed to show a 30% reduction in copper wastage at the bunching process, reduce the extruder changeover time from 35 to 10 min, and clear the testing bottleneck for the heavy fire-resistant cable product line.

TKB now had a taste of the power of Lean and a roadmap to execute for the next 6–9 months. Did they go for it? You bet they did. Albeit through their own internal team. As consultants, we probably shot ourselves in the foot by "revealing too much too soon". But, the job was done—scepticism was replaced by belief in the power of Lean. And, it gave birth to this new approach for SMEs and Lean sceptics—*the rapid process improvement approach.*

Over the last decade, this approach has been refined continuously through the learning from each client experience. In the pandemic period, industries and Lean experts are facing another set of pressures. Uncertainty in market conditions for the industry. Travel and time spent at the clients are at a premium for the consultants. Hence, the rapid diagnosis and quick implementation approach has become all the more relevant as organizations continue to count their costs and remain unsure of committing to approaches; they do not understand up front. This recent example of how a ceramic industry owner converted to Lean in the middle of the pandemic year is another testimonial to this quick-win approach.

The Broken Cup… Fixing It Quickly!

Yash, a second-generation entrepreneur had been handed over the management of the ceramic crockery business by his father. A combination of low raw material costs, availability of cheap labour, and high volumes had so far kept the business profitable. But, Yash had set up a comprehensive plant performance tracking information system and was unhappy with the high percentage of rejections across the process. The manufacturing of ceramicware comprises of two major stages:

Green (pre-firing) stage: any rejected product here can be reused by charging it back into the ball mill.

Whiteware (post-firing) stage—rejection here is a complete loss, and the item has to be either sold as seconds or scrapped fully based on the defect.

Yash was looking to improve margins by reducing these unwanted rejection costs. At a casual dinner with one of his friends, the friend spoke about how Lean implementation at his plant was yielding positive outcomes. This piqued Yash's interest. Though he had never ever heard of Lean or Kaizen, he got in touch with us immediately. He was not sure how it would help him in his operations, but he was clear on his goal—reduce costs. As a qualified finance professional, Yash was also very particular that any amount he spent on Lean had to have a clear payback.

We went with the quick diagnostic and improvement approach. On day one of a three-day visit, we organized the team of process in charges and a factory manager into three teams, one each for the mixing, green forming, and whiteware sections. Capacity not being the focus in this case meant we could dispense with conventional current state mapping and assessments. With the simple paradigm that any "touch" of the delicate ceramicware provided an opportunity for creating a defect; the teams assessed the current state through a *gemba* walk and measured material handling in terms of transportation, number of touches (pick up and place), and motion of people. Simple computation highlighted that there were on average four touches per value-adding operation and that people were moving over a kilometre a day for material handling.

A roadmap was prepared for the next six months. Yash who was personally involved through the diagnostic exercise was excited to learn the potential for improvement, but still sceptical on how it could actually be realized. While we presented him a six-month roadmap, we decided to take up a couple of quick wins immediately to convince Yash. Within a month, projects were taken up in terms of productivity improvement in the final packing line and reducing handling of fired ceramicware. In a second three-day workshop, the packing team converted the batch process to a flow line making some changes in workstation arrangement and layout. Productivity of the team shot up by 50%. Similarly, by connecting the unloading of fired ceramicware, to the inspection and subsequent design pasting processes in

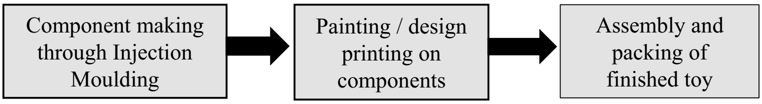

Fig. 4.2 Toy manufacturing process

flow to replace the existing independently operating sections, the number of touches was slashed. Within 15 days, the results were evident. A 50% drop in handling damages and rejection of whiteware!

Having seen the actual improvement and the results with his own eyes, Yash was now keen to move ahead on Lean His next question—"*When can we work on the next process?*"

4.3.2 Problem-Solving Approach

A popular saying goes "The way to a man's heart is through his stomach". Well, the way to an SME entrepreneurs' mind is through solving his or her immediate concerns. And if you can do that through Lean, then the seed of Lean thinking has also been planted. While Lean is a journey, if application of a particular concept or tool can solve a pressing problem, the management is likely to accept it and undertake a more comprehensive journey. The generic methodology can always be applied after alleviating the immediate concern. If the concern and roadmap born out of the assessment coincide, then so much the better! The case of this medium-sized toy manufacturer is a perfect example of this approach (Fig. 4.2).

Toy Story

The Chairman of a large conglomerate had recently paid a rare visit to one of the oldest factories of their toy division. The toy division contributes just 5% of the turnover and is a standalone business that rarely merits his attention. But, this visit turned out to be a wake-up call. The division was in the process of setting up a new factory to run a new product line for a global customer. The Chairman was extremely critical after his visit to the existing factory and made scathing observations about the inventories lying all over the plant, man and material movements, and lack of visible operational controls. While leaving, he told the CEO—"*I will not allow you to go ahead with the new factory if it is going to be run like this. Ensure that things are properly planned and designed*".

A chance meeting of the CEO with one of the group's ex-employees, now a technical adviser got us referred to him. The CEO had no idea about Lean. He told us about the comments of his Chairman and asked for help in designing the new factory operations. We were up to it but said we need to have a look at the existing factory to understand the processes and operations in this industry. A two-day visit threw up the same observations already made by the Chairman. A typical engineering product set up—the operations were divided into three stages.

It was a classic case for applying the typical Lean approach and using all the TPS tools and techniques. But, the immediate problem was to design the new factory. We gave a broad approach on how we would go about doing that. The CEO was ready to have us go ahead with the project and was impressed with our quick understanding of the nuances of the process. We began with process design; the product analysis based on volumes agreed with the customer was inserted into a product process matrix and equipment capacity calculations were done.

At this stage, there was a problem in the new factory registration process and a hold up in the expansion plan. A few months delay was anticipated by the CEO. But by this time, he was convinced on what Lean could do to improve operations in terms of productivity, inventory reduction, and space utilization. He asked us to make a roadmap and initiate Lean in the existing factory which had upset the Chairman, in the first place.

We were on for a full-scale implementation! The minute the CEO realized how Lean could solve his problems, he had no hesitation in taking on an attempt to transform the old factory.

The potential for starting a Lean initiative through problem solving is immense; but, the key lies in understanding the problem and then relating it to the application of Lean concept or tool. Many times, the SME owners are able to define their problem only through vague symptoms. We need to sift through these to identify the root cause of the problem so that we can then solve it through Lean. In this case of a seafood unit, the owner's problem was that his team seemed unable to perform to earlier levels. Read on to see how Lean provided the solution in this case.

Growth Pangs in Feed

A few years ago, we met the Managing Director of a seafood company through a common reference. The seafood industry had been ravaged by a global recession due to disease, and the company had been operating at just 10% of it's capacity in the past two years. The MD explained his problem to us.

"*About three years ago, we set up a new prawn feed mill to enhance our existing plant capacity by about 33%. Then global recession struck the* *industry and we were literally shut for almost two years. Now demand has started picking up to the earlier levels, but my team is unable to manufacture the required quantities. In fact, the factory is struggling to reach 75% of the earlier output and the team has asked me to add another mill to meet targets. I am unable to understand what is happening with our factory* ".

The feed plant was operating from a remote location in proximity to some of the natural agri-based raw materials. On our visit, there we looked at the daily production data captured in plant logs. And quickly compiled a rough Overall Equipment Effectiveness (OEE) calculation for each of the mills (a mill is an independent feed processing line). The OEE was just about 50%. We knew where we had to focus. The next step was to understand the functioning of the plant team. A quick two-day diagnostic workshop with the functional heads got us to observe them closely. And what struck us immediately was the extent to which they were working in their functional silos. It appeared that two years of inactivity had led to an undercurrent of conflicts that were now manifesting themselves on the work front.

Our task was cut out. We need to quickly show an improvement in the OEE. And we could do this only by getting the people to work together in a focused manner. This meant forming cross-functional teams to selectively apply Lean tools. And it worked. Initial focus was on process inconsistencies or *Mura* which was impacting the quality of feed. This in turn had led to the operators lowering the feed rate of the mill resulting in a poor performance ratio. As teams went onto the *gemba* together to observe the 3 Ms and implement countermeasures, they rediscovered their bonding and things started happening.

In six months, the OEE was at 79%! The journey continues.

4.4 Summary

Lean implementations at large enterprises begin by stabilizing the current processes, followed by flow, pull, and single-piece flow, given the TPS heritage and the general approach followed by big consultants. Further, the project initiation is itself a 2–3-month affair to do a detailed current state, future state mapping, and the gap analyses. Considering the various constraints facing the SMEs, it is understandable that such a front-loaded methodology has not found favour. We have come up with a more practical implementation methodology that is judicious mix of delivering quick results, building excitement, and also preparing the SMEs for the long-term discipline that Lean entails. We have used two ice-breakers to showcase the power of Lean at SMEs equally successfully; one that shows a rapid improvement of a bottleneck process and thus improve throughput, and another that solves an immediate problem facing the SMEs. While, these approaches generally result in the SME signing up for the full-scale implementation, there is an occasional risk of client dropping out after this phase, as their immediate concern is resolved, and they have learnt to take Lean forward themselves. In any case, the larger purpose of implanting Lean into the minds of the SME would still have been served.

Commencing the Lean Journey

5

5.1 Introduction

In the previous chapter, we laid out the methodology best suited for designing and implementing a sustainable Lean intervention in SMEs. The journey begins with a diagnostic, and in this chapter, we explain how organizations can assess their current capabilities in context of their business goals. As we saw earlier, organizations often lack clearly defined objectives, may err both in the choice of metrics, and in the way they are measured and reported. When designing a Lean intervention, one would do well to fix the destination first and then go about defining the route to get there. Implementing Lean should not be like taking ones' sports car or bike out for a spin because one feels like it. It needs a clearly stated purpose, which is captured in a set of measurable goals. The current state of operations should then be assessed with respect to these goals and a roadmap drawn up to achieve them.

Lean's biggest attraction lies in its promise of "*Doing more and more with less and less*". The generic definition of productivity is output/input, and conventional focus for improving productivity has been in trying to reduce resource(input) and thereby cost. Lean management adopts a holistic perspective with the current state assessment and target-setting activities focusing on both the value generation(output) and the resource consumption (input).

- *Value: Value comprises of everything that the customer desires (quality, quantity, features, responsiveness, etc.) Time-to-serve* is a direct metric that measures the organization's ability to deliver value to customers. We measure what the current output is and target how much more can be done with the existing resources.
- *Resources: Resources refer to the people, machines, materials, space and time* that are utilized to generate value. *Cost-to-serve* is a comprehensive measure

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G. Mahadevan and K. C. Chejarla, *Lean Management for Small and Medium Sized Enterprises*, Management for Professionals,
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of all the resources consumed in delivering value to the customers. We measure quantum of resources consumed and target how much we can reduce thus consumption for the same or enhanced value.

These two parameters mirror the entire operational performance of a given enterprise. In a well-thought Lean intervention, only those resource optimizations are pursued that do not hurt the company's ability to deliver value to its customers in the short and long terms. We need to have a frame of reference to set out on our Lean journey and the following paradigm succinctly describes what a Lean organization should possess:

> The capability to satisfy customers on quality, delivery, and price
> **through**
> fast and flexible processes that quickly respond to customer needs
> **utilizing**
> available resources effectively, thereby incurring the lowest possible cost and
> **operating**
> a visually managed and self-regulating facility.

Two essential goals emerge from the understanding provided in this frame of reference:

Flexibility of the set of processes that together deliver the value in terms of product and/or service to the customer and best measured through time-to-serve.
Productivity of the resources that go into delivering this value—be it man, material, machinery, or infrastructure and best measured through cost-to-serve.

In fact, right from its origins in Toyota in the 1950s, Lean has been about delivering what the customer wants in the shortest possible time and lowest cost without sacrificing process efficiencies.

In this chapter, we discuss how to diagnose the current state of operations and establish the targets that would go into the framing of an improvement roadmap, the next stage in the proposed Lean implementation methodology.

5.2 Time-to-Serve

Reducing the time-to-serve or lead time for customer requests has a number of advantages. Lead time is defined as the total time taken from the start to the end point in a business process. In manufacturing, this is generally the time taken from the raw material receipt to the finished good stage. Common sense tells us that shorter the lead time faster is the response to (changes in) customer requirements.

It is important to understand that lead time is a direct function of the inventories lying in the value stream.

The Office Commute

Take the example of a daily morning peak hour commute from your home to office covering a distance of, say, eight kilometres (km). The average speed considering the speed limits and traffic lights on the road maybe 40 km per hour, implying one can reach office in about twelve minutes. But in reality, the journey takes a good 25 min. Why? Well, you find that you have to pass through a series of traffic lights at major junctions. At each traffic light, you wait anywhere from three to five minutes, before going through, depending on the length of the queue (inventory) of vehicles in front of you. You cannot reach earlier, because you can go through only after the vehicles already in front of you. Now say you have switched to an early morning work schedule. At this hour, there are hardly any vehicles in front of you at any of the lights and you sail through in fifteen minutes. The reduction in wait time has enabled you to be much faster and therefore you would be much more responsive in the case of an emergency. This same logic (less inventory $\rightrightarrows$ less lead time) holds for all the material and information flows in business processes.

Taiichi Ohno simply summarized TPS in this one sentence:

> All we are doing is looking at the timeline from the moment the customer gives us an order to the point when we collect the cash. And we are continuously reducing that timeline by reducing the non-value-added wastes.

The benefits of lead time reduction are also captured in this observation by Womack and Jones in their book, "Lean Thinking: Banish Waste and Create Wealth in Your Corporation" that, "*every time a company quarters its lead-time it can expect to double its productivity and reduce costs by 20%*". Let us see how Rockwell, an SME, turned around its operations by reducing lead time.

Lead Time Impact on a Seasonal Industry

Rockwell manufactures commercial cold storage products such as freezers, bottle coolers, and cold chests. With an established brand, the company was blessed with a growing demand but unable to meet it during the peak February–May season which accounts for 75% of the annual turnover.

Rockwell therefore implemented a strategy to manufacture additional machines of various product variants in advance of the season and maintain adequate stocks. For this, additional warehouse space had to be leased and machines moved from the factory to this warehouse at the company's cost. The owners also started planning expansion of the factory to increase capacity. At this juncture, they were referred to a Lean Sensei and decided to take his help.

The current state assessment began with measurement of the manufacturing lead time which was found to be about ten days. So, orders for a not-in-stock product variant therefore required about two weeks to fulfil and that too only if all the assembly parts are available. The marketing team was losing several orders to competitors as a result of this lead time. The Lean initiative was designed to first attack and reduce the lead time.

Two years into the lean journey, the lead time was slashed to less than two days, off season stocks kept to a minimum defined level, the external warehouse discontinued, and expansion plans deferred. The pressure had shifted to the marketing team who had to ensure they placed only confirmed orders to the factory as any product could be made and delivered within the week.

5.2.1 Measuring Time-to-Serve

Measuring the lead time is not as simple as it sounds and is ridden with a number of practical difficulties. Some approximation techniques relevant for different contexts are illustrated below to get an indicative value of this number. Of course, in keeping with the Lean principle of "*Go and See*", the preferred technique is direct observation.

5.2.1.1 Direct Observation

A fundamental principle of Toyota Production System (TPS) is *Genchi Gembutsu* (*Go See for yourself*). One way to do this would be to make an indelible mark on the primary raw material before it is issued to the first stage of manufacturing or on the document as it starts its journey through the value stream. The date and time of issue are recorded. The same marked item is also recorded at the end point on becoming a finished good/item. The lead time is simply the end time and date minus the original issue time and date.

This technique can be used in some discrete manufacturing industries where such a mark can be traced as well as for document or information processing service sectors that generate a time stamp at each process. In today's world, use of Industry 4.0 technologies such as barcodes, QR codes, or RFID tags enable this traceability with ease and accuracy .

5.2.1.2 Batch Traceability

There are many industry sectors where the processes are hidden from direct view, and it is impossible to "mark" the material. The chemical, pharmaceutical, metallurgical, and food processing industries are prime examples where we cannot observe most of the processes with our own eyes in the first place.

However, these industries already adhere to a strict batch traceability standard, thus making it easy to compute lead times directly by using the time stamps in the records. In such cases, we try to trace the lead time through available batch records. The snippet below is an example of how the aluminium rolled products industry ensures traceability.

Aluminium Coil Identification System

Way back in the 1980s, the aluminium rolled product industry had developed a dual identification system combining "marking" and "recording". The slab/sheet coming out of the initial casting process is physically "marked" with an ingot/coil number and the date and time of production. Each coil also had its own Coil Card or product route sheet with a provision to record details at each stage. After each rolling or heat treatment stage, the mark gets erased, and the coil number, date, and time of completion of that operation are marked once again using permanent markers. More importantly, this information is also recorded in the Coil Card at each stage. Post the final finishing stage operation, the Coil Cards return to the central Production Planning Cell (PPC) who were then able to calculate the lead time directly by the time difference between the first and last entries.

5.2.1.3 Value Stream Mapping—Computational Method

In "Learning to See", Rother and Shook explain a logical way to compute the lead time from the value stream map (VSM) of a product family. Organizations producing single product families using dedicated resources will find the results from VSM to be a reliable indicator of their lead times. Early in this chapter, we have seen how lead time is directly related to the inventories, and this is in fact the basis for the VSM method of computing lead time. A few definitions pertaining to the VSM are in order:

- ***Total Lead time or Throughput time*** = Sum of processing lead times + Sum of inventory (waiting) lead times across the value stream,
- ***Processing lead time*** = Sum of cycle times + Sum of changeover times,
- ***Cycle time*** is defined as the time between two consecutive parts coming out of a process.
- ***Changeover time (Setup)*** is the time between last good product of one variety to the first good product of another variety in the same process,

- ***Inventory Lead (Wait) time*** = Quantity of inventory/Daily customer requirement or Quantity of inventory in the value stream x Highest cycle time (bottleneck).

This snippet “Plastic Toy Assembly line” illustrates how to compute lead time using VSM.

Plastic Toy Assembly Line

The dedicated line has five operations, A, B, C, D, and E with observed cycle times of 50, 60, 45, 55, and 60 seconds, respectively. The total inventories across the line were physically counted to be 100 pieces. In any value stream, the process(es) with highest cycle time decides the rate of output, and in this case, these are processes B and E which produce at the rate of one toy per every 60 s. With this information, we now compute the lead time for the line, using the definitions above as follows:

Sum of all cycle times per toy = 50 + 60 + 45 + 55 + 60 = 270 s or 4.5 min

Changeover time is zero, as it is a manual process with dedicated line.

Processing Lead time = 4.5 + 0 = 4.5 min

Total Inventory Waiting time = (100 toys × 60 s per toy (60 s/ minute) = 100 min

Each toy waits in the inventory for an average 100 minutes

Therefore, manufacturing lead time = 4.5 + 100 = 104.5 min

The accuracy of this method is better for high volume (“runner”) products with dedicated facilities. The computation gets complex with the increase in product groups with different cycle times and machine set-ups running through the same set of machine centres. We may add here that the lead time is not just a measure of the level of flexibility inherent in the current process but also an indicator of the output capability and we will discuss this in the following section.

5.2.2 Assessing Output Capability

Time-to-serve also captures the current throughput levels or the quantum of product or service delivered to customer. This is the value generated by the organization. We now assess the capability of the current process to deliver the required output, using the following three steps

1. We first calculate the ***takt*** (German word for meter) time. Defined as the rate of customer demand, it is simply calculated as the available working time/demand. So, if the demand is 450 pieces per day and the factory works 7.5 h (actual work time), then takt time is $7.5 \times 60/450 = 1$ min or 60 s per piece,
2. We then calculate the expected output under current conditions. As we saw previously, VSM is a structured tool that requires us to measure cycle times for each operation. We use this data to identify the "bottleneck" operation which decides the output capability of the entire value stream. Normally, the operation with the highest **Effective Cycle Time** (ECT) is the bottleneck and this ECT determines the current output capability. the ,
3. We now compare the ECT with the takt time; ECT $\leq$ takt time implies that the current value stream has the capacity to deliver the targeted output.

The method of computing ECT from observed operation cycle time and using it to calculate expected output varies from industry to industry and depends on factory specific factors. The following subsection presents a few scenarios to illustrate the differences.

5.2.2.1 Discrete Processes

If the same operation is being done on multiple machines or production lines, the ECT will factor in the available capacity both within a machine and across the parallel machines. The example below shows how this was done at a small ceiling fan manufacturing unit.

Motor Winding at a Ceiling Fan Manufacturer

In a ceiling fan manufacturing unit, the motor winding process is critical. The coil winding machine winds two coils at a time. The unit has two such coil winding machines in use.

Observed Cycle time = every 150 s, two wound coils are unloaded from each machine

Effective Cycle Time (ECT)

= {(observed cycle time/ output Per cycle)} /number of machines

$= \{(150/2)\}/2 = 37.5$ s

This means that coil winding process has an ECT of one-fourth of observed cycle time and a corresponding capacity. Since this process has the highest ECT, it is the "bottleneck" and decides the current capacity of the unit. The factory operates a single shift at present. Taking the actual working time of 7 h, the capacity would be:

Capacity Operating time / ECT = $(7 \times 60 \times 60) / 37.5 = 672$ motors per day.

5.2.2.2 Batch Production

In chemical and metallurgical processes, the value-adding process is often a chemical reaction which changes the internal properties of the material including the mass of the product. For example, in a drying process, moisture is removed resulting in weight loss of the obtained output. In reaction processes, the output may be more or less than the input depending on factors such as process yield and/or molecular weights of the compounds. In order to find out the bottleneck, we would therefore need to normalize the output of each stage in terms of a common defined output while making the VSM—this is generally done through a conversion factor we call the batch equivalent.

Let us take this example of a bulk drug manufacturing unit which follows a batch process. Here, we have converted all interim outputs in terms of finished product batch equivalent output of 500 kgs. This is done through the following steps:

Step 1: Calculate the *takt* time (in terms of hours per batch) based on target monthly demand (tonnes/month) and available working hours as shown in Table 5.1.
*Assuming the production runs 30 days in a month and 24 hours a day

Step 2: Yield factor for each stage is known based on chemical formulae. We now work backwards from the final stage computing the input at each stage as being equal to the output/yield. We need to calculate the input as in this industry the capacity of the equipment (reactor) is defined by the quantity charged into it.

Step 3: The input is then used to compute the batch equivalent of each stage based on number of equipment available at that stage. Continuing the same example if reactor capacity is 1200 kg and this input gives us 1000 kgs or 2 batches of final output and we have two such reactors, then the **batch equivalent** for this stage is (# of batches of output per input batch x # of reactors) = 2 × 2 = 4 batches of final output.

Step 4: The Effective Cycle Time (ECT) per batch = {Operation cycle time/batch equivalent}. For the same bulk drug manufacturing unit, this is calculated as shown in Table 5.2.

To reiterate the computation method let us look at Drying II process. Here, the output per drier is 350 kgs, the finished goods batch size is 500 kgs (Table 5.1), and there are 3 driers available. Hence, then batch equivalent = {(350/500) × 3} = 2.1. The average cycle time for a drier based on the observed data from last

Table 5.1 *Takt* time calculation for bulk drug manufacturer

			Current	Target
Requirement	A	(Tons/month)	28	40
Batch size	B	Kgs/batch	500	500
Demand rate*	C = {A*1000/B}/30	Batches per day	1.9	2.7
Takt time*	D = 24/C	Hours per batch	**13**	**9.0**

Table 5.2 ECT calculation for bulk drug manufacturing

Operation activity	Available equipment		Observed cycle time	Effective cycle time
	Nos	Batch equivalent	(Hours)	(Hours per batch)
1. Reaction	5	5	60	12.0
2. Neutch filter	1	1	11	10.6
3. Dissolution	1	1	6	5.8
4. Carbon	3	1.5	18	11.7
5. Acidification	3	3	16	5.3
6. Drying I (350 kgs per drier)	4	2	20	10.0
7. Methanol purification	1	1	11.8	12
8. Filtration	3	3	21	7.0
9. Drying II (350 kgs per drier)	3	2.1	21.4	10.2
10. Milling	1	1	2	2

20 batches was 21.4 h. So, the effective cycle time (ECT) = {Observed cycle time/Batch equivalent} = {21.4/2.1} = 10.2 h per batch.

Further, we can see reaction (process number 1 in the above table) has the highest ECT of 12 h per batch. This is then the bottleneck operation having the current output capability of (24 h/day)/(12 h/batch) × (30 days/month) = (60 batches/month) × (0.5 tonne/batch) = 30 tonnes of finished goods per month.

We compare the current ECTs with the target *takt* time of 9 hours per batch (Table 5.1), and see that the three processes (1. reaction, 6. Drying I, 9. Drying II) are going to be bottlenecks to achieving the target output of 40 tonnes per month. These three processes are highlighted in Table 5.2.

5.2.2.3 Factors beyond the ECT

In a stable process, the operation with the highest ECT should ideally determine the capacity. However, other factors such as equipment downtime due to breakdowns or changeovers, imbalances in material planning or fluctuations in operating staff productivity, and raw material quality also contribute to the degradation of actual output of an operation.

Therefore, the actual output capability of the bottleneck operation should be computed giving due consideration to such factors. The following examples illustrate the adjustments to be made to ECT-based capacity calculations in two different scenarios—one where the process is predominantly manual and the other where it is equipment driven.

Manual Process—Pump Assembly Line

MWM pumps assemble monoblock pumps on a manual assembly line. The pump testing operation was found to have the highest ECT of 4 min. The employees work from 9 am to 6 pm with an hour's break for lunch and tea.

Expected Output = Available time/ECT

= (8 hrs per shift × 60 mins /hr)/(4 mins per pump)

= (480 mins / day) /4 mins/ pump)

= 120pumps per day

However, in practice, it was observed that actual testing operation began at 9.15 am and ended by 5.45 pm. Also, the testing stopped for 10 min every couple of hours to clean the water lines (3 times in an eight-hour shift)

Actual run time = Available time - losses at shift ends

- losses due to water line cleaning

= 480 min - (15 + 15) min - (10 × 3) min = 420 min

This purely manual process demands a fatigue allowance of 5% which means an operational efficiency of 95%

Expected gross output

= Run time × Efficiency / ECT = {420 min/shift × 95 %}/ (4mins / pumps)

= 100 pumps/ shift

The past data showed that on an average 5 pumps were rejected each day after testing process.

Daily expected output = 100 - 5 = 95 pumps

This is the daily expected output under current conditions, and we can see that it is 20% lower than that computed based solely on the ECT. In this case, the output closely matched the actual daily recorded output, and the testing process which had the highest ECT was confirmed as the bottleneck process even after the above adjustments.

Equipment-Driven Process—Welding

In equipment-driven processes, the Overall Equipment Effectiveness (OEE) is a key metric to arrive at the output capability of the bottleneck process.

A battery manufacturing facility works two shifts of 7 h each of actual working time. The manufacturing process steps include—electrode plate formation, frame welding and pressing, plate grouping, cell assembly, formation, battery assembly, testing, and packing. After preparing the VSM, the team initially identified the plate grouping activity as the bottleneck with the highest ECT of 24 s per plate based on the cycle time of a standard 13 plate combination. This operation runs for 13.5 h as half an hour is lost for the shift change activities, and the current expected output is based on 13.5 h run time.

Capacity = Actual Run time / ECT = {13.5 hrs / day × 3600 s / hr} / (24 s / plate)

= 2025 plates per day

The team then verified the expected output from each of the processes in a similar way to rule out any other possible bottlenecks. And it so turned out that the frame welding process also turned out to be a bottleneck process in spite of a lower cycle time of 22 s only. The computation for frame welding:

Recorded average breakdown in month = 8 h

Daily downtime = {8 hrs / month × 60 mins / hr} / {24days / month}

= 20 mins / day

Hourly stop for cleaning of electrode : 5 min

Average number of stops per day for electrode cleaning = 12

Actual Run time = Available time - downtime losses due to electrode cleaning

- breakdown losses = (13.5 hrs / day × 60 min / hr)

- (12 stops × 5 min / stop) - 20 mins = 730 min

Capacity of frame welding = 730 mins / day × 60 s / min} / (22 s / plate)

= 1990 plates per day

Thus, the frame welding turned out to be the real bottleneck in this case, even though it does not have the highest ECT.

It is important therefore to calculate the output capability for all operations regardless of their ECTs. The Effective Cycle Time gives the expected time per unit output and we then factor in equipment/human availability net of stoppages and quality rejections to arrive at the expected output at each process. The bottleneck process is the one which delivers the lowest output in current conditions. **Tip:** We validate this through direct observation at the *gemba* (Japanese word meaning “real place” or place where value is created). Operations before which large inventories are piled up are likely to be bottlenecks.

The expected output should more or less match with the actual recorded output. If the actual output is lower, the reasons are likely to be found in unrecorded performance issues such as short stops or misaligned supplier processes. These issues (termed as *clouds* in VSM parlance) need to be further analysed and are to be included in the improvement roadmap.

5.3 Cost-to-Serve

After time-to-serve, we now move our attention to cost-to-serve. Fundamentally, resources are consumed to produce the output, and the resources cost money. Some of the resources have long been paid for (fixed assets such as plant, machinery, warehouse), some are paid as they are used (materials, direct labour), and some resources cannot be directly costed such as clean air, water, and environment. Though we will restrict our discussion to the first two categories of resources, we should note here that amongst all production systems, Lean implemented in its true spirit results in better environmental sustainability.

5.3.1 Measuring Cost-to-Serve

The highly evolved automotive industry targets reduction in overall manufacturing cost by a certain percentage each year regardless of any rise in raw material prices. These ambitious targets are also passed on their vendors, the auto-ancillary units. So, how are they able to keep reducing costs year on year? The answer is that Lean has become an integral part of their culture over the last few decades, leading to an ever-increasing productivity of their key resources.

Better productivity implies an effective utilization of available resources to meet the target output. An important aspect to note here is that effective resource utilization is viewed through the "*Lean Lens*" of Value Addition versus *Muda* (or waste). For all practical purposes a value-adding process can be simply defined as "A process step that transforms the shape, property, characteristic or feature of a product or service in the direction specified by the customer". Any process step that is not value-adding is by default a *Muda* or waste activity. All activities incur some expense. In our parlance, the portion of expenditure spent on value-adding activities is considered as cost and the rest is wasteful expenditure. Therefore by reducing *Muda*, we can minimize wasteful expenditure and thereby the overall cost of manufacturing. Table 5.3 summarizes the key resource productivity measures and their impact on manufacturing cost.

Table 5.3 Key resources and their productivity measures

Resource	Productivity Measures	Impact
Time	Lead time Value Add Ratio	Delivery performance Response to customer needs
Material	Inventory turns	Cost of inventory
	Rejections & Losses	Cost of Poor Quality
People	Productivity % Value Add	Expense on non-value adding people
Infrastructure (facility)	Proportion of value adding	Expense on non-value added space
	Distance moved by material Number of touches	Expenses due to unwanted handling and transport
Equipment/machinery	Overall Equipment Effectiveness (OEE)	Unutilized (lost) machine hour expenses Loss of opportunity costs

The advantage of using these performance metrics is that they do not require to be benchmarked with others. An organization striving to improve on it's current performance can consider itself to be moving in the right direction. The goal of current state assessment is to collect data, calculate process performance on these metrics, and call out the cost impact of current performance levels. We will now discuss the approach used to compute each of these metrics.

5.3.1.1 Time

We have earlier discussed the importance of lead time, the various methods used for measuring it as well as how capacity is a function of time. The value stream map (VSM) is the assessment tool which primarily deals with time as a resource. A key metric is the value-adding (VA) ratio; this is the proportion of the time when the material is undergoing actual transformation (value addition) versus total time spent by it in the factory. A higher VA ratio indicates that the material is flowing relatively faster through the value stream to reach the customer.

$$\text{VA Ratio} = \frac{\text{Total sum of cycle (processing) times of all operations to deliver unit output}}{\text{Order to Dispatch lead time}}$$

The VA ratio is a good indicator of the level of *Muda* (waste) across the processes as this example of a toy assembly line illustrates.

Toy Assembly and Packing Continued…

There are five operations with observed cycle times of 50, 60, 45, 55, and 60 s, respectively, and the count of inventories across the shop floor was 100 units. Recall from the previous mention of this example (Sect. 5.2.1.3) that a 100-unit inventory implies 100 min of inventory/waiting time, given a maximum cycle time of 1 min.

Total sum of cycle (processing) time per toy

= 50 + 60 + 45 + 55 + 60 = 270 s or 405 min

Lead time = Waiting Time + Processing Time = 100 = 4.5 = 104.5 min

VA Ratio = Processing Time = 4.5 / 104.5 = 4.3 %

In other words, the material spends 95.7% of the total lead time without any value addition and is just idle inventory. This WIP popularly termed as "Waste-in-pipeline" leads to lowering the inventory turns and increasing wasteful expenditure of storing, handling and transporting the material.

5.3.1.2 Material

From a manufacturing industry perspective, it is evident that customers pay for the product or material that meets their specifications. The factory transforms the raw materials to the customer-specified finished product through a series of processes. All value addition is defined on the basis of transformation of material. According to Lean paradigm, any material that does not reach the hands of the customer is a waste or unproductive use of resources. During current state assessment, we measure this fraction of material as rejection and/or loss.

Let us take the example of a sheet metal fabrication unit where the first process is a CNC laser cutting process for cutting discs out of a 25 mm thick steel plate; these discs are later welded to form the base for a solar pump panel support structure. Figure 5.1 depicts the different types of material losses that occur in this process.

The yield loss is the part of the steel plate that is not included in the discs, and it depends on how best we design the cutting pattern to maximize sheet utilization. Design loss is the material removed from inside the circle to give the ring shape and this is due to inherent design of the product. In fact, this is where the additive manufacturing technologies such as 3D printing have an advantage as it is based on adding the material as opposed to removing material to form the part. These new technologies are yet to catch-up on scale and cost of production.

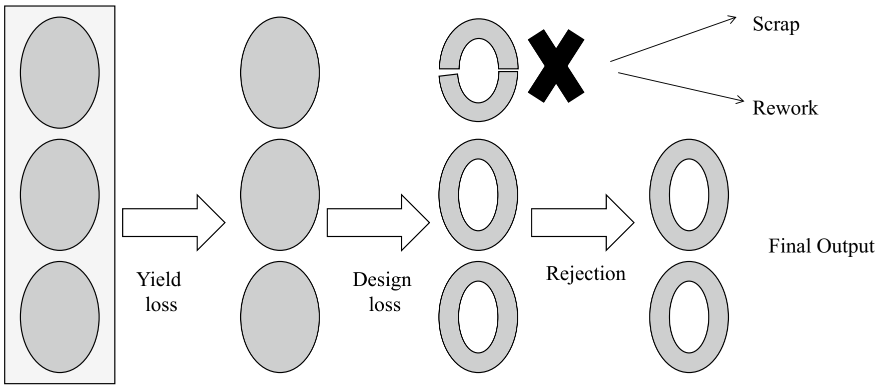

Fig. 5.1 Different types of material wastes

Rejection, one of the seven wastes of Lean, is loss due to defects where the output is not in accordance to customer (next in line process) specification. The rejection may be dealt with in different ways—it could be reworked, sold as seconds, or scrapped, depending on the type and severity of the defect. The yield computations are slightly different in chemical and process industries, as explained in the section on machinery.

5.3.1.3 People

Human resource productivity has been measured right from the start of the industrial engineering era. Typically, output per person per day is used as a productivity measure across industries, e.g. number of toys per person per day, litres of oil packed per person per day, kilograms of seed processed per person per day, etc. But these measures are based on a narrow definition of output and do not provide direction without benchmarks with best-in-class performance levels at that point in time. People productivity measurement under Lean paradigm addresses these limitations and is based on the broader understanding of value addition. Let us recollect here the fundamental principle of Lean—in a product environment, customer is paying for the material, and therefore, only those activities that directly transform the material are seen as value adding. All other activities by default are considered as waste (*Muda*). By this definition:

> Human Resource Utilization = Time spent on value addition/Total time available

Aggregating this for the total human resource employed across the organization tells us what proportion of the total manhours is spent in wasteful activities and can potentially be redeployed into value-adding work, thereby raising the overall productivity. Figure 5.2 illustrates this segregation of value-added and *Muda* times.

In organizations, people work typically in core operations or in support roles. Core operations involve directly transforming the material, information or service, a value-added activity. Support functions include finance, material handling, administration, quality control, and shop floor supervision. Note here that a QC

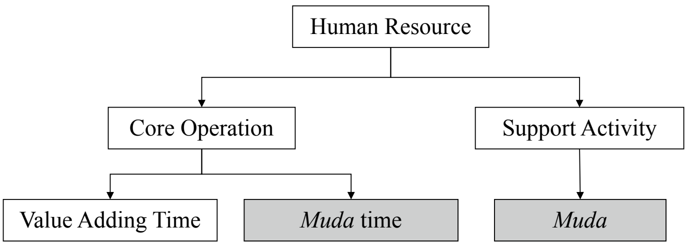

Fig. 5.2 VA and *Muda* times for human resources

inspector does not add any value but only performs the function of gate keeping. Under Lean paradigms, the entire time of the people involved in support functions is *Muda* as none of them are directly involved in transformation. Further, even in core operations, the part of the time spent on actually transforming the material is only considered as value-adding and the time spent in other activities including waiting or idling time is *Muda*. This example from a shrimp processing unit illustrates the concept (Table 5.4).

Shrimp Processing Plant
Within the core operation, we can see that there is cycle time variation among the operations, and the flow is determined by the slowest operations (2. cutting and 4. sorting and setting). The people working in other operations will therefore have some slack or idle time (to the extent of difference of cycle times). For example, the idle time of 1st operation (Peeling) = 46–42 = 4 s.

$$\text{Total cycle time} = 42 \times 3 + 46 \times 4 + 42 \times 2 + 46 \times 8 + 36 \times 9$$

$$= 1086 \text{ person - seconds}$$

$$\text{Total wait time} = 4 \times 3 + 0 \times 4 + 4 \times 2 + 0 \times 8 + 10 \times 9$$

$$= 110 \text{ person - seconds}$$

Table 5.4 Shrimp processing diagnostic

	People			
Process	Support	Operation	Cycle time (sec)	Idle time (sec)
1. Peeling	3	3	42	4
2. Cutting	3	4	**46**	0
3. Soaking	2	2	42	4
4. Sorting and setting	8	8	**46**	0
5. Freezing, packing, and storage	6	9	36	10
Total	**22**	**26**	**210**	**18**
Dispatch section	**20**			
Receiving section	**5**			
TOTAL	**47**	**26**		

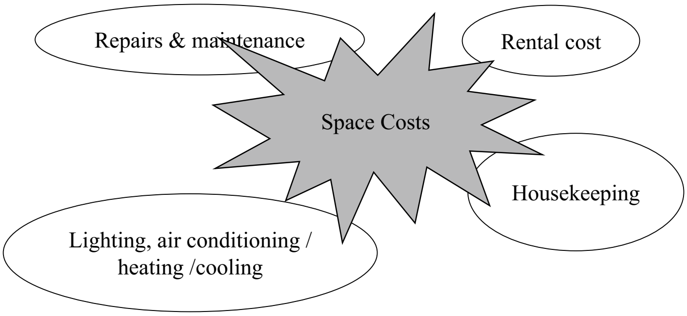

Fig. 5.3 Typical space-related operating costs

So, value-adding ratio within core operation = Value-added time/(value-added time + wait time) = 1086/(1086 + 110) = 90.8%

Proportion of people involved in core operation = 26/(47+26) = 36%

Overall value-adding ratio for People = 90.8% of 36% = 32.7%

This means that of the total manhours available, only 33% is spent on actual value addition.

5.3.1.4 Facility Infrastructure

Facility infrastructure refers to both the total space as well as the equipment available at the factory, and we would like to assess the utilization of the built-up area provided for operations. Two kinds of costs an be attributed to the facility infrastructure; the first is the cost of the space itself, and the second is the expenditure related to material handling and transport within the facility which is a direct function of the design (layout) of the space. We discuss each of these elements below.

Space Utilization

People can be often heard grumbling "We do not have any space to work" or "We can make more but there is no space available, it is so cramped". This invariably leads to management decisions such as taking an extra space on lease or investing in factory expansion to overcome these space constraints. Before making such an investment, it is important to assess the current space utilization as the existing space incurs operating expenses as seen in Fig. 5.3 and creating new space would require a substantial investment.

The value-adding ratio for space is the proportion of the total available built-up area that is being used for actual value-adding operations. The total value-adding area is the sum of all machine and workstation footprints each of which are physically measured. The "mandatory" space needed for operations including for gangways, electrical panels, safety, and environmental requirements is also worked out. The rest of the space is now potentially "available" as it is either idle

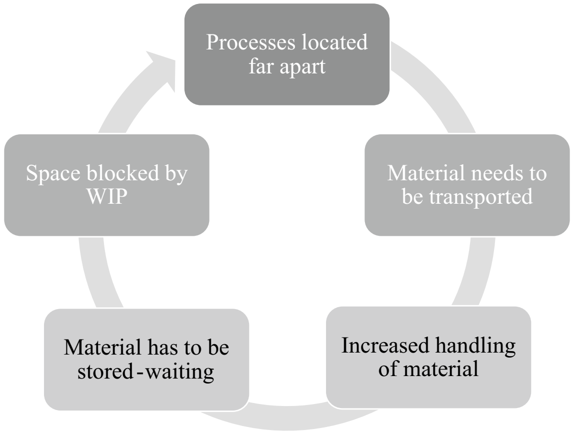

Fig. 5.4 Vicious cycle of layout and material storage

or occupied by the *Muda* of inventory or non-useful items.

$$\text{Effective Space Utilization Ratio} = \frac{\text{Total value adding area} + \text{Mandatory space area}}{\text{Total available factory space area}}$$

The Layout Effect

The way the equipment and workstations are arranged determines the extent of material handling and transportation and movement of operators in an operating unit. It is now an established fact that the facility layout is the single most important factor in determining the level of *Muda* related to material storage, handling, and transport. Close interlinking of supplier and customer processes is the key to smooth material flow through the value stream. The layout can ensure the physical proximity required for this interlinking. All factories grow, morph, and upgrade over the years and processes, if located farther apart lead to a vicious cycle of increased material handling, transport, and storage (see Fig. 5.4) resulting in a further blocking of space which in turn leads to new machines being placed even further away.

The “*Muda Walk*” is a tool used for assessing the impact of the current layout. The idea is to put oneself in the shoes of the material (in a manufacturing unit) or of a customer or service provider in a service facility. You then walk through the value stream from start to finish tracing the exact route taken by the material or the customer/service provider, and on the layout chart, develop the material flow diagram.

> The material flow diagram is popularly known as the Spaghetti diagram. In most legacy plants that have grown over time, the crisscross flows of the material traced through the Muda Walk often resemble a bowl of noodles.

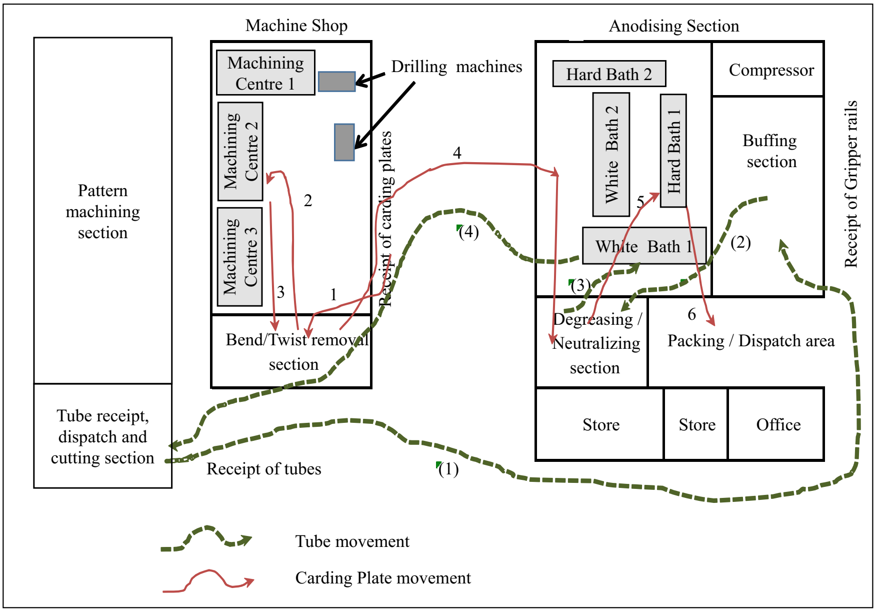

Fig. 5.5 Material flow diagram for an aluminium products unit

Figure 5.5 illustrates a material flow diagram for an aluminium products unit.

Layout effectiveness is best measured through these two parameters:

1. *Distance travelled by the material*: as we trace the route of the material through *Muda* Walk, we keep count of our footsteps and convert this to an approximate distance travelled by the material within the premises, For example 10 steps from Process A to an intermediate storage point is equivalent to 20 feet of material movement.
2. *Number of touches*: one of the fundamental lean principles is "One touch to Value-Add". This means each time the material is picked up, it should be for the purpose of adding value. Hence, the ratio of number of touches to number of value-adding operations is an indication of the extent of extra material handling. The ideal ratio is of course one.

A layout causing greater material handling will result in the following,

- Higher resource requirement—people, space, handling equipment,
- More opportunities for damages/quality problems.

This case example of a crockery manufacturer shows us the importance of measuring and working on the layout.

Broken Cups and Saucers

We recently worked on a Lean assessment for a ceramic crockery manufacturing unit. The process is divided into two main sections—the green stage and the whiteware (fired product). While rejections in the green stage are reprocessed, any defect in whiteware leads to the item being either scrapped or sold as seconds. The whiteware rejection was a whopping 20% with damages and chipping contributing significantly to it. The layout assessment in the whiteware side of the operation threw up the following data:

Distance travelled by one cup or saucer = 220 ft
Inventory points per operation = 4
Number of touches was (15 for three value-adding operations) = 5 touches per operation.

The '*Muda* walk' clearly brought out the fact that the layout had led to multiple storage points which in turn resulted in increased handling. Interlinking the operations in flow sequence was the project accorded priority. Within three months, the team modified the whiteware section layout and reduced handling damages by 50%.

5.3.1.5 Machinery

About a decade ago, a plant's performance was defined by capacity utilization or operating efficiency. A plant operating at 80% efficiency simply meant that it was running 80% of the time, while 80% capacity utilization meant that it produced 80% of rated output. Lean however focuses on the effective utilization of plant and machinery rather than solely on efficiency. The difference in these two approaches is captured succinctly in the following statement.

"Efficiency is doing things right while effectiveness is doing the right things…. efficiently"

Overall Equipment Effectiveness (OEE)

OEE is the single comprehensive metric for the assessment of automated and continuous process plants such as chemical, pharmaceutical, metal, oil & gas, food processing. In discrete manufacturing, OEE should be measured mainly for the identified bottleneck operations, as a lower OEE for a non-bottleneck operation does not imply reduced capacity (unless its ECT becomes higher than that of the bottleneck operation due to reasons mentioned in Sect. 5.2.2.3). In line with the Lean paradigm of value-adding ratio, OEE is simply the VA ratio for a plant or machine. It is a measure of the proportion of total available time spent by the plant or machine in actually transforming material as per the customer specification. The three main components of OEE are availability, performance, and quality which measure the following six major losses.

Availability is the time the machine actually runs net of downtime. The two losses causing downtime are:

- Equipment failure,
- Set-up or changeover.

Performance is how much the machine delivers against its rated output and depends on the speed losses such as:

- Idling and minor stoppages,
- Reduced speed.

Quality is the good output that actually meets customer specifications and excludes:

- Process defects,
- Yield losses.

Computation of OEE is illustrated in this example of an injection moulding machine.

OEE Calculation Method for an Injection Moulding Machine

The machine runs 24 h a day and OEE is also computed on a daily basis. Yesterday there was a breakdown for 90 min and a die changeover due to die wear-out which took 150 min. We first compute the availability ratio.

Total available time = 24 × 60 = 1440 min

Actual run time = Available time - Breakdown time - Changeover time

= 1440 - (90 + 150) = 1200 min

Availability ratio= Actual run time / Total available time

= 1200 / 1440 = 83 %

Next we compute the performance ratio. The machine actually produced 1080 components and has a rated cycle time of 60 s per piece.

So, rated output in actual run time = Actual run time/Rated cycle time = {1200 min × 60 s/min)/(60 s per piece) = 1200 pieces.

Performance ratio = Actual output/Rated output in actual run time = 1080/1200 = 90%

And finally the Quality ratio. A total of 30 pieces was rejected due to defects.

Quality ratio = Good output/Total output = (1080-30)/1080 = 97%

OEE = Availability x Performance x Quality = 83% × 90% × 97% = 72%

So, effectively the machine spent only 72% of total available time in value addition.

Let us delve a little deeper into the practicalities of computing the OEE.

Availability parameters: the availability parameters including breakdowns, changeovers, and planned downtimes are generally captured in a similar manner across most industries. Hence, the calculation of availability ratio is pretty straightforward as we saw in the injection moulding example.

Performance parameters:

1. *Rated Speed*—Defining Rated Speed can be a little tricky. Typical Doubts that Arise Are:
   - Is it the speed as demonstrated by the supplier during performance guarantee?
   - Is it the speed stated in the machine manual?
   - Or is it the best achieved practically demonstrated speed or cycle time?
   - Speed is different for different products—how do we consider this during machine performance ratio calculations?

While there is no one correct answer that fits all circumstances, the following case example can point us to appropriate directions to take in different situations.

Aluminium Strip Casting

In continuous casting of aluminium alloys for sheet applications, the ideal casting speed varies based on the alloy and the thickness of the cast strip. There are no short stops in this operation as even a one second stop of the casting machine will lead to metal leakage and complete breakdown of the process for several hours. The performance ratio has to be therefore calculated for each run based on casting speed alone. The rated speed is based on the supplier's performance guarantee as well as mentioned in the machine manual.

For example, a 1XXX series alloy cast at 8 mm and 6 mm thickness should be run at speeds of 1.2 m/min and 1.4 m/min, respectively, while an 8XXX alloy cast at the same thicknesses has to be run at slower speeds of 1.10 m/min and 1.25 m/min, respectively, due to increased alloy hardness.

In practice, parameters such as mould setting accuracy and molten bath temperature also determine the actual running speed. This means speed varies through the day with variation in process conditions.

Performance ratio is therefore computed as equal to actual output for the day/output at rated speed.

Output at rated speed = (Rated Speed (m/min) × Strip width (m) × thickness (mm)/1000) × Density (kg/cu.m) × actual run time (minutes).

Actual output is a sum of produced good coil weights and rejected material weight (is also weighed before remelting).

2. *Short Stops*

The second loss factor for performance is short stops. Rarely does anyone record these one- or two-minute stoppages. If we do not have an auto-recording mechanism, we can identify the contribution of short stops to performance loss by working backwards from the performance ratio as we can see from the following example of an edible oil packing machine.

Edible Oil Packing

A standard Form Fill and Seal (FFS) machine is used to pack one litre of sunflower oil at a rated speed of 15 pouches per minute. The machine does not have any provision for recording short stops, and one operator handles three machines. We need to assess if there is a significant impact on performance due to short stops. Following data was collected for a one day's production:

Running time: 6 h
Output as per rated speed = 15 pouches per minute × 360 min = 5400 pouches
Actual recorded output as per machine counter = 4800 packs
Performance ratio = Actual/Rated = 4800/5400 = 89%
Actual speed at the which machine was run (as seen from control panel) = 14 pouches per minute
Performance that should have been obtained at this speed = 14/15 = 93% or 7% speed loss.

Hence, 93 − 89% = 4% is the loss due to short stops. If this is significant in a given context, as a next step, we may go for direct observation to record number of stoppages and their reasons.

In today's world, several plants have started recording short stops without operator involvement. Industry 4.0-based Internet of Things (IoT) solutions can automatically capture any machine stoppage with provisions for recording the reason for stoppage as well.

Quality parameters: there are primarily two types of quality losses—rejections and yield losses.

1. ***Rejections***: every industry records rejections and most factory teams even drill down the rejection data to perform a root cause analysis. But one should be also able to identify in-process defects which are sometimes not clearly marked as rejections but taken as part of the process losses. This example illustrates how rejections are identified in a metal casting industry and incorporated into the quality ratio.

Aluminium Strip Casting

In a casting operation, rejections have a huge cost impact. On a particular day, it was observed that 60 MT of molten metal was supplied to the casting machine. This should have produced 12 coils of 5 MT weight each.

No coil was rejected for quality reasons. So, the quality ratio should be 100%. However, on checking, it was found that the total net weight of the 12 coils produced was 59.2 MT. Further examination of the log book showed that due to a surface defect, one coil was truncated and the defective layers taken out separately as a mini coil and sent for remelting.

So, the quality ratio here is actually 59.2/60 = 98.6%.

Yield losses: material yield information is sometimes not readily available. In chemical and process industries, the effectiveness of value addition is diminished by yield losses. In cases not involving chemical reactions, yield is simply material output/input. Where there is a reaction, it would be the actual output for given input as against the theoretical output based on the chemical formula. Let us look at a few examples on how to factor these losses into the quality ratio.

Prawn Feed Operations

In the prawn feed mill, the final product (feed) is obtained after sieving the extruded, conditioned, and dried material. Here, the material falls through a set of vibrating sieves of different mesh sizes and is separated into three parts:

Right size—good material that is packed
Oversize—collected and reprocessed
Undersize fines—collected and disposed.

Now as per the process design, all the raw material fed into the die can be extruded to required size. So, while there may be no rejection of packed feed, the sieves are preventing the undersize and oversize from getting packed.

On a day when 100 MT of material was fed to the die, 93.6 MT was packed. So, quality ratio is 93.6% as this proportion of the raw material was converted to product for the customer. Fines collected in bins weighed 1.4 MT, and the remaining 5 MT was reprocessed.

Oil Yield Loss

Going back to our earlier example of an edible oil packing machine, the quality ratio is a result of rejections and yield losses. Let us say a packing line comprising of a set of packing machines has packed 60,000 one-litre pouch packs in a day. At a density of 0.9 g/cc, this should be 54 MT of good output. At the end of each day, the holding tank levels are recorded.

Oil fed to packing line = Opening Level – Closing Level + Oil inflow quantity.

We see that the oil fed to packing line was actually 60,500 L. The reasons for this difference include:

- Defective pouches—the oil is later reprocessed by cutting open the pouches. Some oil remains adhered to the plastic film and cannot be recovered.
- Oil spillage/leakages in the line or machine.
- Oil “giveaway” which is the excess oil filled into a pouch due to variations in the pouch filling process. The customer is paying for 1 l of oil which weighs about 0.91 kgs. However, there is a variation in pouch-to-pouch oil content which is seen when the operator weighs a set of 5–10 pouches every half an hour. So, the actual weight or oil filled could for example be 0.915 kgs.

It is difficult to measure weight of each pouch and calculate the actual “giveaway” as also the “dead loss” or irrecoverable losses. Hence, quality ratio is computed simply as Packed Output/Input Oil quantity = 60,000/60,500 = 99.17%.

5.4 Assessment Criteria

So far, we have looked at the various diagnostic tools that can be used to assess the current state of any operation and measure the key metrics of time-to-serve and cost-to-serve. Assessing current state and preparing a roadmap typically take about

Table 5.5 Appropriateness of different tools and metrics for different industries

Industry sector	VSM	MFD	OEE	Key productivity metrices
Discrete/engineering	E	E	U[a]	Time, space
Assembly lines	U	L	L	People
Chemical/process	L	L	E	Material yield, equipment
Predominantly manual	U	E	L	People, time, space
Job shop/custom built	L	E	U[a]	VA ratio
Services	U	E	L	Time, space, people

L—low relevance, not required
E—essential, has to be done
U—useful in specific places
U[a]—useful for bottleneck equipment

three days of focused engagement. The key to a quick and effective diagnostic study is to be clear about the metrics to be captured and the tools required to assess the process. How do I decide what is or is not relevant? A fair number of lean practitioners think that the Lean tools are generic and can be applied everywhere. While this may be so, both the effectiveness of diagnostic tools and the relevance of the metrics are dictated by factors such as the type of industry and the situation prevailing at that point in time.

We have summarized the relevance of the diagnostic tools and metrics across industry verticals based on our experience with well over a hundred organizations across multiple industry sectors in Table 5.5. The three tools considered are the Value Stream Map (VSM), Material Flow Diagram (MFD) and Overall Equipment Effectiveness (OEE). The goal is to have a focused and value-adding diagnostic exercise where we assess what is truly important and measure the impact parameters. This will in turn help us prepare a focused improvement roadmap that may significantly cut down on lean implementation time and resource.

5.5 Target Setting

Having understood and assessed the current situation using appropriate metrics, one can proceed to set targets for the organization. Lean targets need to be ambitious yet achievable—only then will the organization be motivated to think differently as per Lean paradigms. These targets are primarily of three types:

1. Growth oriented—how to produce more with the existing resources and facilities,
2. Profitability oriented—how to minimize resource consumption for existing output,
3. Employee well-being—improving the working life and morale of the employees.

5.5.1 Growth-Oriented Targets

The target should consider the projected demand over the next three years. A gap between actual current output and this projected demand points us towards making an in depth analysis on the capability of the value stream. Closing this gap involves a progression of improvements using Lean tools. The first step is to ensure actual delivered output matches the expected output under current conditions as described in Sect. 5.2.2. The next step is to meet the installed or rated capacity of the current value stream which is generally the capacity of the bottleneck process, be it equipment driven or manual process. And finally, if the projected customer demand (target) is beyond the rated capacity, we look at ways and means to augment capacity. The typical roadmap for a growth-oriented Lean program is depicted in Fig. 5.6 with the actions to be taken mentioned under each "step" that help the organization move up to the next level of output.

Some of the principles that are applied in prioritizing improvement areas :

- Improve internal processes first; then work with vendors and sub-contractors,
- Look through the eyes of the customer—hence focus on downstream operations first,
- Focus on the "pacemaker" operation—this is the last process in the value stream after which there exists only continuous flow.

For SMEs looking primarily to enhance output, it is advisable to strike first at the bottleneck operation wherever it may be located, even be it at a sub-contractor or vendor process. After the bottleneck is resolved, one can aim to quickly streamline the flow across the value stream. Once the process is delivering at its rated capacity or more but still falling short of the target, the management may look at alternate strategies to close the remaining gap. These strategies vary from situation to situation and also on the extent of shortfall with respect to the target demand. Some typical strategies that SMEs can look to implement under different scenarios are shown in Table 5.6.

5.5.2 Profitability-Oriented Targets

The popular cost reduction is re-interpreted in Lean terms as "expense reduction". All expenditure is not cost, only that portion that is actually incurred on value addition is treated as cost. Since the primary goal of Lean is minimizing wasteful or non-value-adding activities, the consumption of resources that go into such activities is reduced and the expenses also proportionately come down. Hence, through Lean paradigms, the organization can enhance profitability even without top line growth.

Earlier in this chapter, we have assessed the value-adding ratio for each major resource, be it man, machine, material, or facility. Now, targets can be set on each

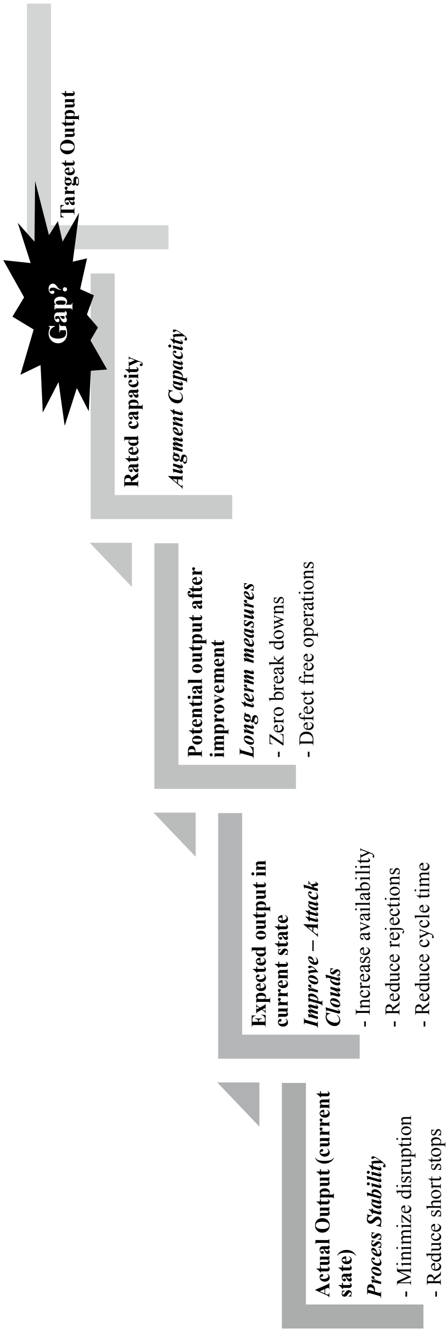

Fig. 5.6 Growth-oriented Lean program

Table 5.6 Strategies to increase capacity

	Gap with target output		
Strategies to be explored	<20%	20–50%	>50%
Increase shifts/hours of work	Y		
Sub-contracting part/whole of the job		Y	Y
Cycle time reduction through adding people	Y	Y	
Low-cost automations	Y	Y	
Machine speed increase		Y	
Adding extra resources (people/facilities/machines)		Y	Y
Expanding the plant			Y

Table 5.7 Examples of profitability improvement targets for a crockery unit

Parameter	UOM	Current state	Target
People productivity	Nos per person per day	137	173
Material yield	% reprocess	8.5%	<5%
	% rejection	20%	<10%
	% rework	11%	<5%
Facility utilization	Distance travelled (km)	0.8	<0.5
Employee strain	Man movement (km)	219	<100

or any of them, in terms of improvement in VA ratio, in other words, increase in resource productivity.

A typical target setting done for a small-sized crockery manufacturing unit is shown in Table 5.7. The processes in this industry are largely manual, and current rejection levels are high. Hence, the focus is on optimizing the man and material resources. Also, note the human well-being factor of employee strain reduction has been included as part of the roadmap.

5.5.3 Employee Well-Being

To sustain any Lean initiative, involvement of all the people working in the organization is a must. A good to way to get the buy-in of people especially those actually working on the floor is to include improvement projects that focus on strain reduction, safety, working conditions and environment. In fact, many of these are the outcome of *Muda* activities and so it is often possible to meet two objectives with the same improvement project.

Take the example of the crockery roadmap in Table 5.7. The current state assessment showed that collectively people were moving 219 km within the factory floor

Table 5.8 Comprehensive Lean target table for an LED manufacturing unit

Section	Paramter	UOM	Current	Target
Materials management	Space utilization (CFT)	% utilized	75%	>90%
	Customer service level	% OTIF kit issue	<60%	100%
	Stores management	Visual	No	Search free
	WIP inventory levels (LED)	No. of days	35 days	<7 days
Final assembly	Productivity	Nos/person/day	309	368
	Material transport	Distance moved	392 ft	<200 FT
	Bulb handling	No. of touches	26	<20
	Rejection	%/PPM	2%	<0.5%
MI line and packing	Wave soldering performance	Ratio	48%	>75%
	MI line productivity	Nos/person/day	333	417
	PCB handling	No. of touches	20	<8
	Rejection	%/PPM	1262	<500
	People productivity	cartons/man-hour	4	>10
Total factory	People productivity	Value adding %	135	160
	Space utilization	VA %	41%	>60%
	Facility itilization	Distance travelled	680	<400 ft
	Customer service (delivery)	% OTIF		
	Quality defectives	% defects	>5%	<2%

each day. Bulk of this movement also involved handling and transporting material between processes. More handling of crockery increases opportunities for damages such as chipping and breakages. Hence by taking up a project to reducing handling and movement, reducing human strain and reducing rejections can both be achieved, and the workers are enthusiastic to work on more such projects.

Finally, to summarize, a comprehensive target setting for an LED light manufacturer that incorporates all the three types of goals described in this section is shown in Table 5.8.

5.6 Summary

This chapter is all about performance measurement. What to measure, the relevance of different measures in different business contexts, how some of the practical difficulties in measurement can be overcome, etc. are discussed. The measures belong to primarily two categories: time-to-serve and cost-to-serve. All the measures in Lean paradigm are clearly defined from customer value-addition perspective. Meaning, whether or not the time and cost is being incurred in adding value to the product from a customer view-point or not. All the time and cost components that do not add value become candidates for elimination, which is the topic of the later chapters. Different organizations adopt Lean for different reasons, such as achieve sales growth or increase profitability, and improve working conditions for the operators. This chapter gives an indication of what measures are suitable for different strategies.

6 Designing the Lean Intervention

6.1 Introduction

We have seen in the previous chapter that current state assessment starts with understanding of management goals, defining corresponding performance metrics, and capturing the current state of the process with respect to the chosen metrics. Post assessment, all these need to be consolidated into a coherent roadmap that defines a stage-wise path towards achieving the stated goals under Lean paradigms.

Suffice to say, the roadmap should be simple, reasonable, unambiguous, and easy to monitor. Documentation should not become a barrier to action. Lean is all about doing and the quicker we start implementing the required improvements, the sooner we begin to see the fruits of undertaking this journey. This chapter discusses roadmap creation, the pitfalls, and how to avoid the same.

6.2 Building a Roadmap

Figure 6.1 indicates the broad stages of framing a Lean roadmap.

The gap between desired performance levels and the current performance levels needs to be bridged. The roadmap details the steps to be taken in sequence with approximate timelines in order to achieve the desired performance levels. Each step may comprise a set of improvement projects that can be executed using specific Lean concepts, tools, and techniques. What differentiates a Lean roadmap is the underlying Lean philosophy that drives the prioritization, sequencing, and focus on standardization of the gains from individual improvement projects. The following are the key components of a Lean roadmap:

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G. Mahadevan and K. C. Chejarla, *Lean Management for Small and Medium Sized Enterprises*, Management for Professionals,
https://doi.org/10.1007/978-981-19-4340-9_6

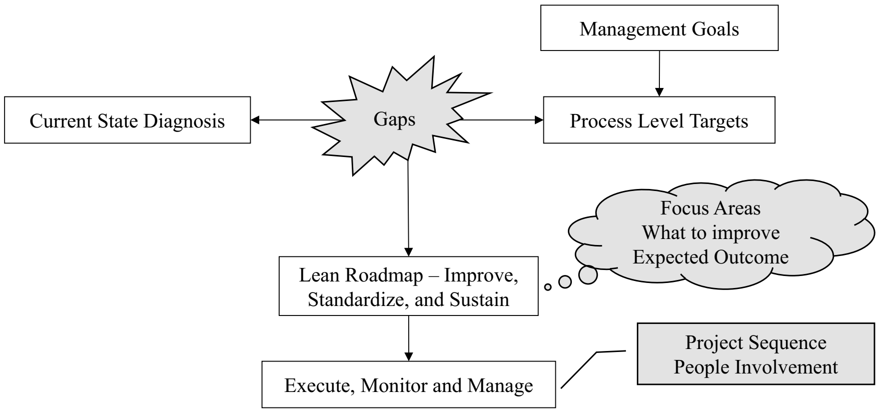

Fig. 6.1 Creating a Lean roadmap

How much	do we target in terms of performance
What	to improve (themes)
Where	to focus our attention (processes)
Why	do we need to improve this (outcomes expected)
When	priorities and timelines (schedule)
Who	will work on these projects (teams).

In the previous chapter, we spoke about target setting in Sect. 5.5. The bulk of the chapter was devoted to the assessment process that enables us to understand the "what", "where", and "why" components. We now crystallize this understanding through a documented roadmap and make it actionable by finalizing the "when" and the "who". We delve deeper into these two aspects here.

6.2.1 Sequencing the Improvement Projects

In an earlier chapter, we saw that SMEs in general have a shorter leverage as their business horizon dictates focusing on immediate concerns. It is essential that we keep this in mind while finalizing our Lean roadmap. Project priorities need to be carefully fixed for both the process and result criteria. The generic methodology discussed in Sect. 4.2 (Table 4.1) lays out a recommended sequence of activities to implement Lean. In the first step of implementation (Create Flow), the methodology emphasizes on "quick wins" or projects that show immediate gains to motivate the SME owners to continue on the Lean path. Some typical types of projects that meet these twin requirements are as follows:

- Solving an immediate pressing problem,
- Increasing output to cater to business growth/market demand,

- Improve productivity and lower costs.

Understandably, most roadmaps for SMEs are designed to start with implementing flow, line balancing, and cycle time reduction at bottleneck operations, because this is where immediate gains can be made with practically no additional investment. We have discussed several case examples of such beginnings to Lean implementation in Chap. 4. In Sect. 6.3 below, we will describe how additional improvement projects can be mapped to the later phases of Lean implementation.

6.2.2 Motivating the Team

People are the key to success in any intervention and more so, in a grass-root-level intervention such as Lean. Aligning all the stakeholders to a common vision is known to be the starting point for ensuring success of any change-related initiative. Most often, SMEs may not have a clearly articulated vision that people can align to. The Lean intervention should be designed such that it excites and motivates people in the organization to take up, implement, and sustain Lean. Designing a right mix of projects at each stage of the roadmap to benefit all the stakeholders will have a big impact on implementing and sustaining Lean.

6.3 Developing the Roadmap

In Chap. 2, we introduced the core Lean concepts of value and the three types of waste popularly known as the 3 Ms—*Muda*, *Muri,* and *Mura.* As a rule of thumb, a roadmap with projects that address all the 3Ms will find buy-in from all stakeholders, given specific benefits to the individual stakeholders as shown in Table 6.1.

Given the lack of awareness about Lean management and its benefits amongst most SMEs, it is essential to choose a mix of projects in the initial stages that can generate interest among all the stakeholders. These snapshots from a mini-cluster of bulk drug manufacturers highlight the impact of having the right mix of projects on the final outcomes of a Lean intervention.

Bulk Drug Cocktail-1

About a decade ago, three bulk drug units took the bold step of attempting Lean when it was almost unheard of in the industry. This meant that it was essential to ensure people on the shopfloor buy into this concept early on. At Porus Drugs, a six-month roadmap was framed with focused interventions every six-weeks. The set of projects to be taken up in the very first intervention included the following:

Table 6.1 Impact of reducing 3 M's

By reducing	Who benefits	How
MUDA (waste)	Entrepreneur customer	• Improves business results—top line and bottom line • Lesser consumption of scarce resources • Quicker service/delivery
MURI (physical strain)	Workers	• Improvement in working conditions and work methods help reduce the strain of daily working • Able to focus and provide better quality
MURA (inconsistency in process)	Managers/engineers/supervisors	• Streamlined work flow reduces stress involved in managing operations • Better control on process = more clarity on service delivery and capacity management

- Reducing variation in the bottleneck operation (reaction) cycle time with the goal of consistently maintaining the lowest achieved cycle time: This would directly increase throughput from the unit. This was to be achieved by optimizing process parameters, and a team of qualified production and quality personnel was formed to tackle this project.
- Reducing cycle time in drying process: The project was originally envisaged as a *Muri* project to reduce strain during loading and unloading of tray driers. This emphasis on reducing physical strain found favour with the workmen there as they were struggling with the manual loading and unloading. Also, the delay in completing the drying was stressing out the laboratory technicians who were forced to test multiple rounds of samples to confirm whether the required moisture content has been reached. The end result of this project would be reduced cycle time and higher output while reducing stress and strain to staff and workers.
- Rearrangement of stores on 2S principles focusing on spare parts and consumables: This project brought in the involvement of stores and maintenance personnel, thereby ensuring people across various functions are exposed to Lean concepts early on.

Hence, through a judicious mix of projects we were able to provide the right challenge to the qualified professionals, allay the anxieties of technicians and the strain of workmen, and bring in people across functions to appreciate Lean. By the end of the journey, the unit had recorded a 20%

increase in output, lead time reduction from 10 days to 4 days, and the drying process had actually been eliminated!!

Bulk Drugs Cocktail-2

The second of these enterprising units was KRR Drugs. The primary goal of Lean implementation here was to identify and minimize waste at the bottleneck processes of reaction and distillation. But the roadmap was drawn up consciously to work on improvements at the milling area—the last stage, where dried granules are milled to a fine powder and packed for dispatch to the customer plant. This process was actually one of the lowest cycle time operations in the value stream. But the operation generated huge amounts of dust making working conditions extremely difficult for the operators.

The strain on the two workmen was unbearable. In spite of wearing all the Personal Protective Equipment (PPE) including boots, overalls, masks, Googles, and helmets, they were covered in fine product dust from head to toe. Visibility in the room was so low that even the camera lens was fogged within seconds of attempting to take a video of the current state. A catchy and bold target was set for the team working on this project-*operators should be able to work in the room without having to wear a mask*. In other words, dust levels in the atmosphere should be zero.

Sources of dust escaping from the process were identified, solutions discussed and implemented within three days, with direct inputs from the operators. On the last day, a complete video of the process could be shot with the workmen operating the process without masks. They were literally in tears as the project concluded, and the senior operator gave an emotional speech in front of the entire staff during the Lean project sharing session. Needless to say, the entire workforce strongly endorsed the Lean initiative and was eager to join and implement subsequent projects.

The importance of getting the buy-in of the workers who are the actual value-adders in any manufacturing organization cannot be overemphasized. For workmen, company profits, turnover, or productivity is of marginal interest unless there are incentives. Even incentives most often reward local or individual productivity and not the throughput from the entire value stream. Since worker acceptance of Lean is crucial to its sustenance, the roadmap should prioritize projects that can directly impact their day-to-day working life. *Muri* or strain reduction is the best bet as the previous drug manufacturing cases and following example from a white goods manufacturer shows us.

Rockwell—90° Makes a Sea of Difference

At this commercial refrigeration unit, makers of deep freezers, and chest coolers, we completed the diagnosis including a VSM and material flow diagram. Management goal was to rapidly ramp up output by 50% to meet market demand. The bottleneck processes were identified from the following overall manufacturing process flow depicted below (Fig. 6.2).

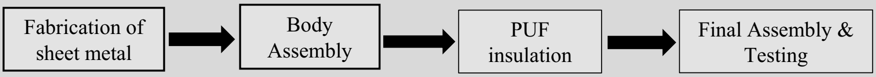

Fig. 6.2 Rockwell manufacturing process flow

Process observations confirmed that the body assembly section was the bottleneck as sufficient bodies were often not available for the customer PUF process. The PUF jigs were found to be empty intermittently during process observations. So, our roadmap prioritized improving the body assembly operations which also happened to employ the maximum number of workers in the factory.

To reduce cycle time, the workstations needed to be balanced and flow established. However, we had earlier observed that the initial clinching operation was being done in an unconventional manner. The smallest built worker was assigned to the two-man team doing this operation. His job was to crouch inside the space made by the two bent sheet metal parts (named Big C and Small C after their appearance) and use the clinching machine to join them together to form the outer shell of the cooler. Once these were joined, the clinching operator was trapped inside. The second operator would then lift the entire shell over the head of the clinching operator and place it on the next station, thus freeing the operator to move about (Fig. 6.3).

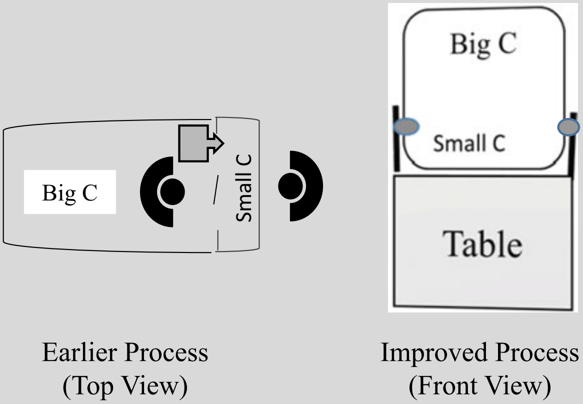

Fig. 6.3 Rockwell: improved clinching operation

Though this was not the highest cycle time operation, we still added this as a first priority project in the roadmap. The project goal was to avoid the operator from having to clinch by sitting inside the shell in an uncomfortable position. Within days, a better method was envisaged and implemented using suggestions by the operators. The existing clinching method was replaced by clinching on a table with the big C being supported in a aligned vertical position using magnets and a fixture. The operators stood facing each other on opposite sides of the table and clinched by running the machine comfortably along the table platform at waist height. This new method was so operator friendly that the entire assembly workforce were delighted and wholeheartedly participated in the assembly cycle time reduction projects at other workstations. Three months after Lean began, the body assembly section provided 200 bodies per day to the PUF process against the previous peak of 120 bodies per day.

One important aspect of diagnosis is getting a feel for the mood of the employees. For an external Lean *Sensei* to be accepted by the grass-roots operators, this is all the more critical. Quite often we find employees comfortable with status quo and unwilling to try and experiment or pursue a different way of thinking. Therefore, the roadmap should have a couple of initial breakthrough projects, which can cut through the natural inertia and reluctance of such employees and get them to try something new. One of the easy ways to do this is to break a few walls…literally, as we can see from the following case let!

Breaking Walls… and Mindsets

RDN was looking to balance its working capital burden while meeting increasing customer demand for its fabricated solar application structures. Over the past decade, the factory had expanded laterally from its single factory shed premises by renting adjacent properties and adding machines and facilities in them.

Current state diagnosis showed a lot of criss-cross material movement in between various fabrication and welding processes located across the three adjoining *galas (narrow independent constructed sheds).* The Lean roadmap for a first cycle of implementation spanning about nine months included projects on layout, reducing bottleneck process cycle times, defect-free welding, pull systems for outsourced galvanizing process, and FG warehouse arrangements on 2S principles. During the diagnostic study and framing of roadmap, we observed that most of the team of young engineers and older supervisors seemed equally reluctant to accept the need to make improvements. Realizing the potential barriers to the Lean journey, we gave the first priority to layout changes in our roadmap.

The proposed flow layout required a section of the wall between two adjoining sheds to be demolished to help drastically slash material handling. The management was historically not known for any radical actions, and the team was also comfortable with this inertia. But we were able to convince the management to give permission and the wall came down overnight. This single action helped break through the barriers in the minds of the employees as they realized the seriousness with which their management viewed Lean. The psychological effect of a wall coming down is well known; the Berlin wall coming down in 1991 to unify long separated people being a prime example. In this case too, resistance to change crumbled just like the wall, and Lean implementation was well and truly underway.

6.3.1 Theme-Based Roadmaps

It is always impressive when a roadmap depicts a clear path to achieve stated measurable business goals. Increasing output, productivity, profit or reducing rejections, or wasteful expenditure all sound good and look good on paper to the top management. However, such roadmaps appear to be "dull" and "unexciting" to the majority of the employees in an organization and even more so if it happens to be an SME. Too much emphasis on business performance results may also result in a negative impact; employees may start questioning "What's in it for me?"

In our experience, an effective roadmap that resonates with operators' concerns is to have themes that can excite, motivate, and align them to the Lean initiative. The end goals are already clear and defined in terms of metrices, and we also have identified projects/focus areas, the execution of which will help achieve these goals. What remains is to present these projects in a theme-based view that help the employees see the benefits of improvement with respect to the immediate issues concerning them. Themes can be as simple and straightforward as *zero defect* or *zero breakdown* or as varied as "*dust-free factory*" or "*strain-free operations*".

Through these examples, let us understand how such themes actually help in developing Lean thinking.

"*No Material on Floor*"—in simple language, material is money in a manufacturing set up, as the customer pays for finished material while the organization has paid for the input materials. When we develop a theme like "*No material on floor*", we are asking people to give due respect to the material that provides them their livelihood. This is the emotional connect. Now from a rational Lean perspective, operations carried on at waist height are strain free and most productive. Most machines have a waist height loading and unloading point. To pick up material from or place it on the floor adds to worker strain and increases operation cycle time. This strain may in turn lead to defects/damages or hygiene issues all of which are *Muda*. Hence, no "material on floor" can positively impact all the 3 Ms and therefore motivate all the stakeholders.

"*One touch*"—hygiene is a basic need in segments like food processing, pharmaceutical and consumer products and every human being can relate to it. In Lean, we say "*One touch to value-add*" because any additional touches will only result in extra handling or transport which is a waste. From the hygiene perspective, every touch increases chances of contamination or defects and people understand this. By aligning shop floor people to this theme, every additional touch can be identified and solutions implemented to eliminate them, thereby reducing the overall waste (*Muda*) in the process.

A single roadmap can also have multiple themes, each one aligned to a different leg of the journey as in this case of an edible oil manufacturer who was looking for a Lean-based continual improvement (CI) program over a one-year time frame. This industry has two major processes—refining and packing. Refining is a continuous process with multiple stages such as deodorization and filtration. Packing on the other hand is a mass manufacturing operation with high-speed unit pack machines followed by manual methods of secondary packaging. We needed to have a common theme that could resonate with all parts of the plant and be able to incorporate all relevant Lean tools so that people could be trained on using them. The core 3 M concepts were ideal as they were generic and all-purpose . Business goals of reducing losses, material wastage, and increasing throughput were translated into process-level targets (see Fig. 6.1) which are seen in Table 6.2, and each target is linked to a set of projects under one of the three themes.

6.4 Preparing for Implementation

Having completed the framing of the roadmap, the next step is to actually implement Lean through the projects identified in the roadmap. Up to this stage, Lean paradigms have been introduced to the key people in the organization, and they have been trained to relook at existing processes under these paradigms. At the same time, they have not been asked or told to actually change anything. But the seeds of Lean thinking if planted properly at this stage do help when it actually comes to implementing Lean.

Lean implementation is all about "doing" process improvement which means re-examining existing processes under Lean paradigms and making changes, primarily in the methods or ways of working. In older factories, this could mean enabling people who have been working in a particular way for the past several years to now do the same work differently. Opportunity as they say often knocks only once, and the same may be true of Lean as well. There are several instances of organizations who have tried and failed in implementing Lean and have now become wary of repeating the exercise.

Hence as we prepare to kick off the implementation phase to create flow, we need to define an approach which can generate the required positive energy and momentum to pull the organization through this journey. We discuss briefly in these subsections the key aspects for preparing a successful approach to implementation.

Table 6.2 Theme-based roadmap for an edible oil manufacturer

S. No.	Theme	Objectives	Goals	No.	Continuous improvement project
1	Reduction in *Mura* (inconsistencies in process)	Minimizing process inconsistency in hydrogenated oil plant	(A) To reduce the excess weight giveaway in pouches	i.	To reduce weight variation to within 4 gm range as per machine capability
			(B) To reduce the pouch film loss from 2% to <0.5%	ii.	To eliminate length variation and sensor related issues
				iii.	To reduce pouch loss during start up
		Eliminating process inconsistency in refinery plant	(A) To improve refinery throughput	i.	Reduce deodorisation steaming time variations and get 100% batches within spec of 2.5 h
				ii.	Study and minimize variation in hydrogenation time and catalyst use
2	Reduction in *Muri*—strain	Eliminating strain reduction in bakery fats plant	(A) To achieve the temperature in blending tank area below 45 °C	i.	Reduce heat losses in blending area
			(B) To reduce the strain during changeovers	ii.	To minimize effort and time required for changeover of micron filter
				iii.	To minimize effort and time required for changeover of strainers

(continued)

Table 6.2 (continued)

S. No.	Theme	Objectives	Goals	No.	Continuous improvement project
3	Reduction in *Muda*—wastage	Reducing residual oil present in scrap	(A) To reduce residual oil going to scrap from 10 g/pouch to <2 g/pouch	i.	Online pouch cutting at packing area and handling of oil
				ii.	Redesign recovery tank using steam/hot air to recover balance oil stuck inside pouch
		Eliminating carton and product wastage in new warehouse	(A) To reduce carton damages during transfer 2000 boxes/month to 500 boxes/month	i.	Observe and correct transfer issues at conveyor, spiral chute
				ii.	Observe and improve manual handling conveyor to storing point and storing point to truck loading

6.4.1 Focused Improvement Workshops

Quick results matter to the SME organization, and hence, the pace of implementation needs to be fast at the start of the Lean journey. Anything with a long gestation period and likely to engage the time and effort of the SME's resources is not going to find favour. Hence, the methodology we choose to implement the roadmap should be tuned accordingly.

One universal fact is that people love celebrating a festival or an occasion be it a marriage or a birthday. We see this all the more in traditional communities that have been in existence for hundreds of years. On such occasions, people come together with families and friends and work towards a common purpose within a well-defined date and time. The comradery between the people many of whom may have not met each other for a while drives the work forward. In fact, this "work" of preparation and organization of the event is so often as much fun as the actual event itself.

Generating this same spirit in the approach for implementing Lean is the key to success. The focused improvement workshop does just this. It creates an occasion for people to come together and work towards implementing a successful project. Our experience of using this methodology at SMEs over the last two decades

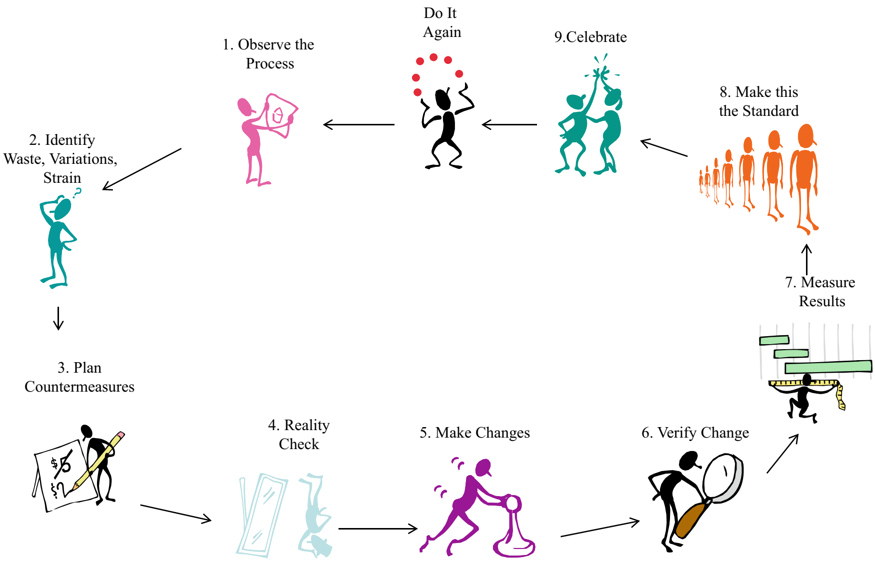

Fig. 6.4 Focused improvement workshop

has served to reiterate its effectiveness in quick improvements leading to lasting results. The typical cycle for a workshop is shown in Fig. 6.4.

Each workshop is normally built around a theme such as "single-piece flow" or "SMED" or "problem solving" and should incorporate the following elements.

6.4.1.1 Cross-Functional Teams

Figure 6.5 illustrates the typical composition of a cross-functional team.

Typically, team leaders are the process owners at the project location as they are responsible for the day-to-day functioning of the concerned process. Supplier team members get to understand the impact of their work on the customer

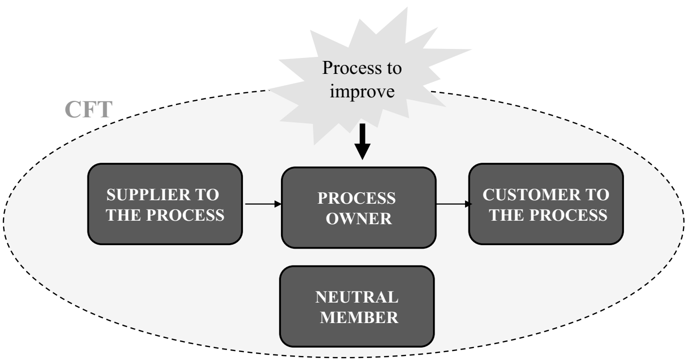

Fig. 6.5 Cross-functional team

(project) process, while customer team members appreciate the difficulties faced by their supplier process in serving them. The neutral member is akin to an umpire or referee. This team member has no direct link to the process being taken up for improvement and hence lacks any bias. She or he is expected to question everything, thereby opening up new avenues of thought to the rest of the team.

6.4.1.2 Short Duration Event

A workshop ideally should last from three to five days at the most; anything longer is bound to create fatigue and disruption in the regular work.

6.4.1.3 Focus

During such workshops, team members are expected to keep off routine work and devote their time and attention fully to the project being taken up. An apt analogy is the focus of sun's rays on a piece of paper. Normally, a piece of paper exposed to the sun does not hange in any manner. But if the rays are focused through a lens to a single point on the paper, it soon catches fire. With focus, the team is therefore expected to achieve in days what would normally take weeks and months.

6.4.1.4 Management Commitment

Full-time participation of the SME owners and partners in the workshops demonstrates their belief and commitment to Lean and sends a clear message to their employees. While they may not necessarily be a part of any project team, they are expected to listen to the team's progress at the end of each day, give required resource support, and take decisions that will help the team execute their project. Finally, they play a big role in motivating their teams.

6.4.1.5 Facilitator

Running a workshop and delivering significant results within days is not an easy job, and the SME would do well to have the right Lean *Sensei* do this job. The *Sensei* trains the teams on relevant Lean concepts, tools, and techniques, keeps the projects moving as per plan, moderates issues that may arise, and acts as a bridge to the SME management. Like any event, the facilitator has a major part in ensuring success.

6.4.1.6 Clear Action Plan

Not everything can be executed in three days; there are always ideas that need external intervention such as purchasing some parts or fabricating something outside and hence need more time to complete. All these are crystallized into a clear-cut time bound and responsibility defined action plan to be monitored by the management. Such action plans should not spill over beyond the month to take advantage of the momentum created by the workshop event and to maintain continued focus on the project.

6.4.1.7 Celebrate Success

Like all special occasions, the workshop should also culminate in a celebration. The outcomes of the ups and downs, debates and arguments, late nights and physical effort that has gone into the improvement activity will need to be validated and achievement toasted by the entire team. The workshop should always conclude with the team on a high! The results of a well-run focused improvement workshop can be phenomenal as this caselet shows.

Pump up the Volume

Our client, a medium-sized pump manufacturer was looking to increase output from their existing facility. While the downstream pump assembly process had a potential to produce 50% more, it was essential for the upstream operations to deliver equivalent enhanced quantities of all the required parts. The machine shop was organized in a typical functional layout with CNC milling machines, presses, turning centres, drilling machines, heat treatment furnaces, etc., all grouped in their respective locations.

Lean flow required the layout to be changed to part specific cells, and a focused improvement workshop was planned to complete this project. In a five-day workshop, the entire layout of the machine shop spread over two large sheds was realigned. On the first day, the existing product–process matrix was analysed to form new cells on paper. These cells were laid out on an AutoCAD drawing with three different layout alternatives generated. By the end of day 2, the team had brainstormed and finalized the new layout, and in the closing session, it was approved by the top management.

Days 3 and 4 were devoted to shifting over a hundred machines, at times even across the two sheds, using two hired cranes. Thousands of parts in work in progress inventories were shifted manually to the new cell locations; each and every team member right from the production manager to the operator were personally involved in shifting this material with their own hands. On the last day, the newly formed cells were run and the processes fine-tuned. The second half of the day was devoted to validating the output over half a shift. The result—over 50% increase in part output in the shortest throughput time!! The workshop concluded with an evening celebration as team members basked in the success.

6.4.2 Post-workshop Reviews and Handholding

Once the euphoria of the workshop dies down and employees get back to routine, it is difficult to keep their focus on completing the pending action points and taking the project to its final conclusion. The role of the Lean champion (see Sect. 6.5) is key to ensuring action plan status is tracked and updated, and the top management kept abreast of the progress. The top management in turn is expected to extend their support to the teams and enable them to complete the actions. This can be best done through the following review mechanisms.

6.4.2.1 Daily Gemba Walk

The SME owner/factory manager should necessarily spend about half an hour each day walking through the Gemba (Japanese word for shop floor). During this round, they should pay specific attention to the processes under improvement and check-up whether the improvements are being sustained. Team leaders can also showcase new actions and improvements they have implemented post-workshop.

6.4.2.2 Weekly Reviews

A fixed day and time scheduled for weekly review of Lean implementation gives the team a clear purpose to orient their week's activities. All the workshop teams are expected to attend review meetings together to ensure continuity in team working. Team leaders are encouraged to present their own action plan status supported by visual evidence (photo or video of changes done). The review meeting is chaired by the SME management as they continue to support the teams through decisions, resources, and motivation.

The importance of the review mechanism cannot be overstated. It is quite normal to see almost zero progress on action points in the first review post the workshop. At this juncture, the continuity of Lean implementation is threatened, and management plays a key role in bringing the momentum back. Completion of 80% of the action points by the end of the month or timeline agreed upon is considered as good progress. This is the point at which the planning for the next workshop begins.

> An organization making components for the defence sector started implementing Lean at their factory as it shifted from a pilot to full production stage. The years spent on doing research and development for the new component had oriented the employees to a laboratory style of working. Full-scale manufacturing that too employing Lean was a huge paradigm shift. After the first implementation workshop, progress on action points was slow and tasks that could be completed in days were being extended to weeks.
>
> After observing this for a month, the factory head fixed a Saturday evening deadline for each team to update their progress on the action points and submit the same with photographic evidence. They were also to submit data on the performance of processes already improved. This report was also initially marked to CEO and the Sensei guiding the Lean implementation. Teams reporting minimal progress for two consecutive weeks were called for a separate review with the factory head to speed up their work.
>
> By the second month, the pace started picking up and the factory head was in a position to plan for the second focused improvement workshop.

All in all, it typically takes SMEs about six to nine months to complete the first cycle of improvements. This entails creating and enabling basic flow (see Chap. 7 for details) and is normally achieved through three or four focused improvement workshops with about six weeks gap between each of them.

6.5 Organization Structure for Lean

Sustainability of a Lean initiative depends on the people driving it, and it is important to identify champions who would take on the mantle. Most large organizations have an internal operational/manufacturing excellence team with people trained in Lean, Six Sigma, and other such excellence philosophies. They are expected to drive the Lean initiative in all the line functions. SMEs lack the resources to have such people on their rolls and most often depend on working with an external Lean consultant or Sensei.

It is important to remember that such external resources are temporary and will never have the ownership for long-term sustenance in the way an employee would. The best way is to identify at least two internal resources from line functions like production, quality and maintenance, materials, etc., who can work closely with the Lean Sensei and learn the entire gamut of concepts and tools. This core team of Lean champions can then take over from the Sensei over a period of time and ensure the sustenance.

Having such Lean champions is a conundrum for most SMEs as a valuable human resource has to be spared for this new initiative. While the champion drives Lean and ensures its success, he or she gets to learn a lot and grow as a professional. This knowledge is again a double-edged sword for the SME as such a person while proving valuable to the organization will also get many more opportunities outside and is likely to leave the organization for better prospects sooner than later. More on this is in our chapter on Lean sustenance.

At the roadmap stage, we may not formally define any roles for the identified team members, but we should at least have them on board so that they are with the Lean *Sensei* from the outset. Individual roles and responsibilities can be defined at a later stage.

6.6 Summary

This chapter presents practical tips in arriving at process-level measures, given organizations business objectives, identify the gaps, and the bridging improvement projects. Once this is done, the next important part is sequencing the projects. Best beginnings are those projects that provide quick wins and also improve operators' day-to-day work. The later sequencing is best done on a theme-based mode, with which every organizational level can get associated with. The chapter presents a few examples of such themes, and the readers may come up with any other such themes that make sense in their organizational setting.

Once the roadmap is ready, the next step is to implement it. The success or failure of Lean depends a lot on the approach to implementation. The authors' decades of experience in implementing Lean have helped refine the focused improvement workshop methodology for rapid improvements that ideally suit SME organizations. The elements that go into such workshops and the post-workshop review mechanism are discussed in detail. Finally, the importance of having a Lean champion to drive Lean in the long term is brought out.

7 Implementing Lean

7.1 Introduction

"*A plan is only as good as its execution*". This management adage aptly sums up this module on implementing Lean. In the previous chapters, we discussed the diagnosis of the current state of operations from a Lean perspective and approaches to developing an actionable and sustainable roadmap. It is now time to act on the roadmap. Implementing a Lean roadmap typically follows these three main phases:

- **Process Improvement** by applying Lean concepts, techniques and tools,
- **Standardizing** the improved processes and monitoring them,
- **Sustaining** Lean through repeated cycles of improvement and standardization.

The three chapters of implementation module, starting with this one, deal with each of these three stages. Of these, the improvement phase has been the most widely written about and discussed both in literature and in practice. Most well-known Lean tools have been developed for making process improvements. The initial improvement phase initiates "*Change*" and sets the ground for the implementation of Lean. A profound Zen saying that forms the basis for Lean—goes:

> If you do not understand something, it does not change anything
>
> If you understand something, it does not change anything

We have understood the current state through diagnosis, identified what to improve and laid it out in the roadmap. But nothing has changed as yet. Change at the *gemba* (production floor) only occurs by taking appropriate action and this chapter focuses on how to go about it.

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G. Mahadevan and K. C. Chejarla, *Lean Management for Small and Medium Sized Enterprises*, Management for Professionals,
https://doi.org/10.1007/978-981-19-4340-9_7

7.2 Begin with Flow

The universal natural principle of Flow forms the core of Lean. In our experience, improving Flow of goods/services through the value stream is the best place to start, because it directly translates to higher revenue and profits for the SME. A good part of the improvement phase thus focuses on initially creating flow and then enabling and supporting this flow on a continuous basis. But what should Flow? It is the value we deliver to our end customer and for which the customer is paying us. In a manufacturing organization, the customer pays for a specified product. Hence, the raw material we procure needs to flow through the processes adding value at each step all the way till it becomes a finished product and gets delivered to the customer. Similarly, the service or information needs to flow in a service industry, where often, the customer or guest is herself a part of the process. For example, in service industries like health care, education, or hospitality the guest should themselves flow through the delivery process.

Taiichi Ohno, placed a lot of emphasis on flow when he stated his view on Toyota's Production System:

> All we are doing is looking at the timeline from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that timeline by reducing the non-value-added wastes

So, by reducing the non-value-added activities, i.e. wastes, we are in turn speeding up the flow of value-added activities and reducing the time for completing the order to cash cycle. ***The objective is to "reduce the time-to-serve the customer", the means is "to increase flow" and the method to achieve this is "to reduce waste or Muda".***

But where does this emphasis on flow come from in Lean thinking? As we mentioned in Chap. 2, flow is the natural order of things. All great natural systems are based on the principles of Flow. For example, the human body is designed with multiple flows governed by systems such as thought (nervous), blood (circulatory), breath (respiratory), food and water (digestive). Each system is designed to let the body absorb what it needs and reject and eliminate from the system what it does not need. We breathe in air (raw material), absorb the oxygen during processing, and remove/exhale the carbon dioxide (waste) all in one seamless flow. It is the same with food and water. The blood is the carrier of all these useful things and is a self-contained insulated system transporting what is required, where needed, and when needed in the quantity required (*this forms the very definition of Toyota's Just in Time system*).

Let us stop and ponder for a moment on what would happen if any one of these flows is disrupted. If we eat too much and overload our digestive system, we are left with an uncomfortable feeling and may even vomit or regurgitate our food—retracted flow. Constriction of blood flow such as a block could lead to a severe breakdown of the body in the form of a heart failure. A cold constricts the nasal passage leading to shortness of breath and affecting our stamina. However, when everything is running smoothly as designed, then we find ourselves in that perfect state of physical and mental fitness and are able to do almost anything we set our minds to achieve.

Similarly, other natural systems such as rivers, trees, the sea, or planetary motion all exhibit their own forms of flow. Even man-made music sounds best when all the notes are in harmony and music flows. Replicating these concepts of flow in the man-made process of manufacturing or service therefore forms the core of Lean thinking.

7.3 Understanding Basic Flow

Understanding a typical river system is a very good starting point to design business processes for flow. In the natural river systems of the past, water found its own path as there was little or no man-made intervention. Over millions of years, the river system developed into what we now see and know. Natural constrictions that came up from time to time resulted in the river choosing an alternate path but ensuring that it continued to flow towards and reach its ultimate customer—the sea. At times, when there is more water than the system can process, such as during very heavy rains, the river will reject this excess by the simple act of flooding surrounding areas resulting in devastating losses of life and property.

Over time, humans started harnessing this flowing river water for various purposes; drinking, year-long food cultivation and generating hydel power. To ensure water is available when and where needed, they developed a series of check dams and reservoirs at strategic points along the flow. The aim was to retain enough water for our needs without hampering the basic flow and also control flooding. When reservoirs are full, dam gates open and the excess water is released to flow into the sea. Now, the end customers for a river include human beings and not just the sea.

In the ideal scenario, the value stream of an organization should be akin to a natural river system, with material, information, or service flowing unhindered to the customer. Value should flow seamlessly without blockage, constriction, retraction, or zig zag movements. But in most shop floors, one comes across the "flooding" of work in process inventories that occupy a majority of the available space. This leads to significant and often incalculable losses for the organization in terms of expenditure on handling, storage, damages, rejections, expiry (of shelf-life items), and housekeeping activities. Hence, there is a clear case for moving towards the ideal state of flow.

Typical process flows designed on Lean principles are like the current man-modified river systems with continuous flow in pockets and strategically placed "reservoirs" of inventory to balance and maintain optimum flow. The system also incorporates checkpoints or quality gates that ensure only the right quality material flows towards the customer process.

The strategic inventory points are designed to have standard WIP which is in turn governed by pull systems operated through tools like *Kanban*. Here, the customer process "pulls" what it needs, when needed, from the standard inventory which in turn triggers the supplier process to produce and refill or replenish the inventory consumed. *Kanban*, a Japanese word for signal, is the primary tool used

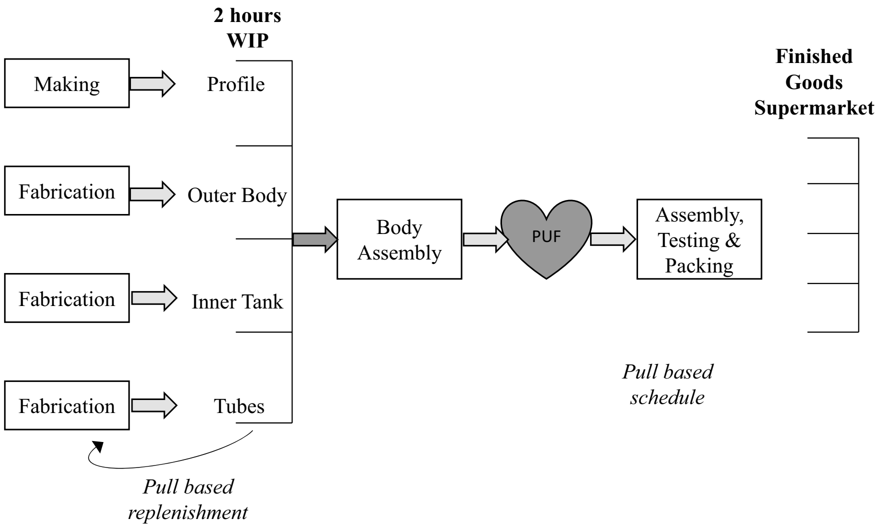

Fig. 7.1 Flow for a deep freezer manufacturing unit

to maintain this supplier–customer relationship. The origins for *Kanban* can be traced to a typical supermarket system, where shelves are loaded with fixed quantities of each product based on typical sales. As customers buy through the day, the shelves are depleted of inventory and are replenished at specific times based on certain rules. In Lean factories too, the standard WIP points are generally called *Supermarkets*. More about pull-systems are covered in subsequent sections of this chapter. At this stage, it is important for us to know that a well-designed Flow actually combines flow and pull.

We see below in Fig. 7.1, basic flow for a deep freezer manufacturing unit. Each section has been designed to have its own flows, and the sections are interconnected by small supermarkets of inventories to maintain overall flow from Raw Material to finished good.

The Polyurethane Filling (PUF) process is depicted in a heart-shaped box to indicate that it is the *pacemaker* of the whole value stream. Its production rate determines the demand and therefore pull from upstream processes while after the pacemaker the process is characterized by continuous product flow. The state depicted here was achieved after two years of focused Lean implementation and resulted in the reduction of lead time from 10 days to 2 days. We present a structured approach to improve the flow in the following sections.

7.4 Key Consideration for Flow

The single most important aspect that determines the flow of material or operations in a facility is the **Layout**. Maintaining a close relationship between internal supplier and customer processes is essential for smooth flow. If the supplier and customer are not located within touching distance, it becomes difficult to maintain flow; handling and transport (*Muda*) of material between the processes becomes the norm and inventories start piling up.

Most Lean interventions are done at facilities with operations that have been built up over a period of time having added product lines, technology, and people as dictated by the business goals and constraints at different junctures. The infrastructure has grown over time and machines added in piecemeal fashion by using available free space. Hence, the layout very often does not support flow. Many industries also design their layout on functional basis grouping all machines of a similar type in a location. This may be done for administrative or technical reasons but lead to increased handling and transport of materials and movement of people. We share a few typical examples of the impact of layout on the flow of operations.

General Hospital—a patient moves through several floors and hundreds of feet to complete consultation and tests. In spite of all the IT-based Hospital management systems, a discharge process even today takes up most of the day. Process observation at a mid-sized corporate hospital showed that the ward nurses had to walk over 400 feet and down two levels to hand over the case sheet for discharge summary. After this, the file moves another 200 feet to the In-Patient Billing counter after which the patient is called in for final settlement. Little wonder then that the documents were waiting to be moved to the next process for 80% of the time as no nurse was going to move one document at a time over such distances; she would rather wait till a set of case sheets were ready and take them down to the next process in one shot.

Food Processing—in a leading pickles brand manufacturing unit, a material flow diagram showed the total movement to be 200 m spread over 3 floors within one plant. In addition, the low-cost pouch packing took place in another shed about 500 m away—the expenditure on transport, people involved in loading and unloading, material movement was approx. 10% of the total cost of manufacture.

Battery manufacturing—a global player in this sector was reviewing the layout for an expansion project. It was observed that each product traversed a distance of 1 km inside the single shed factory, each battery had 75 touches for the 20 value-adding operations and 60% of the people employed there were not directly performing value-added work but involved in some form of material handling and transport.

Textile Unit—in a newly set up line from which products are supplied to one of the world's most admired home products company, a single garment was found to move about 1000 feet horizontally and between 3 different floors via lifts to undergo 10 value-adding operations during which it was touched about 39 times and stored in 13 intermediate points.

These situations, clearly illustrate that to create flow, we need to first address the layout.

7.5 Creating Flow

Not having an appropriate layout is the biggest impediment to flow. Once a suitable layout is put in place, organizations can shift their focus on to other impediments to flow.

The Layout is a function of the process flow; hence, to redesign the layout we would first need to define clearly the process flow. So, our first task is to freeze the process flow design. We will see that this task varies widely from industry to industry. Typically, the entire exercise of creating initial flow can be broken up into four distinct stages:

Stage 1: Refine Process Flow Design
Stage 2: Evaluate and redesign operational layout
Stage 3: Implement New Layout
Stage 4: Run and validate Flow

Information pertinent to the process flow design can be obtained by revisiting some of the key questions (Rother & Shook, 2003) asked as a pre-requisite for making a future state Value Stream Map (VSM). Answers to these questions provide useful insights into designing ideal process flows and layouts.Kindly note that, the Rother and Shook (1999) has been changed to Rother and Shook (2003) to match with list.

Q1. What is Our Takt Time?
As we know, the *takt* time is the rate at which the factory needs to produce to meet customer demand. Comparing the current operation(s) cycle times with *takt* time helps us calculate the number of equipment/work stations needed to meet the target. Once this is clear, we can work on designing a layout to accommodate the required equipment and stations.

For years, McDonald's, the global fast-food giant worked on the model of pull from supermarket lanes which maintained a standard stock of packed burgers. But recently, the focus has shifted to making against customer order and to do this McDonald's have changed their back-end process flows and introduced small automations to reduce cycle time of burger preparation.

At *Subway,* customers wait in front of the counter as their custom-assembled sandwich is made, and hence, the sandwich maker needs to be both fast and flexible. The process design requires maintaining inventories of the components—cut vegetables, sauces, breads, etc., which are then assembled quickly as per customer requirement. The counter layout is also designed to minimize non-value-added time of movement, searching and picking/placing to ensure fast sandwich preparation.

Q2. Will We Build to a Finished Goods (FG) Supermarket from Which Customer Pulls or Produce Direct to Shipping?

The answer to this question directly impacts the entire process flow design. Building to a FG supermarket gives us the leeway to have standard WIP buffers while working to direct customer pull means the process has to be both fast and flexible—here inventories may be kept at component level.

Q3. Where Can We Use Continuous Flow Processing?

Q4. Where Will We Need to Use Supermarket Pull Systems?

Continuous flow is the ideal state best exemplified by an automobile assembly line—the vehicle moves from one station to the next without stopping in between and work is balanced between all the stations. Operations with similar cycle times pave the way for designing such continuous flow streams. But it may not be always possible to design for perfect continuous flow and we may need to provide strategic inventory points in between operations to ensure overall flow.

The answers to these two questions depend on the following:

1. ***Cycle time imbalance***: In case of significant difference between cycle times of supplier and customer process, a decision on flow vs pull is needed. Should we balance cycle times through additional capacity and flow or should we use supermarkets to balance the workflow through pull. For example, in engineering industries, the assembly line works for one shift while the supplier processes (injection moulding/ CNC) work all three shifts and supply to a supermarket.
2. ***Technical Process requirements***: A specific process may require a decision on pull vs flow. For example, after varnishing of the stator used in DC motors, we need to dry the varnish—this can be done overnight in which case a supermarket is called for or we can design and invest in forced drying to facilitate continuous flow. Such changes in process method/technology are therefore to be discussed where required and incorporated at the outset.
3. ***Equipment Capacity Considerations***: Technology dictates that certain equipment like furnaces, drying ovens, reaction vessels, etc., are made to a minimum capacity to be economically viable. Hence, the process design has to incorporate batching before and after such processes which means designing standard inventory points at these places.

The decision of flow versus pull has a major impact on the layout design. For pull systems, the size of supermarket and quantity to be held has to be decided, and based on this the space to be allocated in the layout calculated and its location fixed. In the case of flow, number of machines/work stations may increase and their space and physical location with respect to supplier and customer processes need to be fixed.

In the refrigeration example in Sect. 7.3, we saw a combination of flow and pull from supermarkets. However, while designing the process for their new factory, the team questioned some of the traditional manufacturing methods. They then decided to connect all processes through a continuous single-piece flow and do away with supermarkets. This change in process design was a result of a decision to change technology and incorporate flexible sheet metal working equipment and innovative conveyors for in-line body assembly and PUF processes.

Hence, we should appreciate that the questions asked while making the Future State Map have a big say on the design of Lean process flow and the layout of both existing and new facilities. The answers to these questions form the basis for the systematic step-by-step method of Process and Layout Design detailed in the following sections.

7.5.1 Stage 1—Refining Process Flow Design

In this section, we look at the first stage and the step-by-step method that can be used to achieve the optimum process flow.

1. Define product/service groups through Product–Quantity (P–Q) analysis based on projected business

"*We have over 200 SKUs in out plant, with this complexity it is impossible to implement Lean flow here*" or "*Our industry cannot be compared to Toyota; they make fixed car models but we need to make a variety of products as per customer designs*". How often have Lean practitioners and consultants come across such statements by factory managers and industry owners. These doubts can easily be alleviated through a simple P–Q analysis.

P–Q analysis relies on the familiar Pareto principle—80% of the turnover/output is likely to come from 20% of the product variants less than half of which would be major contributors. The objective of this exercise is to categorize products as runners, repeaters, and strangers which would in turn have a major impact on process and layout design as shown in Table 7.1.

The P–Q analysis is equally applicable in service industries and helps in designing improved process flows as illustrated by the following the examples.

Table 7.1 Product–Quantity (P–Q) analysis and process design

Product category	Proportion of total required quantity (%)	Frequency of production	Recommended process design
Runners	>50	Daily	Dedicated flow line
Repeater	>30	Weekly/Biweekly	Cellular/Group technology
Stranger	<20	Once in a while	Filler in cells or standalone facility used as and when needed

Service Offerings and Designing Their Flows

In the Hyderabad Airport, a study found that a significant number of people travel with only hand baggage—this is therefore a runner category for the airport services. The process flow was therefore redesigned to have a dedicated airport entry and security line for passengers with hand baggage only. This entailed changing the layout and this new line was given access through an entry point located right next to the main airport entrance itself. The change resulted in reduced waiting time and higher throughput of passengers handled.

While designing process flow for an automobile service centre, analysis showed that 40% of the vehicles come in for the routine warranty service. Another 30% is for planned service like engine overhaul, etc., while the rest come in for breakdown repair work. So, processes were redesigned and layouts changed to have the "quick" service bays at the entrance of the workshop. This meant 40% of the vehicles did not even enter the workshop and avoided unnecessary documentation processes and waiting time for this purpose.

2. Runner Products—Calculate takt time and check feasibility of dedicated flow lines

Runners are high volume products / services that are regularly produced and shipped.

The following flow chart in Fig. 7.2 depicts the steps to be followed to complete process design for a runner product.

For example, in the case of routine automobile service, the peak inflow is in the morning hours. Takt time per vehicle is calculated based on the data. The current service cycle times are known and are also part of the cost sheet—using these we

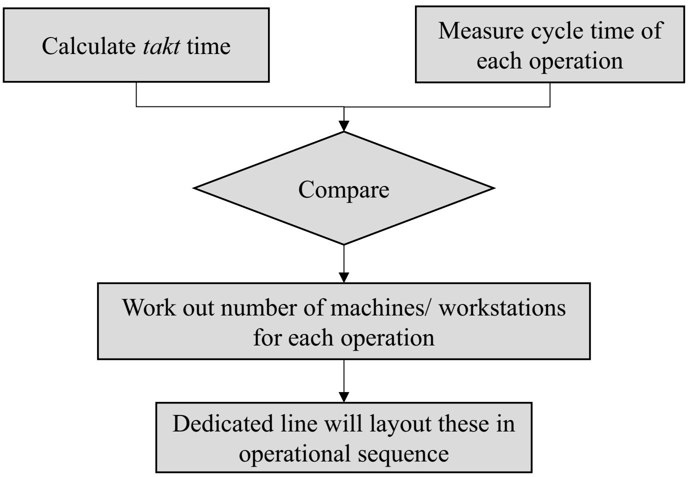

Fig. 7.2 Process design for a "runner" product

can calculate the number of bays and technicians to be allotted to have a dedicated process flow.

3. Repeaters—Prepare product process (P-P) matrix and group products with similar flows

Repeaters are mid volume products / services that are intermittently but regularly required.

The P-P matrix helps group the set of machines/work stations/processes that can service a group of product families. For repeaters, a dedicated line would be underutilized. Using the matrix, one can form operating cells that can process a set of repeater products.

While working on designing a layout for toy manufacturing, we found that the various components required for the final assembly of each toy variant underwent multiple and varied operations. A P-P matrix was developed to identify the products that undergo a similar set of processes Table 7.2; components in the same group are shaded in the same colour.

4. Calculate common takt time for grouped repeater products. input cycle times in P-P matrix and arrive at process-wise capacities and equipment requirements

Let us work on the product group comprising Component 2 (of Toy A) and Component B (of Toy B). Both components require the painting and printing processes. Table 7.3 shows the daily demand and operation cycle times for each item in this group.

Based on this information, the work content per day is computed to be 46,500 s for painting and 23,000 s for printing or a ratio of 1.9:1—so a cell of 2 painting and 1 printing machines can be planned to ensure process flow. This cell can complete the day's requirement for both products in about 13 h. Duly considering the changeover time between the components, regular break timings for lunch and tea, this translates to a 2-shift operation.

Table 7.2 P-P matrix for "Repeater" products

		Painting	Printing	Stickering	Sealing	Sub Assembly
Toy A	Comp 1	Y			Y	
	Comp2	Y	Y			Y
	Comp 3			Y	Y	
Toy B	Comp A					Y
	Comp B	Y	Y			Y
	Comp C	Y			Y	
	Comp D			Y	Y	

Table 7.3 Daily demand and operation cycle times for one group

			Cycle time Data based on pilot run (seconds)				
		Demand per day	Painting	Printing	Stickering	Sealing	Sub Assembly
Toy A	Comp2	500	45	10			Y
Toy B	Comp B	2000	12	9			Y

In a similar manner, we calculate the machine/work station requirement for all the other groups and form cells on paper. The cells/groups so formed will then be fitted into a layout in the next stage.

With the completion of Steps 1–4, the process flow is now defined for runner and repeater products. Any leftover machines and facilities are now grouped separately into a standby cell which can be used for strangers and for new product development purpose while also serving as an emergency backup for the existing lines and cells. The process flow design can now be frozen, and we can move onto the next stage of finalizing layout.

7.5.2 Stage 2—Redesigning the Layout

With the process flow designed, we are now ready to work on redesigning the layout. Layout design for a new facility is much easier than changing layout in existing facility since we start literally with a "blank slate" in the former while the latter has to be done keeping in mind existing infrastructural constraints. The basic steps however remain more or less the same and are described in the following subsections.

7.5.2.1 Preparation—Inspect Physical Location (Built up Area/Land) on Site

The following are the key considerations to be understood during physical factory site observation.

1. **Vaastu/Fengshui**: Many entrepreneurs closely follow belief systems such as *Vaastu* or *Fengshui*. *Vaastu* is an ancient Indian convention of planning space within uilding structure, likewise *Fengshui* in China. Both of them have their own guidelines for locations and directions of specific aspects of layout such as Raw Material receipt, FG Storage, and Dispatch points. They also recommend where and how to place heavy equipment and equipment generating heat such as furnaces, ovens, and boilers. Ancillary services such as canteen, offices, and restrooms are also *Vaastu* dependent. The layout design may therefore need to be worked out keeping in mind at least the broad *Vaastu* guidelines.
2. **Legal**: Various aspects of manufacturing, health care, and hospitality are governed by legal compliances. For example, in a food processing plant, a separate washing area for cleaning trays/trolleys/containers used for transporting the product in between the processes is mandatory and this should not share common space with processing areas. Use of ante rooms to quarantine incoming material is another such regulatory requirement. Locating boilers, ETPs, etc., are also subject to regulations of Pollution Control Boards.
3. **Access**: The receipt and dispatch of material is mainly a function of access. For example, in a primarily export unit, the biggest (40 feet) container vehicles need

to be able to reach the docking point easily. Sufficient space has to be available/provided for manoeuvring such vehicles to enable quick TAT (Turnaround time) which is a key metric for effectiveness of material handling.

7.5.2.2 Designing the Layout

Traditional Lean experts recommend putting up a scaled printout of the layout on a board and using small cut-outs (to scale) of the machine/work station to work out alternative layout designs. Nowadays, tools such as Auto-CAD are well suited to make layout drawings as they are accurate and flexible enough to make multiple on the spot changes during the course of discussions between the stakeholders. Alternate layouts can also be made and compared to facilitate quick decision-making.

Invariably when we make the first layout design, constraints in terms of space or handling related difficulties will be observed. At this stage, the team is encouraged to explore alternate solutions and generate different layout options for discussion and finalization. Some typical situations that come up and are resolved at this stage are:

1. **Lack of space**—alternative storage methods like movable racking systems or vertical storage (Cubic Feet utilized) solutions may help overcome this constraint.
2. **Safety and environmental considerations**—in some cases supplier and customer processes are kept apart due to factors like dust/heat/noise. We work out on how to bring them closer say by enclosing the offending processes (dust/noise) or using better insulation to reduce heat losses into the surrounding areas, etc.
3. **Quality Gates**—Checkpoints are to be created keeping in mind the basic philosophy that a defect should not pass on to the next process. If a defect is generated, we need to consider how it would be handled in terms of rework and when, where, and how would the reworked item join back into the main process flow.

We summarize the learnings from our numerous experiences of (re) designing layouts for a diverse array of industries in this quick guide shown in the box below.

Quick Guide to Designing Layout

1. First fix the RM and FG entry and exit points as decided in Step 1 (Sect. 7.5.2.1) and other key aspects keeping in mind Vaastu, Legal, and Access criteria.
2. Arrange machines/lines as per the defined product groups (cells) and in order of process sequence. While doing this:
   - Maintain close internal supplier and customer process relationship—the output side of supplier process should match with the input side of customer process,

- Fit in sub-assembly/offline processes at locations close to the main line,
- Ear mark material storage (standard WIP) locations as per process design calculations.

3. After completing the main process layout, plot the material/service flow on to it and check if the layout design adheres to the following core principles of material/service flow:
   - No retraction,
   - No haphazard or zig zag movements,
   - No stopping except where defined (standard WIP/supermarket),
   - Minimum possible movement distance.
4. Now add the supporting facilities such as engineering section, office space, utilities, and gangways in a manner so as to align with the main process flow.

Tip: Always keep human safety in mind while designing core material flow; remember that customer pays us for the material—hence, smooth material flow is a MUST and gangways, office areas and ancillary facilities are designed to support this flow.

7.5.2.3 Freezing the Layout Design

The core team may generate several options by end of previous step. These are then put up for discussion among the stakeholders through structured meetings. Normally, the stakeholders include process owners, functional heads of quality, engineering, materials management, Delivery, and HR. In the case of a new facility, **it is advisable to involve the major plant equipment suppliers at this stage** as they would be in a position to elaborate on equipment constraints or specific requirements which would impact the proposed layout. Also, any customization needed to implement the decided layout can be discussed and taken up by the supplier.

The alternative layouts can then be compared on the following Lean metrics:

1. Material handling—distance moved, number of touches,
2. Inventory—number of additional storage points beyond defined standard WIP,
3. Value-Added Space utilization = Value-Added space (core process/machine footprint)/Total available FSA.

Post-comparison, the team may select the preferred layout option and work a little more on fine-tuning this before consensus is reached. This final approved layout is signed off by the stakeholders and then shared with all concerned for implementation.

7.5.3 Stage 3—Implement Redesigned Layout

However, good the layout and flow look on paper, there are always several tricky issues when translating the same on to the physical space. The Pareto principle applies here as well—80% would adhere to the design while 20% may need to be fine-tuned and adjusted during the physical setting up of the process. A simple and systematic approach to implement the physical layout involves the following steps:

1. Start from the end—could be the FG storage / loading dock/ billing counter and work backwards,
2. Mark each process/machine footprint area by chalk on the ground, taking care to orient the In and Out of Customer and Supplier processes,
3. Now start placing the equipment in the areas marked starting again from the end process,
4. Fine-tune/adjust machine orientation by physically positioning operators and checking ease of work.

Tips for Machine/Work Station Placement

- No value-adder should move more than one step to pick up or place the material,
- No material to be kept in a position that requires operator to turn around,
- Customer orientation—material should be placed such that the customer process can directly work on it,
- Where possible, use gravity for moving materials in case the distance between processes is beyond the one-step rule,
- Mark location of Standard WIP as per process flow design.

7.5.4 Stage 4—Run and Validate Flow

Running the process in the new layout gives us a clear picture on how effectively it is working and what else needs to be fine-tuned or worked upon to establish flow. In Lean, we focus on value addition and therefore observe the flow of value-added activities. From this perspective, direct process observation of running process should help us identify:

1. Points of inventory build-up between processes,
2. Operators or machines that are found waiting,
3. Extra motion of people to fetch/place things,
4. Any movement of material beyond designated place.

Items 1 and 2 are a direct indicator of cycle time imbalance between the operations. We need to work on how to balance the entire line and achieve smooth flow. Items 3 and 4 indicate that we need to fine-tune the material placement and work out how to make it strain free for the operators. A common-sense approach using ECSR (Eliminate, Combine, Simplify, Rearrange) works best and fastest in streamlining this new layout.

Balancing Cycle Times … Streamlining Flow

ECSR is a popular acronym for describing ways to improve processes. Let us understand it's relevance to streamlining the flow in a newly changed layout.

- ELIMINATE Abnormal activities and Waste (*Muda*)—this is useful in reducing cycle time of bottleneck operations to bring them in sync with the rest of the line.
- COMBINE Short cycle activities—if two or more operations are much faster than the takt time, we can combine them into one station and increase productivity. Similarly, a faster supplier process can help a slower customer process by "passing the baton" or delivering the material at point of use thereby reducing non-value-added picking time of the customer process.
- SIMPLIFY—Operations to eliminate *Muda* and *Muri*—again helps to reduce cycle time.
- REARRANGE Line Operations—for balancing the flow. A good option here is introducing the material feeder—instead of many operators spending part of their time in fetching required components, one feeder will do the running around and supply all the stations at their designated locations.

In most plant processes, in spite of our best efforts, there will always be some processes or operations that are highly imbalanced and cannot be brought into line through the process improvements described above. These are the points where we need to plan for strategic inventory utilizing appropriately designed PULL systems. More on this is explained in the next section. From the layout perspective, once the appropriate inventory points and quantities are fixed, space would need to be provided for storing this inventory whether on the floor or in racks. Also, material handling to and from these inventory points needs to be facilitated through walkways or gangways.

7.6 Pull Systems

Pull systems link supplier–customer processes through defined standard inventories that operate under a set of rules. Let us relate to pull from this example of a daily

Table 7.4 JIT rules for standard inventory points

Question	Answer
What	Specific items/parts to be kept as WIP
When	Frequency or time when inventory should be replenished
How much	Quantity to be maintained—minimum and maximum levels
Where	Location for each specific item

routine. Following a long meeting that has cut into the lunch hour, you are hungry and walk down to the Subway in an adjoining block to order a sandwich. It is assembled to your specification, wrapped, and handed over for consumption. In this case, you, "The Customer" are pulling what you want ("Specific Sandwich"), when you want (when hungry), in the quantity you can consume, from Subway, "The Supplier". Subway does not prepare and keep a bunch of sandwiches ready and displayed at the counter and call customers to come and buy them, which would be a Push system.

Similarly, the standard inventory points that connect processes in order to maintain flow are governed by a set of rules based on the concept of Just in Time (JIT) management—one of the two pillars of Toyota Production System (TPS). These JIT-based rules are derived from the answers to four basic questions shown in Table 7.4.

Kanban is a powerful tool that can answer these questions and manage the inventory points. Literature on *Kanban* types, calculation, and method of implementing has been widely published. Studies on Toyota' *Kanban* cards and their rules are also widely available in the public domain. Here, we focus our attention on visual *Kanbans* that are simpler, more effective, and sustainable on a typical shop floor. A good visual *Kanban* is one which is integrated into the existing process and can take one or more of the several forms illustrated here.

7.6.1 Space

A marked space on the floor or in a rack when empty or filled can signal the supplier process to either produce and replenish or stop producing as these two cases illustrate.

In a factory assembling Air Handling Units, the throughput depends on availability of the entire kit of assembly components. While implementing Lean, it was found that kit shortages were leading to delays in assembly.

The factory had a daily target of 6 product units which could be of different variants. The kit of fabricated sheet metal parts was delivered on wooden pallets. A simple pull system was developed to link the assembly section with the adjoining machine shop. Six pallet-size boxes were painted, on the floor.

Once a kit is ready at the machine shop, they were asked to place the pallet in a vacant slot.

At the end of the day, the number of vacant slots is visible and schedule is made for the machine shop to produce the kits to fill all the empty slots. If the slots are full, the machine shop stops producing as there is no pull from the assembly process.

In the deep freezer manufacturing plant we saw earlier in this chapter, the main transition point is from body assembly to the PUF jig. Once PUF operation is completed, the body gets onto the assembly conveyor and flows continuously through assembly, testing, and packing. The freezer bodies are placed in individual jigs for the PUF operation; at any time, anywhere from 5 to 7 different products are run in parallel.

At this transition point, a simple visual pull system was put in place to avoid overproduction from the body assembly section. Low floor belt conveyors with capacity to hold a maximum of 10 freezer bodies connected the two processes. Each conveyor catered to one product variant. The PUF cycle time was 12 min, which means 5 bodies can be completed every hour.

A mark was painted onto the side of the conveyor at the 5-body mark. This is the signal for assembly section to start assembling more bodies of the product variant that is moved on that conveyor. The minute the conveyor is full, assembly stops production.

7.6.2 Storage or Material Handling Containers

Storage containers can also perform the role of *Kanban* signals. An empty container returned to the supplier process can trigger the supplier to produce and fill it. By defining specific container types or colours for specific items, the signal will indicate what to make and the container size (capacity) indicates how much to make. These could be trolleys, trays, plastic bins, or any other types of containers that are normally used in the process under consideration.

Biscuit Manufacturing—Trolley Kanban

For hard dough variety of biscuits, the process requires that the mixed dough “stand” for 30–45 minutes so as to develop the specified properties before it can be charged into the moulding hopper for biscuit forming. Hence, there was a need to avoid either overproduction or a hand to mouth situation as this would either compromise the quality or create a gap in the production line. The total mixing cycle time including charging, mixing and unloading was studied and found to be 15 minutes.

A pull system was set up earmarking a separate space in the existing layout for a three-trolley lane with each trolley location marked on the ground. Each trolley has the capacity to hold one batch of mixed dough. Initially the forming line commences production by pulling in trolley 1 only after the third trolley comes into its location. By this time, the dough in the first trolley dough has completed 30 min of standing time. The emptied trolley goes back to the mixer for refilling. This system was therefore implemented with four trolleys in circulation at any point of time. If an empty trolley did not come back to the mixer, the mixer would stop production after the batch already in process. At the same time, if the mixing operator observes that the trolley lane is full, he will not commence mixing of the next batch (Fig. 7.3).

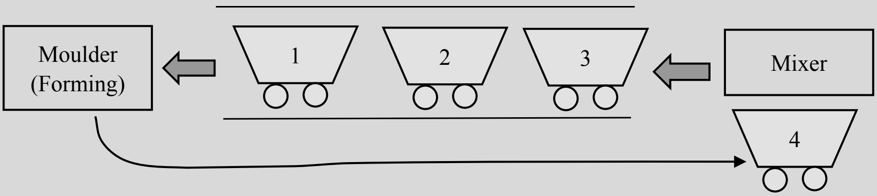

Fig. 7.3 Biscuit manufacturing—Trolley *Kanban*

This system ensured that the process quality requirements and the flow were both maintained.

Pull-Based Replenishment Through Trays

At a restaurant buffet, one of the pain points observed from the customer perspective was a lack of soup bowls during the peak lunch hour. The bowls are kept in the shelves at the buffet counter. At the counter, guests pick up and fill the bowls which after use have to be collected, washed, dried, and put back onto these shelves. Guests were often seen waiting at the buffet counter for fresh bowls and following up with the staff. These bowls then be brought from the washing area in a hurry with the staff making multiple trips to bring out bowls as per need. Even the planned restocking activity often interfered with the guest picking up food at the buffet counter as the waiter would take time to pick out the fresh bowls from his holding tray and place them carefully on the stack on the counter. A maximum of 64 bowls could be stacked in this manner.

This process was replaced by a "two bin" tray-based pull system. New trays were procured, each able to hold 24 bowls in a single layer. The counter could accommodate four such trays in two slots of two trays (one above the other) each. As a tray became empty, the waiter would take it to the washing areas and this empty tray signalled the back-room staff to refill the tray with clean bowls. As soon as one slot became empty, the waiter would bring in filled trays and place them in the slot. Meanwhile the guests would continue to take bowls from the other slot.

This pull based replenishment also saved time as tray replenishment took only 30 s in this new method as against almost 5 min being spent earlier in stacking the bowls on the counter.

7.6.3 Electronic Signals

Electronic signals can also be used as *Kanban*. The most common example is the sensor-based refilling of containers, tanks and hoppers in various industries. With the latest developments in Internet technologies collectively known as Internet of Things (IoT), things like barcodes, QR codes, and RFID tags are being increasingly used to play the role of *Kanban* cards.

Palm Oil Packing Machine

The high-speed packing machine line that fills and packs a typical 1-L pouch is fed by a service tank containing the refined oil. It is not advisable to keep the oil in stationary condition for long duration and hence the service tank has a small capacity. The main tank has a stirring system and holds the bulk refined oil. As and when the oil level in the service tank reaches a defined minimum, the sensor is activated and signals the pump in the main tank to fill up. As the level reaches maximum, the signal again goes to the main tank pump to Stop.

7.6.4 FIFO Lanes

FIFO lanes were first made famous by McDonald's standard WIP chutes where a fixed number of pre-packed burgers of each type would occupy chutes sloping down from the kitchen side to the delivery counter. As a pack is taken out for delivery, the rest of the packs slide down and after a point a signal goes to the kitchen to replenish the chute. A customized FIFO lane designed for a pizza preparation and delivery process at a restaurant buffet is illustrated below.

Pizza Preparation

Pizza slices are a runner item at the A'la Liberty restaurant buffet; pizza is on the menu on all seven days of the week. A cold pizza slice is a big "No! No!!" for customers, and hence, the timing of preparation is essential. Too early and the pizza gets stale. Not in time means customers have to wait and are unhappy. To get over these issues, a FIFO lane-based pull mechanism was devised to control the flow of Pizza preparation and delivery process (Fig. 7.4).

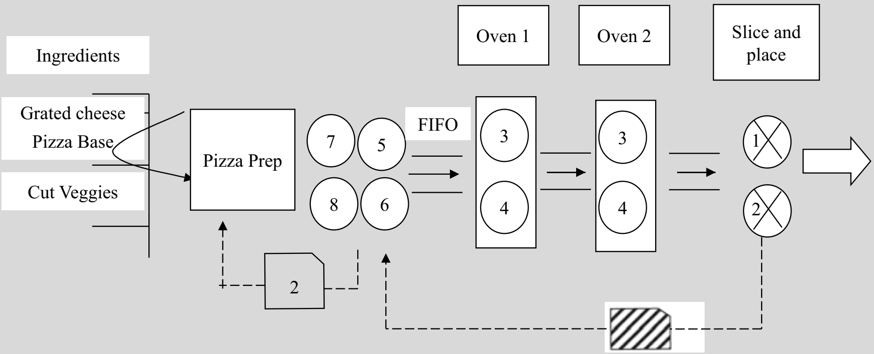

Fig. 7.4 FIFO-based pull of pizzas

The oven is divided into two plates—first is used for pre-baking and the second for finishing. Each plate can accommodate 2 pizzas side by side and give a consistent quality. Hence, a simple pull system was put in place with a fixed quantity of 2 pizzas to ensure no unnecessary WIP or finished pizzas are made, thereby reducing quality variations/wastage.

As the sliced pizzas are picked up, the two fresh-baked pizzas from plate 2 are removed, sliced, and placed on the counter. The empty trays of plate 2 are now filled by two pizzas from plate 1 (prebake) which in turn pull pizzas from the preparation section and signal the assistant chef to prepare two more pizza (base + toppings). If there is any delay in pick up of sliced pizzas, the ovens are switched to keep warm mode.

7.7 Value Addition Must Flow

Our excitement at seeing a perfectly balanced one-piece flow in an assembly line set-up sometimes makes us forget that what should flow is Value-Added Work and not necessarily the material. Even in the assembly line, material does move from one station to the other, so there is an element of waste or *Muda* of transport. Of primary importance therefore is the flow of value-added activities in a manner that the product / service or information being processed spends a bare minimum of time waiting. We examine two diametrically opposite scenarios illustrating flow of value added activities is illustrated, thereby covering the entire continuum in between.

7.7.1 Product is Fixed

There are industries, where by design the material cannot even move, for example, a building under construction is a fixed object. In such a case, what should flow and how do we create it? The case below shows us one way to deploy Lean thinking and create flow in such a scenario.

Towering Heights

Our client was awarded a contract to construct the then tallest building in Mumbai, India, comprising six basement levels and fifty floors above ground. The initial part of the construction activity involved laying the slab and columns for each level to complete the skeleton of the building. When we first walked into the site, the first two basement levels had been completed by the team. Each level with about 50,000 square feet of slab and 112 columns had taken over 30 days to complete, and at this rate, a significant delay was anticipated leading to the triggering of the late penalty clause. The client management was hoping that Lean would help turn the situation around.

We had to first come to terms with the unique nature of building construction. Materials are transported to point of use, but the product is assembled at the spot and remains there. Hence, we needed to relook at flow from the perspective of activities rather than the material in order to reduce lead time. This meant that the people, machines, materials, and supports all had to move (a*Muda*) where required in order to sustain the flow of activities. Once the site team got this clarity, the first thing they did was to observe, analyse, and identify the "waiting" periods or time during which no work was happening at the site. Table 7.5 shows the observations made by the team for the sequence of activities to complete one column.

Table 7.5 Towering heights

No	Activity	Standard time (h)	Actual time (h)	Observations
1	Marking	1	7	Waiting for inspection
2	Staging	4	7	Material transportation, missing parts
3	Cage fixing	2	6	Delay in supply, rework in positioning as cages do not match
4	Formwork	6	8	Delay due to error in order of fitting plates
5	Pouring	1	1.3	
6	Setting	12	12	
7	De-shuttering	1.5	6	Waiting for gang, some plates bent
8	Green cutting	0.5	0.5	
9	Curing	0.5	0.5	
10	Remove staging	1	1.5	

The team then worked on improving processes identified through these observations. A key change was to sequence the work gangs as Cage fixing, shuttering (formwork), and pouring of concrete were all done by different gangs. By synchronizing the working of these gangs and ensuring availability of all materials at site, the flow of activities improved to the extent that the next level was finished in 20 days and the one after that in just 12 days!

7.7.2 Person is Fixed

The biggest successes achieved by implementing flow manufacturing have happened in assembled products. Assembly and packing operations are known to be the most amenable to single-piece flow, and typically, many of these are already manufactured in such lines. The identification of bottleneck operations through process observation and reducing the cycle time of such operations through tools such as Operations Analysis and Line Balancing have given significant results in terms of productivity and throughput increase.

But is One-piece Flow the only and best way for an assembled product to be manufactured? Does it always give the highest Value-Adding Ratio leading to most effective resource utilization? We find that there is an alternative—the single-person work station; where the entire set of processes is carried out by one person from start to finish. This actually harks back to the pre-mass manufacturing days of craft production. These two cases show us that this concept can at times and situations be actually more effective than one-piece flow. At the same time, deployment of the single-person work station comes with its own set of challenges and its success depends on the ability and tenacity of the implementing team.

Moulded Plastic Toys

The global toy industry is seasonal in nature with peak sales just before Christmas, and the manufacturing level fluctuates accordingly. At FS Toys, the manufacturing team was working to ramp up the output for a blockbuster toy being produced on a conveyorized assembly line manned by 11 people. The highest production achieved till date was 800 units per day. The Lean project team recorded a maximum cycle time of 30 s per toy. They also observed that at each work station the operator picked up the toy from conveyor, completed their work, and placed it back again. This handling itself took around 5–6 s and also interfered with their concentration as the operator had to keep diverting her attention from the value-added operation she was doing to pick up the next piece coming on the conveyor. The team brainstormed and came out with two improvement options to try out.

Option A—Single-piece flow

The belt conveyor was removed, and work tables were reoriented to enable operators to stand side by side in order of operation sequence. Each operator could pick up the piece from her right side,work on it and place it to her left all with a single touch. One person was redeployed as a material feeder to supply all the parts in front of the respective work stations. During the production run, the measured output shot up to 1000 units per day with the same team of 11 people.

Option B—Single-Person Work station

Two single-person work stations were set up next to each other—all six assembly operations were carried out by the first person and all four packing operations by the second person. Each station had all required tools—for example, the first station had two different fixtures, two pneumatic screw guns, and all the assembly parts arranged in order of assembly sequence.

The cycle time achieved was 75 s per toy in each station which translated to an output of 260 toys in a whole day for the 2-person cell. 5 such cells employing 10 people with the 11th person as a material feeder could make up to 1,300 toys per day!

Here, it was clear that the single-piece work station scored over single-piece flow as value-added activities flow better. However, the team decided to go with Option A as they felt that it was difficult to train people to work on the multifunction mode required for Option B.

Electronic Product Assembly

Linkwell manufactures electronic energy meters against orders mainly obtained through government contracts. Hence, the business is of a fluctuating nature with peaks and troughs depending on when governments float tenders for contracts. Further, the margins are low and getting further eroded due to higher conversion costs. The team started working on how to increase the productivity and lower cost so as to remain competitive and profitable. In keeping with Lean paradigms, they started with the final assembly and packing line.

In one line,12 operators worked to deliver 2000 energy meters per day and Linkwell operated eight such lines. The team observed the highest cycle time to be 12 s, while the rest of the operation cycle times varied from 6–10 s. The team brainstormed and tried out two alternative methods to improve performance.

Option A—Line balancing

Operators sat side by side in a long line in the existing process. The team modified this to a U-shaped line so that people could stand on both sides. After line balancing, a smooth single-piece flow was established delivering an output of 2,000 units per day utilizing only 8 people.

Option B—Two-person cell

A small table was cut out from the existing long table and two work stations were created one on each side. The first operator assembled the product and slid the assembled unit to the second operator who then packed the product, accessories, and instruction cards. This cell was able to deliver 700 units per day.

The original productivity of 170 units/person/day went up to 250 in Option A and 350 in Option B. The team decided to run one line using Option A, one cell using Option B and continued running other lines in existing process. After a month, the teams met, analyzed the data and concluded that Option B was the best. Within the next month, they dismantled all existing assembly lines and replaced them with the two-person work stations. Linkwell found that this two person cell enabled easy scaling up or down of production based on market conditions. All that had to be done was to add or reduce the number of such cells. This ensured that a lot of fixed overheads became variable thereby reducing the cost of manufacturing.

7.8 Flow in Services

Adapting flow to service environments needs a bit of creative thinking as the customer is often a part of the process. Both the single person and line concepts can be applied to such customer facing processes as well as we see from these examples.

The well-worn Subway example is a case in point. The customer is standing in front of the counter and watching her sandwich being prepared. All through this preparation process, there is continuous interaction between the supplier and customer as the preparation is being customised to the customer's needs. Obviously the customer cannot be kept standing for too long as other customers start queuing up and waiting their turn. The flow of activities consisting of preparing the sandwich, wrapping it, add-ons, and billing has been designed as per a single-person work station framework. Even the flow of interaction that happens while making the sandwich is in sync with the activity taking place.

A typical South Indian wedding lunch requires hundreds of guests to be served within a limited time of about an hour. The wedding ceremony takes place in the morning and tradition dictates that guests eat lunch before they leave, most often to their workplace. Hence, everyone is in a hurry to eat but the dining hall capacity is limited. Most often, three or four batches of guests may be served in succession on the same table. Here, the layout and workflow are adapted to increase speed of service—guests remain seated while the servers move in tandem serving more than 20 items during the course of the meal. As each item is delivered directly on his or her plate (often a disposable banana leaf), the guest spends time only in the value-adding activity of eating while socializing with companions. The layout has long narrow tables in parallel with guests sitting on one side of each table facing each other across an aisle. Servers move in the aisle linearly from one end to the other serving first one table and then returning via the other table.

7.9 Enabling Flow

Creating the initial flow is the essential first step of implementing Lean. But like any natural system, this flow has to be nurtured and maintained throughout the operating period day after day for years. This is never easy as some disruptions keep occurrig from time to time which affect the output and delivery. It just needs one or two such disruptions to flow for the management to decide on repositioning inventory buffers at those places. Strategic inventories may help in maintaining overall flow, but they bring along their own set of problems.

> Inventory is analogous to the water in a sea. The ship appears to be sailing smoothly when the water level is high and the underlying rocks are hidden deep underwater. But as the level goes down, these jagged rocks may even sink the ship if not navigated through. Inventory buffers also have a tendency to hide inherent problems and thereby become a barrier to improvement (Fig. 7.5).

Fig. 7.5 Inventory is analogous to water in the sea

Where no problem is perceived, there can be no improvement

One important purpose of creating basic flow with minimum possible inventory points is to reveal the underlying conditions or obstacles to smooth flow. Toyota's success has been strongly attributed to the urgency in continuously surfacing and then solving such problems to smoothen the flow and keep improving towards the perfect state of single-piece flow. Every time the root cause of a problem is identified and addressed, the flow becomes smoother and remains undisturbed for longer intervals of time. As the famous philosopher Swami Vivekananda once said:

> In a day when you do not come across any problems, you can be sure that you are travelling in a wrong path

In fact, the largest set of Lean tools which are also the most widely used and documented deal with ways to solve the typical obstacles to flow. Table 7.6 summarizes typically faced impediments to flow and the tools used to address them.

Several publications on TPS, Lean, and Kaizen have described these concepts, tools, and techniques in detail. In the following pages, we look at how organizations have solved specific issues using some of these Lean tools and techniques.

The very first thing which comes to sight after basic flow is created is the imbalance in cycle times between operations. As we run the process, pockets of inventory alternating with idle machines or operators quickly come to light. A word of caution here, it is not essential that we immediately address each and every such imbalance but rather identify and work first on the one (or more) bottleneck operations that keep the process from meeting its customer requirement targets.

Table 7.6 List of lean tools and the flow impediments they address

Resource	Typical flow impediments	Lean concepts and tools used	Outcomes
Methods	Cycle time imbalances	Line balancing Work station improvement waste elimination	Reduced cycle time, Increased throughput, and output
	Inconsistencies in process	Standards, Visual Management	Reduce variations and improve reliability
People	Absenteeism/Turnover	Single-person workstations Multi-skill operations and cells Strain-free workstations	Operational flexibility Reduced fatigue
	Skill dependency	De-skilling of process	Anyone can do the job with minimum training
Machines	High changeover time	SMED (Single minute exchange of Dies)	Reduced changeover time and cost
	Short stops and breakdowns	Root cause analysis Autonomous maintenance	Minimize stoppages Maintain machine condition
Material	Defects—rejections	Problem solving techniques (5W1H, 7 QC Tools, etc.) Jidoka "Autonomation" Poka Yoke " Mistake Proofing"	Reduce defects and cost of poor quality Defect does not pass on Defect is not generated
	Availability/shortages	Pull systems—*KANBAN*	Avoid stockouts as well as excess inventories

Such operations can be improved by observing and minimizing the three wastes of *Muda*, *Muri,* and *Mura* as highlighted by this case of Rockwell.

The Heart of the Refrigerator

At Rockwell, the flow of the deep freezer assembly line and its sub-assembly branches were smoothened through line balancing. The line showed an improvement in output from about 90 units to 110 units in an eight-hour shift operation. However, the market demand in peak season required the line to deliver 200 units per day. Observing the entire line, the team saw that the freezer bodies coming in from the PUF process onto the final assembly conveyor were piling up before the first stage itself. This operation involved fitting of the base plate sub-assembly consistsing of the compressor, condenser, and fan motor (core refrigeration system) on to the freezer bodies waiting for this operation.

The cycle time of this operation was already in sync with the rest of the assembly operations for a target in excess of 200 units per day. So why were bodies held up here? The root cause was found to be the brazing operation in the base plate sub-assembly line. This critical operation connects various system tubing components and is followed by a leak test before the sub-assembly reaches the main assembly line for base plate fitting. Delay in brazing kept both the base plate fitting operator and the freezer bodies "both "waiting (Fig. 7.6).

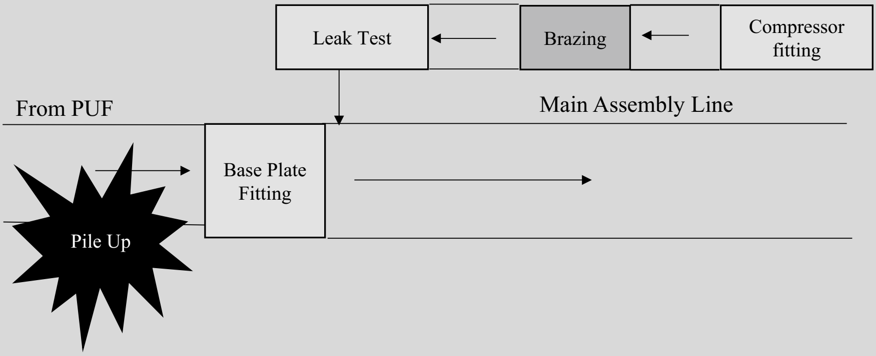

Fig. 7.6 The heart of the refrigerator

The team focussed on a detailed observation and video analysis of the brazing operation to identify the *Muda, Muri, and Mura* and its impact on the cycle time. The overall cycle time was 240 s which matched the current capacity of 110 units in eight hours. The value-added part of brazing actually occurs when two tubes are joined by melting the brazing rod. The team observed that this was being done at six different points, involved the use of two types of brazing rods (copper and silver), and took 60–75 s. The rest of the time, about 165 s, was for various non-value-adding activities including pick up or placing tools, brazing rods, adjustments, operator motion, and rework.

Within a couple of days, the team implemented Kaizen-based solutions such as improvement of the work station to reduce motion and strain, rearranging work sequence for better flow of activities and transferring a couple of preparation activities to the earlier supplier process to avoid readjustments by the brazing operator. The cycle time dropped to 140 s, and output of the line shot up to 190 units per day! Target in sight!!

The workmen on the shop floor are the real value-adders of any organization and therefore the key resource from any perspective. So often, the absence of one skilled or specialist operator brings the entire production to a grinding halt. This “master” worker may start taking advantage of the factory’s dependence on him and starts dictating things leading to further disruption. The recommended way to overcome this skill dependence is to de-skill the process. This is not as impossible as many managers think and one of the world's great Lean organizations IKEA shows us how it can be done.

IKEA's DIY Furniture—de-Skilling Perfection

Anyone who has bought a piece of furniture from IKEA anywhere in the world can relate to the concept of de-skilling. The customer can easily take home the purchased items in their own vehicle as they are always packed a flat pack. Each pack contains the kit of components to be assembled, the joinery (mostly screws), tools (allen keys), and an assembly instruction booklet. By following these instructions, you are expected to assemble the furniture be it a bookshelf, table, cot or chair without having to possess any carpentry skills, technical knowledge, or tool skills.

This is the ultimate example of de-skilling where any person should be able to assemble the same item in his or her house anywhere in the world in a reasonable time without having to possess any special knowledge or skills. How has IKEA made this possible? Through visual standards that are simple, unambiguous, and reasonably easy to follow. The entire assembly instruction is purely visual without a single word being printed in any language. Dos and don'ts are clearly depicted with visual cues. Tools and hardware are also standardized to a large extent and many designs incorporate "tool-free" assembly. All this means that even an illiterate person can follow the instructions perfectly.

If you want to learn more, just go to an IKEA website, click on any product, and look at the product details to see for yourself how this works!

The Tricolour Problem

A leading manufacturer of electrical cables in the UAE was implementing Lean to increase output from their existing facility in order to meet the demands of the construction boom. Flow of material through the various stages had been streamlined leading to an increase in total output measured in terms of kilometres of cable. But customer order deliveries were still getting delayed. Further diagnosis showed that the goods were actually held up in the finished goods warehouse because the entire kit or set of three coloured cables were not ready for dispatch. Since all three types of cables (insulation coloured black, yellow, and red) are routed together in a cable tray at the building site, they need to be available in equal quantities at the same time.

On analyzing the problem, the root cause was identified as the changeover time at the extruder, the penultimate process in the value stream. The extruder sheaths the copper cable with the coloured insulation, and it was observed that a colour changeover took 35–40 min on an average. To avoid frequent disruptions and increase the output from each extruder, long runs of each colour were being planned.

The solution was pretty straightforward—use SMED to reduce the changeover time. The team conducted a three-day Focussed Improvement activity starting with observation of the current changeover process, analysing the reasons for it taking time, identifying several improvements in methods and tools, and enhancing involvement of the available operators. By the third day, the changeover time was brought down to 10 min which meant that three changeovers could be completed in the same time as earlier without impacting the overall output.

Now, all three colours are run even within the same shift producing equal quantities as per customer requirement and dispatches are effected within the same or at the most next day.

In recent years, the shift towards employment of contract, migrant workers in emerging fast-growing economies like India has given rise to other peculiar problems such as mass absenteeism. An entire group of workers from the same village or town take leave en masse to attend a festival or a wedding function. The hapless SME is left to firefight to meet customer delivery schedules. As this problem recurs, the SME looks to automate to replace labour but is hesitant to take the risk of the high investment. One way out is to reduce the need for workers by increasing productivity as this example of seed industry demonstrates.

One of the biggest contributions made by Toyota to Lean is the concept of reducing changeover time. They realized at the outset that the high changeover time of the sheet metal presses led to long production runs that in turn resulted in large inventories of parts which disrupt flow. With Shigeo Shingo's help, this part changeover process was relooked at, leading to dramatic reduction in the time taken. What took hours was brought down to minutes and gave birth to the concept of Single Minute Exchange of Dies or SMED. Product changeovers are a source of disruption in most industries and SMED is the best way to deal with it.

Seeds Packing Productivity

One of the major constraints for a seasonal industry such as PAN Seeds is the inconsistent availability of workforce. The plant operates with contracted labour gangs, each gang being allotted one or more godowns as the processing, packing, and storage facilities are called. The workers are involved in all the activities of the godown right from unloading incoming seed, yard drying of seed (sunning), operating packing line, and loading packed product. In the peak season months of November and April–May, gangs are often found shifting from one activity to another leading to a loss of packing line output. Data of the past season showed multiple line stoppages as the entire gang intermittently stopped the line and to help out in other activities such as Sunning or loading for dispatch.

The Lean project team took up the goal of establishing packing line operations free of *Muda* and *Muri*, such that the line could meet the target output with a minimum “fixed” workforce. Then, these workers would continue to run the line through the day while the others would work on the other activities in parallel. The workers were free to rotate jobs among themselves. Through a combination of line balancing, improving work stations, and combining operations, the worker requirement for a semi-automatic packing line was brought down from seven to just three people.

This packing line improvement project was completed in the first week of the season and all the lines were operated using the new methods for the rest of the season. Output was about 10% higher than the previous season even though a lesser number of people were needed to run the line.

Jidoka is the second of the two pillars of TPS; it loosely translates to autonomation or applying human intelligence to machines. The use of *Jidoka* in stopping the production line when a problem is detected and bringing people together on the floor to solve it with a sense of urgency has paved the way for the continuous improvements seen at Toyota. Jidoka, one of the two pillars of TPS, has also proved to be the most difficult to replicate and practise. If the process is unstable, the line may be stopping several times a day leading to complete disruption of schedules—no line manager or SME owner is going to accept this. A way to partially implement this is that whenever the line stops, record the problem and restart the line immediately. Through this, data on recurring problems can be collated and the team can prioritize and commence problem solving using the structured techniques available.

In general, problem-solving techniques are classified into two types—forward thinking and backward thinking. The first approach is by far the more popular and uses relatively simple techniques that involve moving from the cause to the effect. Likely causes are brainstormed and then verified through field observation, data collection and analysis to arrive at the specific cause(s) actually bringing about the effect (problem). The 7 QC tools are an example of forward-thinking technique as is the popular Why-Why analysis. The backward thinking approach is used mainly to solve chronic and complex problems that are not solved by forward thinking. An advantage of backward thinking approach is that one need not be an expert in the process or area where the problem lies. In this approach, facts and logical reasoning are valued over opinions. The 5 W-1H and Kepner-Tregoe (KT) techniques and their offshoots are examples of this “detective” method, which employs a process of deductive reasoning to eliminate various possibilities and arrive at the actual root cause. The use of simple Why-Why analysis to arrive at the root cause of a management problem is highlighted in this example of material shortages for a mechanical assembly process.

The Incomplete Kit

Even after the final assembly and packing processes were streamlined at Linkwell and hourly production rates improved, the daily actual output achieved against the plan was found to be varying. The single biggest reason for production shortfalls and firefighting to achieve targets was found to be the non-availability of the full kit of materials required for mechanical assembly. A Why-Why analysis was done to identify root causes and the team then developed actions to mitigate them. As seen in Table 7.7 multiple branches of whys can emanate from the initial problem giving rise to multiple root causes each needing their specific solutions.

Table 7.7 The Incomplete Kit

	Why	Why	Why	Why (Root cause)	Solution Proposed
Full kit not available	Specific item shortage	Delay in getting stock	Wrong data	Manual excel working	ERP changes
			Sub Contractor (SC) item delay	SC capacity	Improve SC process
		Issued to other SC	Issued quantity as per month plan	Defined in current SOP	Change SOP

Initially, the sub-contractor (SC) process flows were also observed and one-piece flow was established to enhance their capacity. But they were also found struggling because of shortages in components. Based on monthly plan, the Planner would split the component quantities to each sub-contractor and instruct stores to issue them kits accordingly. The stores would issue kits based on this plan which could be for anywhere from a week to a month's production. Meanwhile, a SC who came to collect material at a later date would find shortage in an item that would have been issued in bulk to another SC. The planner would then intervene and transfer part quantities from one SC to the other in order to keep production going. Over a period of time, this practice had resulted in large mismatches of component stocks at different SC locations.

To ensure equitable distribution of kits and better controls, a new Standard Operating Procedure (SOP) was defined. Kits equivalent to 3 days production capacity of the respective SC unit are issued twice a week, each kite is collected by the SC he has a day's safety stock from the previous draw kit remaining in his premises. The units assembled by the SC are also routed through stores system. To collect a 5000 Nos kit, the SC has to have produced and supplied 5,000 Nos from the last kit collected date. This gives control on the conversion and ensures no excess supply of materials. As both schedule and quantity are fixed, kits for the day are prepared in the morning and placed in designated kitting areas. SCs are given time slots post-lunch to pick up their kits and are able do so with minimum waiting time.

With this changed practice, the problem of kit availability could be overcome resulting in consistent day-to-day production as per designed flow.

The use of pull systems and tools like *Kanban* to solve problems pertaining to material availability has already been discussed earlier in this chapter. Strategic use of pull mechanism enables flow to be maintained without disruption.

7.10 Summary

The chapter plunges into action from the roadmap creation phase discussed in last chapter. The most logical way to organize and initiate improvement projects would be to achieve a basic flow first. The core to implementing Lean in an organization is creating basic flow and then working on enabling this flow to sustain throughout the operating time. In any sector be it manufacturing or services, layout of the facility is the key factor influencing the extent and smoothness of material, service, or customer flow. (Re)designing the process and then the layout on flow principles will serve as the base to create flow. Once the layout is implemented, the process is validated and fine-tuned and this marks the creation of basic flow. The basic flow is complemented and completed by a judicious use of pull systems that regulate fixed inventories at strategic points along the material's flow. The triggering mechanism to replenish the inventory is established through *Kanban* techniques.

The chapter cautions the reader that a blind flow of materials is not advocated, rather one must carefully look and ensure that only value-added flow is designed into the system. Maintaining this flow all the time and under all circumstances is never easy, and there are any number of factors that contribute to periodic disruptions. Many popular Lean concepts, tools, and techniques are used to work on improving processes and overcoming these disrupting influences. Every such constraint that is removed enables flow to smoothen further and remain undisturbed for longer and longer periods of time resulting in a consistent increase in the overall throughput of the system. The chapter also presents scenarios from services industry where all these methods are implemented.

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8 Stabilization

8.1 Introduction

Process improvement under Lean paradigms is a relatively simple task; however, maintaining this improved level over time and delivering a sustained result is much more difficult. In fact, occasional Kaizen bursts leading to process improvements are far removed from true Lean philosophy. We can relate the Lean journey to that of a professional sportsperson . In the early daysthe sportsperson works on technique and fitness to prepare for competition and may suddenly win a medal or break a record. She or he is euphoric and celebrate's the success with one and all. Then, the weight of expectation bears down as she/he is now expected to regularly perform and win medals at this achieved level for years together. The careers of sports icons like Lionel Messi, Rafael Nadal, Michael Phelps or Alison Felix are a testament to years of diligently following a routine and maintaining discipline be it of diet, exercise regimen, or practise. What we as the audience get to see and appreciate is only it's culmination in the matches and victories (the results). The longevity of these legends is largely due to the years spent in continuously evolving, improving, and adapting themselves with the changing conditions be it environment, competition, or their own ageing mind and body.

It is said that in a competitive environment, to maintain the same level, one needs to constantly strive to reach a higher level. This is equally true of any organization or process. The Lean path of continual improvement is sustainable only through a step-by-step ascent striving constantly to reach that ever elusive perfect state. Implementing a cycle of process improvement under the Lean paradigms as discussed in Chap. 7 helps us climb the first step. After improvement, the process needs time to breathe and stabilize before we can plan the next climb (Fig. 8.1). The stabilization phase ensures that the improvement levels achieved in process performance are institutionalized and there is no slipping back to earlier levels, even after attention is taken off the process.

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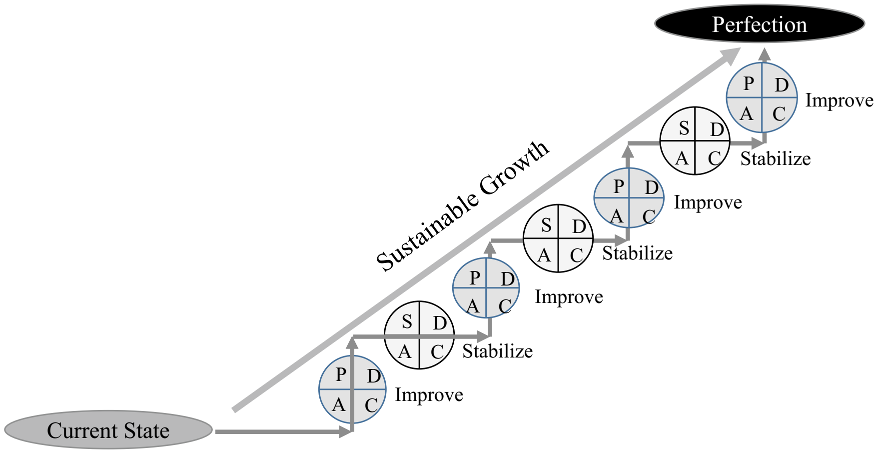

Fig. 8.1 The staircase of continuous improvement

In this chapter, we discuss the stabilization phase and explore a few key concepts and techniques that help develop and implement standards. Organizations that are able to combine improvement and standardization into regular and well-thought out iterations become truly sustainable Lean entities.

8.2 Standards

What is a standard? From an operations perspective, a standard is defined as the "*simplest and best way to achieve a defined quality level of product and/or service at that point in time*". In Lean perspective, the standard is the one which distils the excitement of improvement into a routine and disciplined way of working. Such standards enable the process to achieve consistent performance every operating minute.

A secure standard is one which is simple to follow, reasonable in its scope, and unambiguous in its definition. Such a standard is more likely to be adhered to without deviations in practice. It is a fact that human beings receive over 80% of all information through their eyes. Hence, the best standards are the ones that are visual in nature. For example, the road rules illustrated through signposts are universal and largely self-explanatory such as the Red–Orange–Green stoplight which is a visual traffic management standard. The functions of standards include the following:

- Reveal problems and deviations,
- Enable error-free and uninterrupted process flow,
- Facilitate standard operations,
- Generate people involvement, responsibility, and accountability.

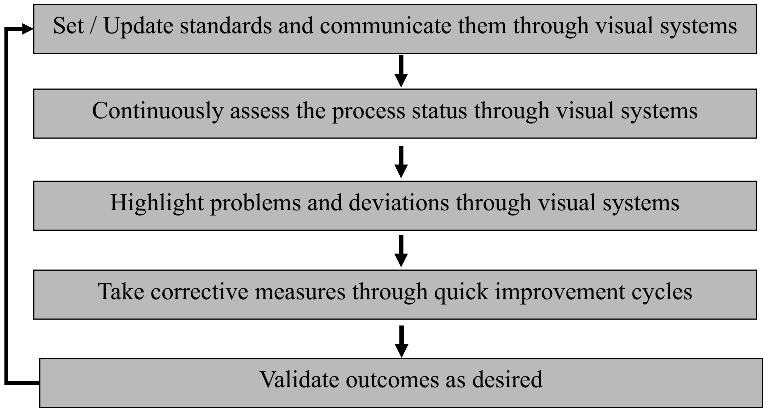

Fig. 8.2 Revising process standards

Standardization is all about ensuring the current running process is always following the defined standards. In case a deviation occurs, the process owner needs to act to correct it immediately. Toyota, one of the origins of Lean thinking, believes that *Kaizen* is all about "*improving and resetting*" standards. Every time we complete a process improvement and validate outcomes are as desired, we need to revise the process standards as shown in Fig. 8.2.

In any manufacturing process, man and/or machine work on transforming the material using defined methods in a facility; the interplay between all these resources impacts process performance. Hence, in order to standardize processes, we need to develop standards for each of these resources and the methods that bind them together. Figure 8.3 shows us various tools that are used for standardization.

In the rest of this chapter, we discuss the relevance and impact of the standardization tools through examples of how organizations across a diverse cross section of industries have adopted these tools to ensure stabilization of improved processes.

8.3 Standard Operating Procedures (SOP) and Work Instructions (WI)

SOP and WI are well-known industry practices that are also embedded into the requirements of ISO certification. In layman terms, SOP lays out the procedure to be followed for a process to deliver the expected quality and quantity of output in a safe manner. The WI provides detailed step-by-step instructions on how the SOP is to be followed. In short, SOP tells us *what* needs to be done and the WI explains *how* to actually do this.

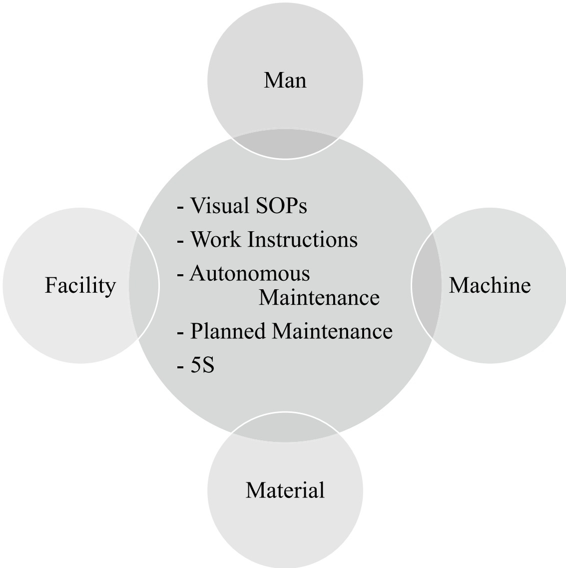

Fig. 8.3 Standardization tools

The trick lies in making the SOP practically implementable through an effective set of WIs as the following example of biscuit manufacturing shows us.

Work instructions—The Practical Standards

A few years ago, we were working with a leading biscuit brand, helping them achieve product quality consistency across their multilocation factories. Through this, the goal was to reduce both customer complaints and internal rejections. The organization had well-documented quality and process standards which had been in place for years in spite of which the variations in the manufacturing process remained significantly high.

The preparation and usage of the milk spray solution was one such process observed to have a high number of deviations from the standards. This "milk" formulation is sprayed onto the biscuit surface as it moves on the web conveyor from the forming stage into the baking oven. On average about 5,000 biscuits pass through the spray point every minute. The milk provides a subtle flavour in taste and gives a shine to the appearance of the biscuit, both key parameters from the customer viewpoint. The formulation is first prepared at a separate station and then brought in barrels to the biscuit making line and poured into a chilled holding/service tank of the spray unit. The standards specify the parameters to be maintained such as recipe of mix, temperature, pH, and consistency. The kaizen team recorded repeated deviations in maintaining both the pH and temperature (14–18 °C) of solution, and went on to observe the process to identify the causes for this variation in the consistency (Fig. 8.4).

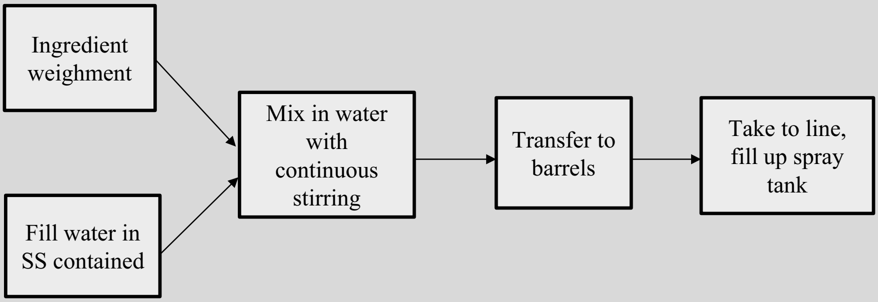

Fig. 8.4 Process for milk solution preparation

The milk solution is refilled into the spray tank every three to four hours. It was also observed that the temperature reached 28–30 °C by the completion of refilling and then slowly decrease to the specified range after an hour . This variation was resulting in surface finish inconsistency over the course of the day . The team made several improvements in the preparation work station to reduce operator strain , provided for an arrangement of chilled water, and implemented a simple pull-based system between spray unit and preparation station to avoid overproduction and stocking of solution in barrels next to the biscuit line. Having validated these improvements, the next step was to ensure 24 × 7 adherence through detailed Work Instructions (WI).

The WI converted the four-step SOP into detailed step-by-step instructions for preparing of formulation and supplying against the spray tank (customer process) requirement. These were displayed in the local language to facilitate training of the frequently changing casual workers. Finally, to ensure that workers were able to easily follow WI, visual standards were implemented. The refill level in the spray tank was marked as was the location of storing the barrel to maintain pull system. The uneducated worker also knew when to top up the tank, where to place the half full barrel and when to bring the next barrel from the preparation station.This conversion of an SOP into practical WI implemented with the aid of visual standards was a great success and replicated across all the factories making this product.

Figure 8.5 depicts the flow of activities needed to ensure complete adherence to process standards. The key is having a mechanism to identify deviations from the standards. If work instructions are in place, one then needs to check if they are practically simple and easy to follow. WI can be appropriately strengthened by revisions and by making processes visual. We then validate if these steps are able to ensure complete adherence to standards. If deviations recur, they need to be further analysed for root cause(s) and process improvements through Kaizen implemented to eliminate these causes . The WI are then once again revised

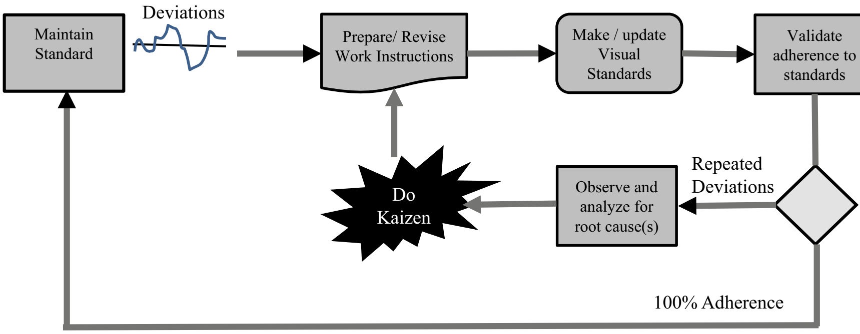

Fig. 8.5 Converting standards to sustainable practices through WIs and visual standards

to incorporate improvements done and the validation step repeated to confirm adherence to standards.

Standards play a vital role in process industries which operate wholly through equipment and have minimum manual intervention in production. The main job of the operator or supervisor here is to ensure all equipments are running as per the standards. This example from a bulk drug manufacturing unit shows how supervisory standards can be developed to aid this.

The Supervisor Walk

At KRR Drugs, the solvent recovery process was identified as one of the bottlenecks to enhancing plant capacity. Having reduced the cycle times of the main reaction process, it was found that getting the required quantity of solvent for doing the reaction was taking time and the reactors had to wait. Adding fresh solvent was an expensive option, it is only used as a top-up while most of the solvent is recovered through fractional distillation process in columns. After separation, the recovered pure solvent is pumped into holding tanks from where it is drawn into the reactor as required.

Detailed observations of a few cycles enabled the team to identify the wastes in the process and work on implementing solutions to minimize them. The improvements focussed on timely maintenance of parameters like steam pressure, temperature, chilling water flow and temperature, transfers from one column to another, and the management of discharge to ensure no mixing of fractions. Having validated the improvements, it became essential to maintain these practices 24 x 7 to ensure consistency of all batches. The team developed a set of standards known collectively as "*the supervisory walk*". This is similar to a typical heritage walk that tourists take during visits to famous historical sites. There is a route map and an audio guide—the visitor follows the route in sequence, stopping at each marked point where he or she can plug in the audio and listen to the stories and history of that section (Fig. 8.6).

Fig. 8.6 The supervisor walk!

In the plant, every one hour, the column supervisor commences his walk from point 1 on the route map and follows the route in sequence up to the finish point. Each point marked on the route is numbered on the floor in a painted circle. The supervisor has to stand inside the circle and can view the specified task to be done at that point through a cue of visual standards. For example, at one point, he needs to check the steam pressure and the pressure gauge is marked with green and red zones and an arrow points down at the gauge and the valve to make adjustments next to it. The valve rotation direction is also marked for increase and decrease of the pressure.

The supervisory walk has ensured that the supervisor covers all the critical points of the process every hour without fail and without missing any of them. Visual aids enable the entire route to be covered in just 20 min leaving him free for other jobs for the remaining 40 min of each hour. *Within days of implementing this standard, the process consistency stabilized completely enabling the plant to increase its output by 25%.*

8.4 Autonomous Maintenance (AM)

In the previous section, we discussed how standards help people focus on value addition and adhere to the defined process. But a lot of the work in manufacturing is actually done by machines and the utilities that go into supporting these machines. Where product flow and quality depend on machine operations, any malfunction or a breakdown is going to disrupt this flow. For example, the team has been able to reduce the cycle time of a bottleneck machine through reducing *Muda* and *Muri*. Now, the machine is expected to deliver a higher output consistently. But at the end of the month, we find that this increase in output has not actually materialized to the extent demonstrated in the improvement phase. On further analysis, we find out that machine breakdowns, short stops due to malfunctions, and reduced machine performance have all contributed to a reduction in actual machine running time. Hence, even with an improved or lower cycle time, the end output is not significantly higher.

Many a times, the machine does not actually stop, but there are minor niggles that are likely to impact the performance in terms of speed and process consistency. For example, we often find injection moulding machines operating at a higher cycle time per part than the standard. Further analysis might show up the fact that the product quality is impacted due to overheating of the die which in turn is linked to the below-par performance of the mould cooling system. In this case, abnormalities in the cooling system have led to the machine speed being reduced in order to maintain quality.

When we walk through a plant, the machine condition can easily be verified at a glance by the number of "*bandages*" seen on it and the conditions of the surrounding floor area (spillages, oil leakage, dust and dirt). These *bandages* are temporary measures to overcome or bypass abnormalities that have occurred in machine parts. Just like the human body, for a machine too, what begins as a minor abnormality today may lead to a major breakdown tomorrow if not addressed at the earliest. This is where Autonomous Maintenance comes in.

Autonomous means Self, and this philosophy of self-maintenance borrows from our daily life. For example, we have a daily routine of brushing our teeth on waking up every morning and before going to bed every night. As young children, this practice was drilled into us by our parents, and in the initial days, they would even supervise us as we brushed. Over the years, we follow this routine without even thinking about it. Why do we brush our teeth? The main purpose is to avoid build-up of plaque and germs that could lead to bigger problems; of course, we also want to have fresh breath and presentable appearance to the world outside. As we brush, we also inspect for any visible defect such as reddishness of gums or discolouration of tooth. We feel for any shaking tooth and sense any pain which is a signal of some other underlying issue. In case of pain, depending on its severity, we may undertake either some home remedy or visit a dentist to get it attended to immediately. This daily cleaning, inspection, identification, and immediate correction of abnormalities is the core of Autonomous Maintenance (AM). If we however choose to ignore the pain or do not bother about brushing regularly and therefore fail to spot an abnormality we may find ourselves heading to a dentist in an emergency and end up with a major expensive treatment such as a root canal or surgery.

In AM, we take ownership of our machine and the responsibility to maintain it in the condition originally given to us. At the first signs of deterioration, we take care through prompt corrective actions. In a factory, the person who operates the machine for eight hours every day is the one who knows it best. But he or she does not actually own it, just like a driver (chauffer) who is a salaried employee paid to drive and maintain a car. AM focuses on motivating the operator to take ownership of his or her machine in the same manner as their own personal vehicle.

AM standards then assist the operator in maintaining the machine condition with minimum effort and spending the least time. AM is one of the pillars of the house of Total Productive Maintenance (TPM), another managementphilosophy that has originated from Japan. The Japanese Institute of Plant Maintenance (JIPM) has been promoting TPM worldwide and has defined a standard for implementing AM in a step-by-step manner. More can be read about this in any TPM book. However, the standard TPM methodology talks about a timeline in years and hence does not hold attraction to the SMEs. Here, we discuss how AM can be implemented in SMEs in conjunction with Lean within a reasonable time frame of about six months. The step-by-step approach is shown (Fig. 8.7).

A factory team which diligently follows the above steps will definitely notice abnormalities start coming down in a six-to-nine-month time frame and also see the impact of this in terms of reduction in machine breakdowns and process problems. AM is a very important standardization tool because keeping the machine operating in its peak condition is a basic pre-requisite for ensuring the continuity of the improvements done in the earlier phase of Lean.

It not only brings in ownership for the machine and process by the people who actually run it but also leads to widespread involvement of the entire workforce making them an integral part of the Lean journey. Most organizations we have

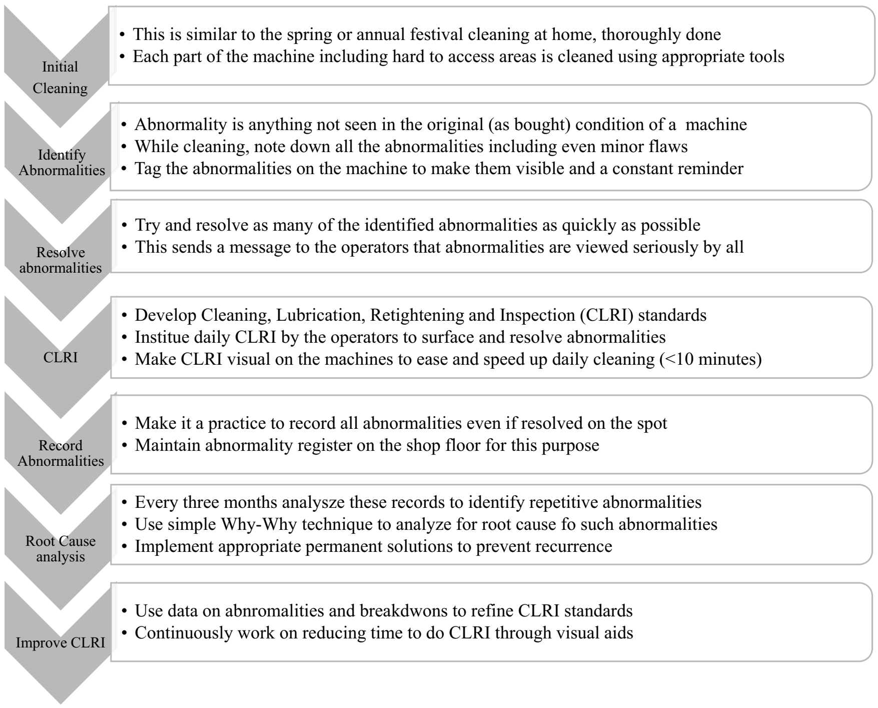

Fig. 8.7 Steps to implement AM

seen make an earnest beginning at implementing the steps of AM. However, in a majority of them, AM has ended up as just another colourful checklist displayed on the machines with few people actually practising it as a daily routine. The first three steps (Fig. 8.7) are done with a great gusto as they are often carried out in a focussed training workshop or event mode in which cross-functional teams are excited to outdo each other in identifying and resolving more abnormalities. Step 4 also takes off due to the interest of the maintenance and production team members in sitting together to develop CLRI sheets, decorating the machine with symbol stickers, and training the operators to do CLRI.

But as weeks go by, the interest often starts to wane as day-to-day firefighting due to production target pressures or client schedule changes start taking precedence over the routine of CLRI. The number of abnormalities recorded comes down as people start accepting some of them as normal condition. Another major hurdle is the delay in resolving abnormalities either because maintenance team is over stretched or there is a delay in procuring needed parts. The machine owner gets de-motivated after a while and starts feeling that recording abnormalities is futile as they are anyway not going to be resolved.

Providing the right environment and the motivation for people to practice this daily routine of AM is the responsibility of the top management. Simple measures like allowing the machines to be stopped for cleaning, encouraging the reporting of abnormalities, and supporting their quick resolution will go a long way in sustaining this important standardization tool. Let us look at how a couple of SMEs have got down to making AM a success.

AM to the Fore at PAN Seeds

Even for a seasonal industry, the paddy (rice) seed processing and packing plants operate in a really narrow window. India has two main crops—Kharif (summer) and Rabi (winter) with the monsoon in between. As the germination property of seed is critical, it is essential to process and pack it just in time for the season. Hence, the plant has to ensure the entire market demand is met during its short runs of only 30–45 days in the pre-winter and 60–75 days in summer. Any plant breakdowns during this short window lead to an immediate and irrecoverable loss of sales in the market.

Realizing the criticality of machine uptime, PAN Seeds dived wholeheartedly into implementing Autonomous Maintenance as an essential part of the Lean journey. Due to the seasonal nature of the industry, there are no full-time permanent operators in PAN. During the season, labour gangs come in and take up the job of running the packing lines and helping the supervisor in running the grading line. Despite the transient nature of workforce, PAN felt it was essential to have some form of AM in place. Initially, the senior supervisors and plant supervisors (known as Godown boys) were trained in the first four steps of AM and they personally took ownership for the daily

CLRI activities, filling up the abnormality registers and taking corrective actions.

In the next phase, the labour gangs were trained on CLRI on the job. In this phase (Kharif season), daily cleaning and practice of CLRI was done by entire workforce which also helped reduce the effort and time needed for this activity. Though paid on a piece rate (per tonne of seed processed) basis, these part time workers understood that keeping the machine in good condition was only going to help them maximizing their earnings and took to implementing AM without hesitation.

By end of May (Kharif season), the plant teams had adapted CLRI completely. Every evening, the team members cleaned and inspected their respective machines, noted down abnormalities, and kept an eye out for sources of dust. Data was compiled in June to understand the impact of AM on plant performance over the year. OEE of the main plants had risen from 70 to 85% as a result of significant reduction in breakdowns and short stops. As PAN moved into the second year of their Lean journey, the team moved ahead in AM based on the learning of the previous two seasons. The focus now shifted to bringing down the time and effort for daily CLRI activities without compromising on its rigour. This could be achieved by doing the following:

- Few non-critical activities shifted from Daily to Weekly/Monthly frequency after finding no abnormalities reported earlier,
- Separated the activities that can be done while machine is running, to reduce the machine stop time,
- Identifying and containing or minimizing sources of product dust and seed spillages thereby reducing the cleaning time, and
- Marking visual standards at all the CLRI points including gauges, oil levels, valves, motors, panel fans, etc., to reduce inspection time.

Now in the third season, the CLRI which used to take 30–40 min in the previous season is now being completed within 15 min providing further impetus to continue doing this routine!

ICLEAN Says… "I Will Clean"

ICLEAN, a pioneer in the design, manufacture, and erection of clean rooms for the pharmaceutical industry, has invested a lot on state-of-the-art machines over the years. In 2015, more than six months into their Lean journey, AM was introduced to help stabilize the plant performance. Thanks to implementing flow, cycle time reduction, and SMED in the AMADA bending machine and the powder coating line, ICLEAN had enhanced its output capability. Now, it was time to ensure the machines operated in a trouble-free manner to sustain the improved output levels.

Within a couple of months, CLRI standards were ready to be implemented as a daily routine. The plant operated in two shifts and this begged the question—who will do the CLRI and when? To avoid eating into “production time”, the plant management decided that the major part of CLRI that required machine stop condition should be done during the shift change time. The factory already had a 30-min window from 2.00 to 2.30 pm for shift handover. During this period, the operators of both the first and second shifts are available at the machine together.

Now, both sets of operators work together for about 15 min, cleaning the machine and completing the checks as per CLRI standards displayed on their machines. Abnormalities found are recorded in a register provided for each section. The maintenance engineer reviews all these registers on a daily basis during his plant walk and plans with his team for the resolution of the abnormalities. As and when an abnormality is resolved, he signs off against the corresponding entry in the register.

This synergy between the production and maintenance teams has worked well in sustaining the AM practices over the last three to four years.

The need to implement AM is even more acute for SMEs than larger organizations. Most often the maintenance team is limited to a mechanical fitter and an electrician who report directly to the production manager, there being no separate maintenance engineer or manager. It is the responsibility of the production head to take care of the machines in order to meet the targets. Any machine breakdowns are attended to by the machine manufacturer’s team who are likely to have been given an Annual Maintenance Contract (AMC) for preventive and breakdown maintenance. The service engineer may be delayed either because of being busy at another factory or by virtue of having to travel from an outstation location and this means the breakdown can take a day or more to resolve. Hence, it is all the more important that SMEs adopt AM to maintain their machines in good operating condition and minimize the chances of failures.

8.5 Planned Maintenance

Planned Maintenance (PM), the second important pillar of TPM, is complementary to AM and once again draws from our daily life routines. Let’s recollect our oral care example from the previous section.While brushing of teeth, gargling, etc., are part of daily self-care routine, we may also make half yearly or annual visits to the dentist for teeth cleaning and check-up. The dentist looks for signs of wear and tear of our teeth and may suggest preventive treatment to ensure long-term health. This is Planned Maintenance—it simply means periodic inspection and taking preventive measures aimed to increase the longevity of the part or machine.

PM can be done through Time-Based Monitoring (TBM) and Condition-Based Monitoring (CBM). Visiting a dentist every six months for check-up is a time-based activity while going there when you experience a slight discomfort (abnormality identified during daily self-care) is what we call CBM. Maintaining our car is another good illustration of this concept. We do (autonomous) self-maintenance in terms of daily outer body dry cleaning and checks like tyre pressure and some weekly or monthly activities such as wet cleaning, vacuum cleaning of seats and upholstery, checking of engine oil, coolant and brake fluid levels. .But there are also certain PM activities specified in the car user manual. For example, the manual tells us that we should monitor and replace the tyres after 4 years or 40,000 km of use whichever is earlier (TBM). The tyres come with an ingrained mark (arrow) indicating the tread depth to be maintained for safe driving. When the tread wears out and the tyre surface reduces to below this mark, it is a signal to change the tyres; this is CBM.

Hence, PM, whether time based or condition based, focuses on replacing the worn-out parts in advance so as to avoid major breakdowns thereby extending the long-term operating life of the machine. It requires a degree of technical competence and an understanding of the internal workings ofthe machine. This is why, very few SMEs have even attempted to implement this concept. Most SMEs continue to depend on external service technicians to do this job, if at all, or simply attend to breakdowns as and when they occur. However, not reading the signs of wear and tear or monitoring conditions can prove disastrous when there is an unexpected failure and breakdown at a critical juncture and one finds that the required spare is also not available in the stores. PM checklists are therefore also a direct input to spares management—based on the expected replacement schedule, the organization can procure and keep the parts in stock.

A reasonably competent engineer can scan the equipment manuals and be able to develop a first-cut TBM sheet. CBM may require procuring certain instruments such as vibration testers and clamp meters, most of which are relatively inexpensive and easy to procure. Once the TBM sheet is put into practice, it will keep getting refined or updated over a period of time, based on data of wear and tear, abnormalities, and failures. This updation as we already saw is the inherent characteristic of any good standard.

8.6 5S

Almost a hundred years ago, Henry Ford initiated "CAN DO", to streamline the operations of the Ford factory. Decades later, the Japanese established a similar concept which became popularly known as 5S. 5S goes a long way in stabilizing the improvements in any process as we will see in this section. The similarities between CANDO and 5S are captured in Table 8.1.

Lean practitioners believe that 5S is the foundation on which the House of TPS (Toyota Production System) is built upon. Most like to start a Lean journey with

Table 8.1 Ford's CANDO and Japanese 5S

Ford	5S	What it means
Cleaning up	*Seiri* (Sort)	**Distinguish** between what is necessary and unnecessary. **Dispose** the latter
Arranging	*Seiton* (Set in Order)	**Enforce** a place for everything and everything in its place
Neatness	*Seiso* (Shine)	**Clean up** the workplace and look for ways to keep it clean
Discipline	*Seiketsu* (Standardize)	**Maintain** and monitor adherence to the first three Ss
Ongoing improvement	*Shitsuke* (Sustain)	**Follow the rules** to keep the workplace 5S-right. "Hold the gain " through self-discipline

5S; the rationale being that the initial "Sort out" helps realize quick financial gains through the disposal of unwanted and unused items. This gain will motivate the top management to pursue Lean further. While this is not a bad start, we have seen many organizations take up 5S as a one-off activity, thereby failing to capitalize on its true benefit. 5S involves building up a routine that is to be followed with discipline thereby making continuous improvements stick. The best part about the 5S concept is that it is as much relatable to the improvement phase as it is a tool for standardization. Because all 5S begins with an effort to change the mindset of the people and orient them towards Lean thinking.

We saw earlier that Lean is a paradigm offering an alternate view of the processes and activities in an organization. The ability to use this "Lean lens" calls for a change in our mindset, and it is 5S that provides us the framework for bringing about this change. Table 8.2 summarizes how the 5S relate equally to the change in mindset, improvement thinking, and to standardization.

The highest level, self-discipline, can be understood through another daily life situation that each of us would have experienced at some point in time. Adherence to the traffic stop lights. In normal working hours, you would be halt as the light turns red and move on after it goes green. Everyone is doing the same thing, and in all probabilitly, a cop is monitoring the junction. Now let us say, you are driving home one night at 2 a.m. and reach an intersection. It is very quiet with only an occassional vehicle passing by. The junction is unmanned, and the light turns red just as you reach it. It will be another three minutes before it turns green again. You are the only one there. Will you wait or go past? When you automatically come to a halt and wait, you are following the standard (that may be easy to deviate from) even when no one is monitoring you. You are doing it on your own accord because you believe in it. This is individual self-discipline. Now, if everyoneon the roads behave in a similar fashion, the community can be said to have achieved the 5th S—Sustain.

Only a handful of organizations have actually reached this level of self-discipline. There may be individuals or sections within an organization who

Table 8.2 5S related to personal change, lean improvement, and standardization

5S	Personal Change	Lean Improvement	Standardization
Sort	Remove unwanted thoughts and information clutter	Eliminate unnecessary wastes (Muda, Muri, and Mura)	Discard unused and unwanted items from the workplace
Set in Order	Clarity of thought—prioritize what to do when	Arrange value adding processes in flow	Arrange the required items to maximize value addition
Shine	Keep polishing up your knowledge and skills	Make abnormalities and deviations visible	Keep workplace clean and inspect for abnormalities
Standardize	Make it a practice to follow the first 3S	Write and implement standards for the improved process	Monitor adherence to first 3S's through assessments
Sustain (Self-discipline)	When the 4S becomes a way of life	Follow improved process without deviations under any circumstance	Everyone in the organization practices 3S even when no one is monitoring

may be there but most organizations reach the 4S level and depend on periodic assessments to motivate and drive employee teams to keep practicing 5S.

So how does 5S typically get implemented? The factory is divided into Zones—a section (say machine shop) or a line or a department (e.g. stores) can be one Zone. Each Zone has a designated Leader who takes ownership for 5S in his or her zone. After a formal kick-off session, the Zone leaders and their team members undergo a few rounds of practical training. The best way to start is to do an initial assessment of all the zones using standard 5S checklists. Each zone is scored and improvement opportunities identified from amongst the low score parameters. The initial score sets the base level from where the zone is expected to improve in practice and adherence of 5 S and strive towards higher scores. A quarterly assessment in conjunction with a Reward and Recognition (R&R) program keeps the momentum going as each zone tries to become the best. The 4th S is the critical stage of 5S implementation. The organization needs to have patience and will to stick with these assessment cycles and R&R programs for at least 3 years to ensure they become a part of routine. As scores start plateauing, the 5S standards in the checklist themselves need to be reviewed and improved to take the factory to the next level. Figure 8.8 depicts a typical 5S implementation cycle.

This implementation cycle serves the purpose of not only sustaining improvements but also to bring in a culture of continual improvement. Teams need to improve their workplaces, methods, and processes further through Kaizen activities in order to increase their scores. After at least two such cycles, the organization may reach the Sustain level where Lean and 5S is a way of life.

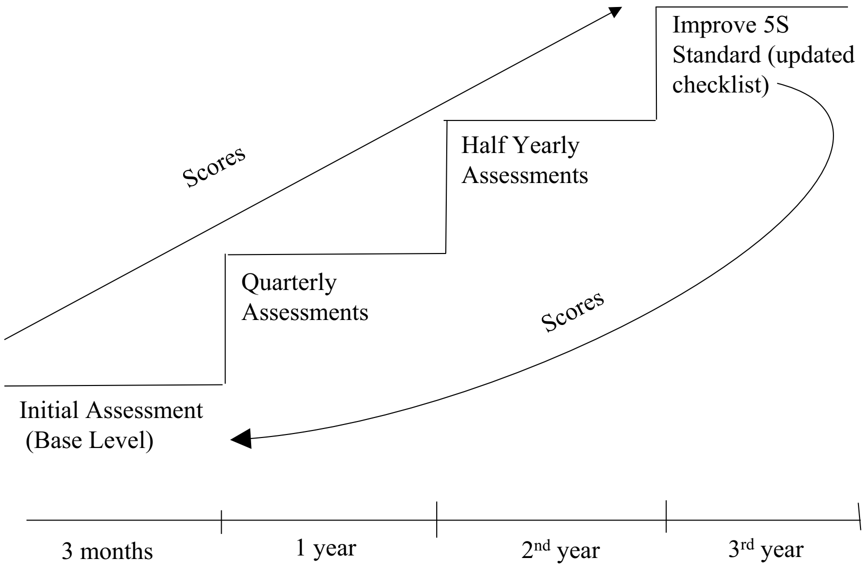

Fig. 8.8 5S implementation cycle

Sustaining Lean….How Linkwell is Implementing 5S

At the end of an improvement packed nine-month Lean journey, Linkwell formally launched 5S across its multiple factories with an initial assessment done by the Lean consultant. A basic 25-point checklist covering six key aspects of operational excellence, viz., Safety, Quality, Machines, Workplace, Material Flow, and Daily Work Management, was used to assess Lean sustainability.

Each production line or standalone unit was designated as a Separate Zone while non-production zones included stores, finished goods warehouse, utilities, laboratory, and administration. The assessment key was tweaked to have variations for each type of Zone. For example, stores or warehouse was assessed more on material storage systems and documentation while these were less emphasis on machines, tools, dies, and fixtures. The reader can view the typical checklist used in the detailed case study on Linkwell.

Simplicity is the key to making such assessment-based models a success. An easy-to-understand and use 4-point (0-2-4) scale was used to score each parameter. For example, one of the questions focussing on Autonomous Maintenance, reads "Is the machine maintained in a clean condition?". If the observation showed one or two instances of dirt or oil spillage, then a partial score of 2 marks was given. Perfect cleanliness earned a full 4 marks, while several instances of such "non-conformances" resulted in a Zero-mark score. Since the scoring was based on direct observation of the process and assessment done jointly along with the concerned Zone Leader, there was very little subjectivity involved.

The assessment process itself evolved to ensure a seamless handover of the Lean initiative from the external consultant to the internal Lean Core team. The initial assessment was done completely by the consultant with the core team observing the process. The second assessment was done jointly. The third assessment was done by two-member internal teams and moderated by the consultant. To avoid any bias or variation, one team covered all the production zones and the other team focussed on non-production zones.

Scores from the third assessment were used to prepare the honour rolls. In a special awards function chaired by the Executive Directors, thetop scorers in production and non-production categories were presented a rolling trophy for Best 5S Zone . The Executive Director of the company also personally handed out individual certificates to the team members of the winning Zones and reiterated the management's commitment to Lean in her closing remarks.

Has Linkwell been able to sustain 5S and through this continue the Lean journey over the next two years? Read more about this in the case study on Linkwell in the latter part of this book.

5S competitions are a positive way to motivate the teams to keep practicing and can even be run between multiple organizations. For example, in India, the Confederation of Indian Industry (CII), a national body, invites members to participate in the annual competition. Implementing Lean under the National Manufacturing Competitiveness Program, cluster program gave us an opportunity to utilize 5S as a competitive tool to encourage participating industries improve their workplace and sustain the Lean journey. A snapshot of this is shown in this snippet.

Inter Factory 5S

Under the National Manufacturing Competitiveness Program run by the Indian Government, SME clusters were formed to share consulting resources and implement Lean to improve their profitability and long-term sustainability. Of the eighteen-month schedule, the last six months were devoted mainly to implementing 5S and sustaining the improvements made through 5S assessments.

The Light Engineering cluster included several small organizations, and we designed a simple 20 parameter checklist to assess them and guide them on 5S. The same checklist was used for all the 10 participating units which meant that the scores could be compared and made available to all of them. Each factory was able to see where they stand with respect to the others and were therefore motivated to be seen as the best. This healthy competitive spirit helped in pulling up the scores of nearly all the factories over the six months (Fig. 8.9).

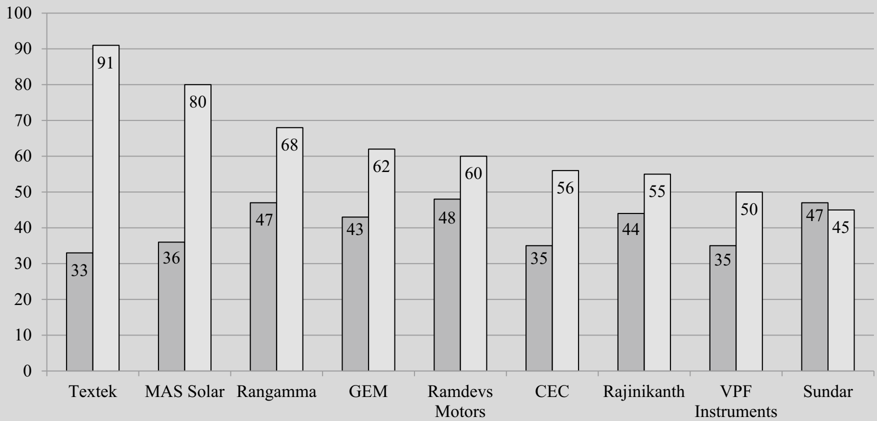

Fig. 8.9 5S Assessment score card—LE cluster

Chart comparing scores of each factory for Assessment 1 and Assessment 2.

The improvement in scores was a reflection of the shop floor adherence to Lean practices that had been implemented over the previous nine months.

Unfortunately, the smaller factories have found it difficult to sustain Lean post-withdrawal of the external Lean consultants. When we surveyed the practices of one of the clusters a year after we completed our engagement with them, many of them had stopped the 5S assessment and the continual improvement journey. The single biggest reason for this was that the designated Lean champion had left the organization and there was no alternate or backup person to carry forward the initiative. We discuss more on this in the next chapter on sustenance of Lean in SMEs.

8.7 Summary

In this chapter, we discuss various steps an organization can take to guarantee the continuation of improved performance of a given process after a Lean intervention. A typical Lean intervention is done in an experimental mode, and in order to stabilize the results, certain resource conditions need to be institutionalized. For people, this is achieved through documented work instructions/standard operating procedures. For equipment, autonomous and planned maintenance are a way to not only extend their operating life, but also operate within specifications. 5S is an organization-wide initiative to stabilize the process improvements and pave the way for continual improvement. The methods stipulated in these SOPs, AM, PM, and 5S documents are collectively referred to as standards. Standards reflect the overall organizational knowledge of the current best procedures. Lastly, they are upgraded every time a continuous improvement project needs to be embedded into the regular functioning of the organization.

Sustaining Lean

9

9.1 Introduction

Management involves culture setting, people management, organizational routines, performance management systems, and the way organization interactions with various external stakeholders such as customers, suppliers, government, and public at large. It also involves design of end-to-end value delivery process. Lean management specifically ensures a smooth flow of value across departments and busts any batch formation to serve the convenience of departments for e.g. large machines, huge changeovers, big facility, long lead times, etc. A Lean organization is focused on creating more value for the customers while using fewer resources. This is made possible by a heightened awareness of the customer value, product quality, process capability, among very empowered workforce. A deep understanding of the process capability is essential to keep it available when there is a pull signal and resist from just-in-case pre-production. A Lean sales operation tries to stabilize and pass true demand to operations, as against quota-driven push of discounted sales. This results in a stable flow of orders across the entire supply chain, thereby eliminating variance-related inventory expenses across the chain. The cycle stocks are reduced by reducing the changeover, transportation, and other non-value-adding components of lead time. At the foundation of all this is a steadfast commitment to quality at the source to keep a tab on quality-induced uncertainty. No defect is allowed to enter the system, and a 100% inspection is instituted through process autonomation. If a defect is found, an immediate cure is performed to eliminate the root cause and the recurrence of the problem.

Lasting results from Lean management accrue to firms that ingrain the Lean thinking into the firms' daily routines. Results ranging from 'less than best' to 'dwindling within a couple of years' are seen by a large number of firms that adapt Lean management, either because they picked only few techniques and not the whole thinking or did not create a series of ever increasing challenging kaizen projects to maintain the momentum. In the initial years (upto 5 years), it is easy for

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G. Mahadevan and K. C. Chejarla, *Lean Management for Small and Medium Sized Enterprises*, Management for Professionals,
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firms to slip back to unthinking, batch mode of old ways of doing things, riding on the success of Lean in getting through the immediate crisis/challenge. So, for Lean to unleash its full and cascading benefit, the organizational culture must be such that it relentlessly pushes the processes towards the ideal, never resting in status quo. However, organizations that do not go whole hog, also do realize benefits to the extent steam lasts in them or by virtue of the improvements already done.

And yet, unfortunately, a number of organizations (including some very big) limited their understanding and hence application of Lean to inventory control, process improvement, lead time reduction, or such operational goals. The result of such narrow thinking is now evident in the form of public outcry in many forums that JIT and therefore Lean are the causes of shortages in the pandemic. One can easily verify the falsity of these claims by looking at the performance of truly Lean organizations versus those whose Lean adoption is atbest partial.

Toyota has been on the Lean journey for over 70 years now, and the DNA of continual improvement and Kaizen culture is well entrenched. But of the thousands of organizations across the world who have been trying to follow "The Toyota Way", only a handful have truly sustained continual improvement. When it comes to SMEs and family-managed businesses, the record is even more abysmal. Our own studies of SMEs that were part of the Lean cluster scheme have thrown up certain recurring issues that have primarily contributed to this failure to sustain Lean. We look at these issues and try to identify ways and means to tackle them.

Based on our numerous implementation experiences, we observed that SMEs that sustain Lean master a few key maturity stages. Our model highlights various short-term temptations for the organizations to overcome in their Lean journey, and through this model, we want to make SMEs vary of potential paths of least resistance, so that they can challenge themselves with higher goals. Good news is every organization has to go through these hoops of ever-increasing improvements, and bad news is only a few cross-over all the hurdles in their journey to perfection. Nonetheless, the journey is itself very rewarding for every organization, regardless of the stage. After describing the model, we then proceed to review the factors that contribute to persistence or dropping of Lean, distilled from our interations with a number of SME owners and managers. The chapter is concluded with the summary of empirical findings from a study of Lean sustainability conducted by the authors in an SME cluster from Southern India.

9.2 Sustenance Stages of Lean Adoption

The following Fig. 9.1 shows various stages of sustenance of Lean adoption. These stages are briefy described below. All the case examples we have provided in this book relate to SMEs that are on the Lean path of their own will and not due to customer or regulatory enforcement. The automobile industry is an example of enforced Lean where the car manufacturer (OEM) works with and expects Tier 1 and Tier 2 vendors to follow JIT and other Lean concepts to align with the OEM's requrements in terms of quality, quantity, or price. Vendors who are lagging may get downgraded and orders reduced.

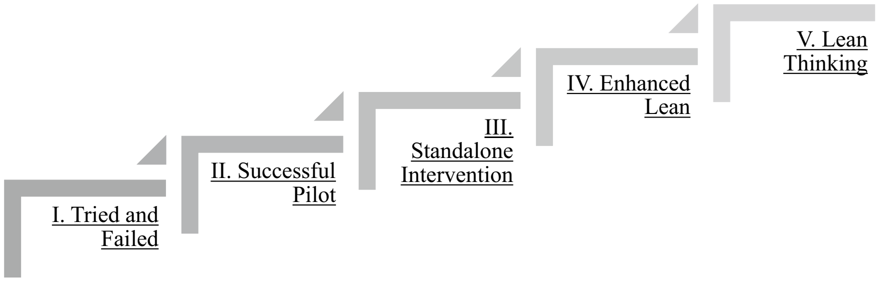

Fig. 9.1 Sustenance stages of Lean adoption

9.2.1 Stage I: Tried and Failed

Firms in this stage are those who have tried Lean and percieve no improvement to their operations. Typical reasons for these initial failures are (a) not having or creating a compelling narrative for Lean, (b) not creating circumstances suitable for Lean implementation, (c) trying to implement Lean without the right *Sensei,* (d) not providing basic training on Lean to the core team, and (e) half-hearted Lean implementation without empowered team, etc. When the management does not see the results and percieves that the effort is "*eating away*" the productive time of the team, they would quickly dismantle the team and go back to old ways of doing things. They would further justify their inaction with some excuses such as Lean is not for this industry, or we just do not have bandwidth. Following caselet illustrates one such example.

MGP, a producer of polycarbonated sheets, had set up a spanking new facility riding on the high market demand. The partners were earlier importing these products and trading them but spotted the opportunity to manufacture and sell the products themselves. Their children had recently graduated from management schools, and one of them had visited Japan as part of the course. She was enamoured by what she saw there and invited her professor to visit the MGP factory. After meeting the partners and a half-day training cum observation exercise on basics of Lean, the partners agreed to do a Lean pilot to make their plant operations efficient. However, there were no clear business goals defined for this initiative.

A couple of months into the implementation, notwithstanding small successes like productivity increase in a couple of processes and systematic arrangement in the stores and warehouse, the initiative lost steam. The partners used to sit in the corporate office and visited the factory only once in a while. There was no consistent communication from them to the plant employees on Lean and its importance.

By the third month, one of the partner's started questioning the fees being paid to the Lean consultant, and the value MGP was gaining out of the exercise. At this stage, Lean stopped.

9.2.2 Stage II: Successful Pilot

Typical approach to Lean implementation is through a pilot project, in which a small area is chosen for testing, training, and showcasing the results to management, supervisors, and workers. Firms that reach this stage are the ones that have got the intended benefits from the pilot implementation. However, if the chosen area for pilot Lean implementation is the major bottleneck of the firm and if the performance improvement is enough for the firm to tide over its immediate needs, then it may so happen that the firm may decide to not pursue/scale Lean to other areas. Ironically, the success of Lean itself in this case is the reason for the firm to not extend Lean. Some firms after a while, even slip back to previous non-Lean methods at the pilot area, perhaps because the crisis has passed on. Following caselet illustrates one such example.

RDN, a fabricator of structures used in the solar industry, was struggling to meet the customer requirements which had piled up due to simulatneous wins of several government contracts. The second-generation entrepreneur had studied operations management a couple of years ago and reconnected with his teacher to take advice on sorting out the plant operations. We were called in to help RDN and suggested implementing Lean to increase output while reducing inventories and lead times. RDN agreed for a six-month Lean intervention to be extended to a longer term association.

The first three months were a revelation to RDN. The plant layout was completely changed to get flow. Bottleneck process of welding was improved through operations analysis and waste reduction. The internal supplier customer links especially to the galvanizing sub-contractors was strengthened, and finished goods warehouse streamlined to facilitate count-free, search-free storage, and easy retrieval of items for dispatch. The operations team was young and energetic and seemed to be enjoying Lean.

RDN was happy as orders started to get fulfilled and material shortages started coming down. Then, the Lean intervention petered out. RDN management felt the team's bandwidth was not adequate to continue the Lean journey at the fast pace in which it had moved till then. They wanted time to hold the gains and prepare their team before restarting the next phase.

It has been about three years now, and RDN has not moved ahead. They have made some strategic decisions like starting their own galvanizing facility and integrating the plant processes. They continue to maintain the flow and pull systems set-up during the pilot Lean phase. And remain content!

9.2.3 Stage III: Standalone Intervention

Several SMEs who have tasted success in the pilot stage have gone on to implement Lean across the major part of their value stream. They have seen an improved operational and business performance during this period of Lean implementation and have been satisfied with their achievements. However, they have not felt the need to build a culture of continual improvement or build internal teams to take Lean forward. One of two things generally happen to them in the long run. They sustain what has been achieved over time without really trying anything new or improving further. Or, they start slipping back to some extent over the years. In both cases, since the organization has tasted the fruits of Lean, they genereally end up reconnecting with their *Sensei* either when the business faces new challenges or when things start slip up badly. For these organizations, Lean is not a conitnuous journey but a series of intermittent standalone interventions. A bulk of companies typically belong to this category. A caselet is described below.

We had an opportunity to work with a seafoods pioneer way back in 2010. The industry was limping back after two years of global disruption, and the CEO suddenly found that his plants were finding it difficult to meet the rising demand inspite of having the capacity. This was a continuous process for making prawn feed, and initial data showed a low OEE of 50% due to a variety of factors such as quality problems leading to running the mill at low speeds and die changeover time being high. A six-month intervention ensued, stabilizing process parameters (eliminating *Mura),* reducing changeover times, and streamlining the raw material handling leading OEE to shoot upto 78%. The CEO was pleased, and we ended the engagement on a high note. The plant sustained and kept up its performance over the next few years.

Meanwhile in 2014, the company now growing rapidly sets up a new plant on the west coast to cater to the market there. Within the first year, the familiar issues started to surface and the CEO once again got in touch with us. We worked with this plant for almost nine months with similar results and left them to sustain.

By 2020, the SME has grown to a large publicly listed company with global tie ups and has set up two more plants. They have recently roped in an international consulting firm to work on improving plant performance across their plants!!

9.2.4 Stage IV: Enhanced Lean

Firms in this stage truly understand Lean well enough to be able to confidently apply them in other production/operations areas with their own internal team and without any support from external *Sensei*. The Lean team is clearly identified, trained, and empowered to deploy the concepts to pre-determined improvement roadmap. Management in these firms in this stage develops, commits to, and communicates improvement roadmaps.

Reaching this stage is not easy. Over the years, there are so many challenges and disruptions that can derail Lean such as business cycle downturns, key employee turnover, pandemic, product life cycle changes. The firms in this zone are the ones with discipline of execution, firmness of vision, alacrity to adjust to internal and external changes, take failures on their stride, and move on to keep getting better. The following caselet is an illustration of such an example.

Our client, a supplier of facility equipment such as clean rooms, Air Handling Units, clean room accessories, laboratory furniture to the pharmaceutical industry, has grown tenfold in the last decade. In 2010, they were categorized as a small to medium industry, operating in a couple of factory sheds when the top management happened to attend a Lean seminar at their customer's (a global pharma major) training academy. We started a year-long Lean journey helping them implement basic flows and gain throughput and reduce wastes throughout their operations across product streams. Five years later, they reconnected to take their plant operations to the next level and we strengthened Lean with stabilization tools such as AM and PM in addition to enhancing the flow and further reducing WIP in between the downstream processes.

When they had grown big enough to relocate the mutliple business divisions to a new green field factory, they used Lean right from the initial process flow and layout design stage. A core team of Factory Manager, Methods Manager, and Director (Ops) who were all well versed in Lean by this time worked on translating this Lean layout to reality.

In 2020, they decided that Lean should become a regular part of their developmental activity and formed a core four-member Lean team from existing staff. Customized 5S assessment checklists were used to monitor zone performance and motivate team members to keep improving their scores. The past year has seen two rounds of such improvement. The team also regularly conducts internal refresher training programs on relevant Lean concepts. In parallel, the factory at a second location is also on the Lean path to catch up with the main unit.

As the company is on the threshold of breaking out of the SME category, the management has acknowledged the part played by Lean in their growth story.

Meanwhile, the case of Linkwell is another good example of an SME driving Lean in the long term. Please see the appendix for the detailed case study of their Lean journey so far.

9.2.5 Lean Thinking

Think of a mini Toyota or an IKEA. Firms that reach this stage have extended Lean to not only all the support functions within their organization, but also encourage their customers and suppliers to adopt the same. These firms would institutionalize Lean, by linking Lean goals to individual performance appraisal. Most employees adopt Lean as part of their regular work, and in other words, Lean philosophy is their way of thinking. Lean is part of the organization DNA and runs in the day-to-day thinking and decision-making of each and every employee working there.

Unfortunately, very few SMEs have got to this stage, though several of them as we saw in Stage IV are likely to get here soon. Of course, by the time they reach this level, they are often no longer SMEs thanks to their sustained growth.

9.3 Factors Affecting Lean Sustenance

Factors contributing to either sustaining or dropping of Lean are categorized into the following sub-groups.

9.3.1 People Related

The most common cause for dropping Lean is attrition of key employees, especially the Lean champions who are able to get alternative employment opportunities thanks to their knowledge of Lean. Another is the shifting/migrant workforce and their lack of ownership for the process/organization.

9.3.2 Scaling Across

In most organizations, Lean strategy is first formulated and implemented for the core operations. Once operational efficiencies have improved, the pressure of business growth often shifts to the front-end sales and marketing. Procurement is also pressed to deliver and follow principles like JIT to align with the core operations. At this stage, the organization needs to initiate Lean in the other functions including purchase, sales, accounting, and HR, among others. If this natural roll out does not happen, there is imbalance among the functions leading to a gradual drop in the sustenance of Lean in the core operations.

9.3.3 Creating Headroom

Perhaps, a less spoken reasons for Lean to lose steam especially in its early stages (within 2 years) are because of the organizations' inablity to balance the long- and short-run effects. One of the immediate effects of Lean is increased productivity, capacity, and lowering of direct costs. If there is no sufficient demand for the newly available capacity, senior management finds it difficult to justify the fixed expenses such as wages. They may be forced to downsize, the very anti-thesis for Lean to sustain (Sterman et al., 1997). Thus for the SME to keep up the momentum, it is important for its senior leadership to find suitable avenues to deploy the released capacity so that the true long-term outcome of Lean to achieve higher profits for the organization is ensued rather than a debilitating short-term cost reduction. Long-term commitment of the top management/owners and their inability to align Lean initiatives to the changes in business environment and strategy also leads to a roll back of Lean over time.

9.3.4 Making Own Lean Operating Model

In many cases, the top management has not really understood Lean philosophy, but only the few select tools and techniques were deployed which gave them quick benefits and stopped at that. The few firms we spoke where Lean sustained were unequivocal about making Lean as their own manufacturing system. By this, we mean that the day-to-day running of the organization is completely governed by Lean principles.

9.3.5 Periodic Lean Assessment

Having a periodic assessment of Lean activities and results and incorporating it into the organizational reporting hierarchy help in sustaining Lean. A direct benefit of periodic reporting is that it helps keep track on the progress of Lean implementation and early course correction whenever a deviation from expected pattern is observed. In SMEs, regular reviews (fortnightly/monthly) by the owners keep the pressure on the plant team while also providing them with timely decisions and resources to complete their activities. In the larger context, this mechanism helps in establishing a data-driven decision-making culture, which is essential for Lean to survive and thrive.

9.3.6 Top Management Commitment

Much has been said about the importance of top management involvement to ensure the success of Lean in the first place and sustain in the long run. Apart from the pressure to show improvements, this also passes an important signal to the operating staff that the senior management is serious about the Lean results. One of the SME owners we spoke to was emphatic about the importance of senior management's preparedness to get their hands dirty, willingness to change their worldview, and willingness to learn the right way. When the senior management is seen to be prepared to change their perspective and is willing to experiment, the next levels of management would find it easier to adapt and convince the rest of the organization.

9.4 Empirical Study of Lean Sustenance

One of the authors of this book was engaged with ten manufacturing SMEs, part of a Lean cluster, based in the southern part of India. This Government of India sponsored program had the following five objectives:

i. Reducing waste
ii. Increasing productivity
iii. Introduce innovative practices to improve overall competitiveness
iv. Inculcate good management systems
v. Imbibing a culture of continuous improvement.

The author led a team of Lean consultants that worked on implementing Lean at these SMEs. The 18-month long Lean intervention ran the whole gamut of training, identification of improvement opportunities, implementing the same, and finally setting up processes to ensure sustenance of the Lean management. The implementation resulted in differing levels of success at individual units which were recorded and documented in the form of case studies and a summary report submitted to the monitoring government agency. Out of our own interest, we surveyed these SMEs about a year after the consulting team disengaged with the cluster to understand the levels of sustenance. This section presents the differences in sustenance of Lean in different companies.

The cluster of companies measured and undertook improvement targets in the following four groups of operational metrics.

1. Productivity improvement (PI-A, PI-L): asset and labour productivity/utilization-related metrics,
2. Process improvement (PI-CT, PI-WIP, PI-P, CC): cycle time, WIP, and customer-centric metrics,
3. Culture building (CB): implementation of systems such as Kaizen reporting, responsibility matrix, and checklists is grouped as culture-building metrics,
4. Quality improvement (QI): defect reduction and implementation of quality management systems are covered under this head.

The overall improvement (in terms of reported instances of increased value for each of the metric) soon after implementation is as shown in Fig. 9.2.

Of these group of metrics, process improvement (PI) and culture building contribute to long-term sustainability of Lean. When these companies were surveyed for the status of the metrics after about a year of implementation, the following were reported.

- Unfortunately, largest deterioration occurred in culture-building metrics (70%),
- Within culture building, 5S, Kaizen reporting system (KRS), and TPM implementation are the reported metrics which deteriorated,
- None of the productivity improvement metrics have deteriorated. Further, only a couple of process improvement measures have deteriorated, indicating that the concrete benefits attained in terms of productivity and process improvement last longer than softer measures such as culture building.

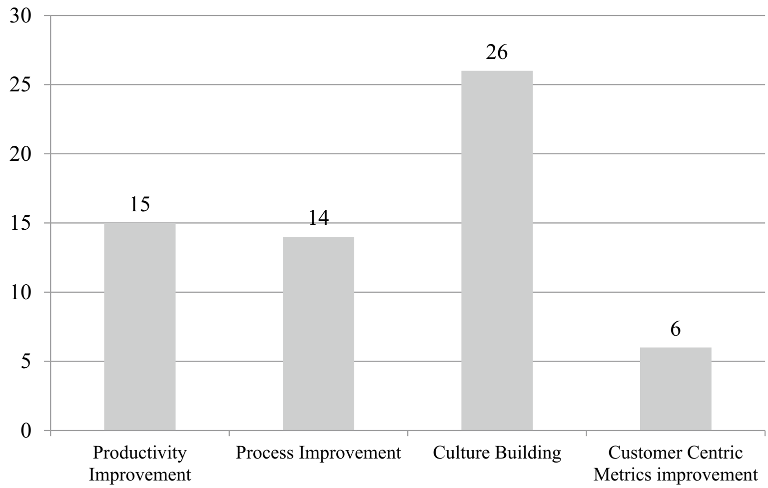

Fig. 9.2 Post-implementation improvements at the lean cluster

While the other operational measures such as productivity and customer-facing metrics did improve/stayed at the implementation levels, from a sustainance standpoint, the deterioration of CB forebodes a bleak future for this cluster. All the firms in this cluster belong to either Stage II or Stage III of the Lean sustainability maturity model presented earlier. The reasons for deterioration include loss of steam by top management, lack continuity of workforce, not finding new applications for Lean, etc. and agree with what we have presented in the previous sections.

9.5 Summary

In this chapter, we discuss the sustenance of Lean implementations at SMEs. We present a maturity framework based on our direct experience with over a hundred SME implementations across sectors and geographies. The reasons contributing to either sustenance or deterioration are discussed. Finally, a study of findings from Lean implementation at an SME cluster is discussed. We highlight the pitfalls at different junctures of a Lean journey for an SME to caution them against and prepare well for next level of improvement.

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Beyond Lean 10

10.1 Introduction

Every organization with a long-term vision should aspire to excel in all aspects of their business. The new millenium has given birth to alternate thought processes and concepts, some of which complement Lean admirably and can help SMEs move closer to excellence. Sustainability is the overarching umbrella under which operational excellence tools such as Six Sigma, Theory of Constraints, Industry 4.0, and Time-driven Activity-Based Costing (TdABC) can be pursued by SMEs (Fig. 10.1). Each of these tools is in alignment with Lean philosophy and thus can reinforce the benefits accrued from Lean implementations at SMEs.

Each of these is a powerful, wide-reaching, and interrelated idea that can not only significantly impact organization's long-term performance, but also provide competitive advantages previously unavailable. SME owners and managers might find it useful to understand and integrate these concepts to turbo charge their Lean implementation and uplift their business models.

In our experience, we see many businesses shying away from learning and experimenting with these new concepts. Perhaps, a simplified explanation of these ideas, along with suggestions on how to integrate into the Lean implementation, could help in breaking down the mental barriers. Further, not all the ideas cost a lot of money to implement. The ubiquity of technology, and cloud-based solutions have helped break the economic barrier in adoption of many of these newer concepts. We will provide a brief overview of these developments and place them in the context of Lean management from an SME perspective in this chapter. In the process, we explain how these developments might be integrated with existing Lean implementation or help start Lean initiatives.

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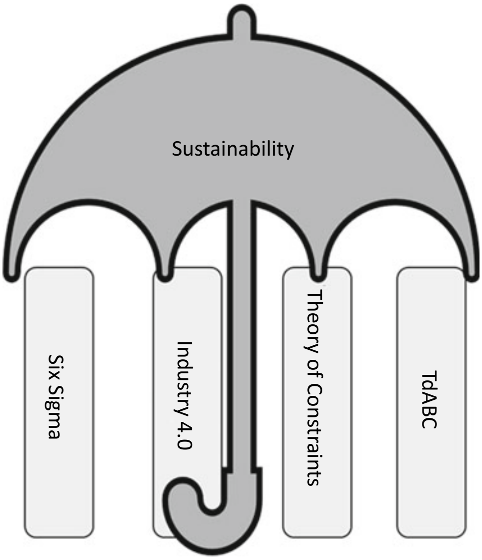

Fig. 10.1 Schematic of initiatives complementing Lean

10.2 Sustainability

10.2.1 Description

Sustainability refers to balanced growth that addresses the economic, environmental, and social goals of an enterprise. Until recently, sustainability was treated as an additional expense that eats away the profitability of an enterprise, especially by SMEs. This perspective is now questioned by all and sundry, due to irrefutable evidences in terms of environmental and social disturbances across the globe caused by unsustainable business practices. Many governments, quasi-government bodies, and not-for-profit organizations have taken up the cause of sustainability and bring awareness of the ill effects of unsustainable development to all the stakeholders. Besides, there is also growing and substantial evidence that points out that the long-term economic performance actually gets positively impacted for those organizations which take care of the environment and the society they operate in. For example, in their study involving close to 250 SMEs, Sajan et al. (2017) have established that Lean management practices enhance the overall sustainability in terms of economic, social, and environmental performance of the organizations. There are several other SME-specific studies covering sustainability, firm performance, and other related factors using samples of SMEs from different nations. Few such studies are summarized in Table 10.1.

Table 10.1 Various studies focusing on sustainability in SMEs

Researcher	Source	Topic	Findings
López-Pérez et al. (2018)	1000 Spanish SMEs	Effect of sustainability on business outcomes	• CSR, reputation, and financial value of the firms are higher for sustainability-oriented SMEs • This linkage is stronger for family businesses than non-family businesses
Masocha (2018)	208 South African SMEs	Effect of environmental sustainability on firm performance	• Environmental sustainability practices positively impact firm innovation, ecological, and social performances
Battistella et al. (2018)	7 European tourism SMEs	Sustainable business models	• Economic, societal, and environmental challenges affect sustainable business model (value proposition, value creation, and value capture) development in different sectors of service SMEs
Pigosso et al. (2018)	108 Danish SMEs	Potential for eco-innovation	• Potential for eco-innovation among SMEs increases with the industrial symbiosis opportunities and usage of green business models
Schmidt et al. (2018)	16 SMEs in Brazil	Adoption of sustainability practices	• There is a need to strengthen the adoption of practices such as values and transparency, internal audience, environment, supplier customer, and community relationships among SMEs
Jahanshahi and Bre (2018)	40 SMEs in Iran	Role of top management behaviour	• Top management behaviour integrity increased the team innovativeness and sustainability implementation

In terms of contribution to UN Sustainable Development Goals (SDGs),[1] SMEs contribute to Decent Work and Economic Growth (SDG#8), Industry, Innovation and Infrastructure (SDG#9), and Responsible Consumption and Production (SDG#12). The UN environment program has charted a roadmap to aid SMEs adapt resource efficiency practices through national technical assistance packages, training and network activities, and implementation tools such as methodologies, toolkits, guidelines, and standards.[2] A recent report by World Economic Forum using inputs from over 300 CEOs and founders of SMEs highlights that SMEs

[1] https://sdgs.un.org/goals.
[2] https://www.unep.org/regions/asia-and-pacific/regional-initiatives/supporting-resource-efficiency/asia-pacific-roadmap-8.

have a potential to achieve sustainable growth, positive societal impact, and robust adaptive capacity leveraging their size, network, people, and technology.[3]

10.2.2 Integration with Lean

The roots of Lean lay at frail and short-on-capital business and social conditions prevailed at Japan post-Second World War. Thus, by design, Lean's foremost objective is to identify and avoid wastes in any form. Less waste implies more sustainability.[4] This can be achieved only when all the employees are committed to the goal and work in empowered cross-functional teams. So, in a Lean organization, the fundamental building blocks required for sustainable development, viz. eye for spotting wastes, customer centricity, respect for employees (celebrating team success rather than exploitation mindset), and long-term perspective (and not getting drawn by short-term benefits that actually harm the long-term sustainability) are already present. Key green enablers relevant to SMEs are life cycle assessment (LCA), reduce, reuse, and recycle (3R), environment emission control, and green procurement (Ahmad et al., 2020). Pursuit of these enablers feeds into the essence of Lean implementation at SMEs and derives long-term sustainability benefits.

- *Life cycle assessment* refers to the holistic assessment of the environmental footprint of the product right through design, production, usage, and disposal and undertaking early measures that minimize such footprint. There are a number of easy-to-use public databases and resources available[5] that SMEs can use to make a standardized assessment of the products and services they procure, design, produce, or consume.[6]
- *3R (reduce, reuse, and recycle)* is part of larger concept called circular economy. In linear economy, products are discarded as waste into landfills once the usefulness of the product is perceived to be diminished. As against, in a circular economy, efforts are made to increase the economic life of products by reducing their consumption, reusing by finding secondary uses for the product reaching their end of life, and finally recycling either as newer products (remanufacturing) or into constituent elements. Institutionalizing 3Rs into a Lean SME saves energy, effort, material, and investments required for the given production levels. Further, remanufacturing as a business idea itself has a big potential for SMEs to undertake.
- *Environment emission control* refers to the practices that evaluate all the effluents (wastes) and by-products (solid, liquid, and gas) of a given firm for their

[3] https://www3.weforum.org/docs/WEF_Future_Readiness_of_SMEs_2021.pdf.
[4] https://www.sme.org/technologies/articles/2017/january/lean-green-boost-sustainability-with-lean-manufacturing-principles/.
[5] https://nexus.openlca.org/databases.
[6] https://www.globallcadataaccess.org/.

suitability to be released into environment, for selling downstream, or treating them appropriately, if found unsuitable for releasing/selling.

- *Green procurement* refers to reducing supply chain carbon footprint by sourcing environment-friendly raw materials and insisting for eco-labels for component procurement. While SMEs may not be able to afford frequent supplier audits, eco-labels/green stickers can help them decide which of the suppliers are more sustainability oriented. Further, they themselves can begin the practice of eco-labeling their products to draw customers with sustainable mind-set.

10.3 Six Sigma

10.3.1 Description

Six Sigma as a quality improvement methodology was pioneered by Motorola. General Electric then expanded the scope of Six Sigma to include non-manufacturing processes and has rolled the methodology across the enterprise. GE is credited with the current popularity of Six Sigma as a five-phased process improvement methodology: design, measure, analyse, improve, and control (DMAIC). DMAIC is built on Deming's Plan, Do, Check, and Act (PDCA) framework for process improvement. Six Sigma is a highly rigorous problem-solving tool grounded firmly in statistics and requires significant amount of data to be collected for analysis. Like Lean, Six Sigma encourages unit experiments to establish the process relationships. Six Sigma compares Voice of the Customer (specifications) with process capability for measuring the Defects Per Million Opportunities (DPMO). A process is said to be performing at Six Sigma level, if there are no more than 3.4 DPMO. Voluminous, highly repetitive processes are best suited to benefit from Six Sigma implementations, provided all process data is measured and documented.

10.3.2 Integration with Lean

Among all the initiatives listed in this chapter, Six Sigma is the one which is most commonly used in conjunction with Lean. So much so that the phrase "Lean Six Sigma" is now a fairly common terminology among operations excellence circles. As noted in previous chapters, variation (Mura) is one of the main sources of wastes. The main strength of Six Sigma methodology is the robust procedure to capture and control process/output variations. And thus, the fitment of Six Sigma into the execution stage (series of Lean projects to reduce/eliminate variation) of the overall Lean methodology is as snug as a hand in glove. Therefore, Lean plays the role of overall concept map and a philosophic vision and Six Sigma a powerful execution tool to translate parts of the vision into action. However as cautioned before, Six Sigma relies heavily on data and statistics and yields best results when processes are fast and repetitive. SMEs should evaluate this requirement before integrating Six Sigma into their Lean implementation. Please see below the caselet of Avanti Feeds, where we used Lean Six Sigma to improve OEE.

OEE Improvement Through Lean Sigma at Avanti Feeds (AF)

A decade ago, the global seafood industry was just emerging out of a severe disruption due to ravage by disease. AF, a pioneer in prawns and prawn feed, was trying to get their feed mills back on track to supply to growing demand. However, for several months output lagged well below the expected levels. Lean experts were called in. Being a continuous process plant, our first diagnostic was to compute of Overall Equipment Effectiveness, which was low at 50%. The main culprit was the performance ratio, i.e. mill speeds were only 60% of the rated speed. The reason was quality problems at the customer ponds for the feed when produced at higher speeds. The complaint was that the feed was floating on being thrown into the pond instead of sinking and be available to the prawns at the bottom of the pond.

At this stage, it was clear that the only way to increase OEE significantly was to solve this “floating” problem. Two key product quality parameters, size and moisture content, were taken up as they in turn influence product stability and floating. Regression analysis was done to relate process parameters such as mill speed, mix moisture, and % of various raw materials, with mill speed and product moisture. Using this analysis, control limits were fixed for each of parameter and process control charts established at the shop floor. Substantial variation was seen in the mix moisture and mill temperature parameters and the process capability prevailed at 1.55 sigma. A target of 3.5 sigma was fixed.

Root cause analysis was then carried out to identify reasons for these variations. A series of kaizen projects such as introducing error proofing, visual controls on the steam valves, and workstation improvements at the water addition stage helped in bringing down the variation in moisture content and maintaining specified mix temperature before the critical die extrusion process where the feed is actually formed into pellets. Mill speed was soon increased back to 90% of rated with no negative impact on product quality. OEE went up to 70%!!

10.4 Theory of Constraints

10.4.1 Description

Goldratt’s Theory of Constraints (ToC), as the name suggests, is based on a clear definition, identification, and management of the constraint (also called a bottleneck) faced by a firm. A constraint is defined as anything (a machine, a worker, a policy etc.) that limits the ability of the firm to increase its throughput. ToC offers an approach to identify bottlenecks that limit the output and, hence, a guideline to prioritize the improvement initiatives. The ToC-based Drum-Buffer-Rope (DBR) approach is used to schedule the bottleneck at its capacity, which defines the drum beat of the factory. The buffer is placed before the constraint (constraint buffer) and as well at the end of the line (customer buffer) to prevent the possibility of starving bottleneck or missing customer orders. Lastly, the rope is the information link between the level of buffer before the constraint buffer to the beginning of the line which gets triggered based on the lead time. Thus, a DBR schedules the bottleneck, the downstream production of bottleneck flows, and the upstream production is pulled using the rope.

In most ways, ToC is almost identical to Lean value stream concepts. We said previously that a pacemaker process in the value stream defines the rate of throughput. A pacemaker is defined as the process in the value stream after which there exists only continuous flow. The pacemaker pulls from the upstream processes using standard WIP (akin to constraint buffers) and through the mechanism of kanbans. In Lean, the pacemaker is the single point of scheduling and replaces the machine-wise or section-wise schedules of traditional organizations. So the DBR approach and the Lean value stream are quite similar.

A key difference is that Lean focuses and improves the value addition in each process step, by eliminating waste, while ToC's focus is in improving the throughput especially at the bottleneck.[7] Both approaches are wary of the conventional accounting methods that mask the true costs, and contributions by processes, and thus mislead managerial decision-making. Throughput accounting and Lean accounting are proposed as part of these respective methodologies.

10.4.2 Integration with Lean

But for the minor differences in the approach of the two methods, viz. ToC and Lean, as stated above, they should be considered complementary to one another, rather than competing. ToC offers an excellent framework for enhancing throughput by an effective constraint management, which is based on the following five iterative steps:

- Identify the bottleneck,
- Exploit the bottleneck,
- Subordinate everything else to the bottleneck,
- Elevate the bottleneck, and
- Review the system for the new bottleneck and start the process over again.

[7] https://www.lean.org/the-lean-post/articles/what-is-the-theory-of-constraints-and-how-does-it-compare-to-lean-thinking/.

Most importantly, the simplistic financial metric structure of ToC that relates throughput, operating expenses, and investments could be appealing and easier to follow by many SMEs as it gives a clear picture on the cost benefit of any improvement and offers the SME a clear sight of financial gains. The constraint-based thinking of ToC is also relatively easier to understand. Considering these advantages, it would be highly beneficial for firms and consultants to judiciously integrate the concepts and practices from ToC and Lean into their operations excellence journey.

10.5 Industry 4.0

10.5.1 Description

At the heart of Industry 4.0 is a set of technological developments that are grouped as cyber-physical systems (CPS). As the name suggests, CPS provides a 360°, seamless, persistent, and Internet-enabled interface between sensor generated data acquisition, analytics-based data processing, and robotics-based process control. Increasing semiconductor-based electronics in various machinery, equipment, and utilities enhanced the digitization of manufacturing and allied operations such as transportation and storage. Further, increasing use of information systems such as ERP, MES, and Web 2.0 to plan, execute, integrate, and monitor internal and extenal business processes has resulted in digitalization of business and non-business organizations alike. Both digitization and digitalization have become a rich source of real-time data, which coupled with other emerging technologies such as robotics, machine learning, Industrial Internet of Things (IIoT), analytics, and big data have made Industry 4.0 necessarily a new way of doing business. Besides, the affordability of most of these technologies has contributed to the rapid adoption and quicker payback of investments in Industry 4.0 even by SMEs.

According to BCG,[8] firms can achieve close to 40% cost reductions when Lean and Industry 4.0 are jointly implemented, as against approximately 15% from each of these individual initiatives. One of the direct ways in which Industry 4.0 supports Lean is by drastically bringing down the gap between the time to sense and the time to act, reducing the information lead time. Lean firms can enhance flexibility, productivity, speed, quality, and safety by adapting Industry 4.0 powered tools such as sensors, predictive analytics, and virtual reality. Specifically, a sample list of Lean tools and supporting Industry 4.0 technologies are mapped in Table 10.2.

[8] https://www.bcg.com/publications/2017/lean-meets-industry-4.0.

Table 10.2 Lean tools and supporting technology solutions mapping

Lean tool	Technology solution
SMED	Robotics
Poka-yoke	IoT devices, barcode scanners, pick-to-light, camera
5S audits	Visual management systems
Root cause analysis, continuous improvement	Big data, analytics
Kanban	Sensors at critical components
Standardization, training	Virtual reality
TPM	Augmented reality
Teamwork	Collaboration tools

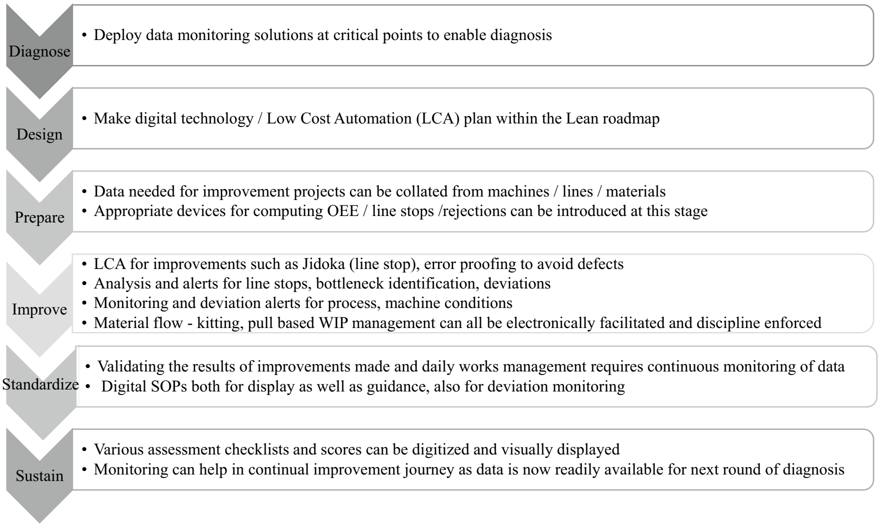

Fig. 10.2 IIoT solutions for different stages of Lean implementation

10.5.2 Integration with Lean

Different stages of Lean implementation at various SMEs in our experience are benefitted by Industry 4.0 (specifically IIoT) solutions as outlined in Fig. 10.2.

Powering the fundamental Lean principle of waste reduction by leveraging the relevant technology in various maturity stages of SMEs should be the goal of integrating Industry 4.0 with Lean, in other words, digitally enabled Lean.[9] There

[9] https://www.mckinsey.com/business-functions/operations/our-insights/industry-4-0-demystified-leans-next-level.

are a number of case studies that detail successful integration of Industry 4.0 with Lean (Mrugalska & Wyrwicka, 2017). As with every other new technology, implementation should always be carefully thought through and backed by a pilot implementation that clearly captures the lessons learnt. What works for one industry or even one firm does not automatically guarantee that such technology will be successful for an other firm. Blind imitation without appropriate customizations is one of the major reasons of failures of technology implementations.

Lean Industry 4.0 for 24 x 7 Process Performance at ICLEAN

We have been working with ICLEAN over a decade implementing Lean in bits and pieces, extending the concepts in every successive intervention. In 2017, we helped design a layout for their new integrated and expanded facility with a 75% jump in output expected to cater to customer demands from the pharmaceutical sector. The Lean layout was implemented in 2019, and within a year, streamlined flow and standard practices were established. At this point in time, two constraints were identified that could hinder the plant performance.

1. Complete kit of items to be available against each customer project to ensure delivery and installation at the customer site. It was quite normal to find a shortage of a couple of panels at the FG stage resulting in delays in dispatch and necessitating costly crisis-mode operations at the plant to produce the missing panels.
2. The last process before packing is the "*Infill*" where insulation foam is filled into the panels on large jigs that maintain shape during the exothermic expansion process of curing. This turned out to be a constraint as most of the panel preparation and post-curing activities were manually done. Delays in this process manifested as an ever-present inventory of panels before the Infill process.

The company decided to go in for IoT-enabled solutions that can ensure 100% adherence to the defined Lean flow and process. A solution comprising two parts was designed and implemented in 2021. First is a track and trace system using barcodes on each panel. A barcode is placed on each panel at the end of first process—sheet cutting, and on scanning—it records the panel number that has been generated by PPC in the project-wise schedule. This barcode is scanned at each stage up to dispatch, and information on completion status of any customer order is always available online. If all the panels are not complete at any stage, and an attempt is made to start the next order, an alert is flagged.

The second is an OEE monitoring system at the Infill jigs. Each jig has a fixed capacity based on panel size. The curing time depended on the thickness of fill. If the jig is not opened after curing time is done or not closed within a set time interval, a sensor reads this as a short stop and records the loss time. The system is configured to send escalations to production and plant managers as the loss time crosses certain thresholds.

Thus, by using IoT to complement already established Lean layout and flow, ICLEAN hopes to avoid crisis-mode operations, and also achieve the targeted output consistently.

10.6 Time-Driven Activity-Based Costing (TdABC)

10.6.1 Description

Traditional accounting accumulates costs department-wise and allocates overheads for periodic reporting. Due to inherent inconsistencies in the overheads allocation, the information from traditional accounting systems does not reflect the true cost of business processes, leading to difficulties in accurately matching revenues with expenses. This problem is exacerbated due to increasing mechanization of organizational processes that use shared resources and overheads rather than direct labour. Process-based approaches such as Time-driven Activity-Based Costing (TdABC) by Kaplan and Anderson (2007), Lean accounting (Maskell & Baggaley, 2006), and throughput accounting (DugDale & Jones, 1998) have been proposed to overcome these limitations of traditional accounting. Of the three, TdABC is well established and has more implementations than the latter two. Given the GAAP reporting requirements, all these alternate accounting systems typically implemented as add-ons to the existing systems, that draw on the conventional accounting transactional data, and recast costs as shared resources are consumed in revenue generation. Figure 10.3 provides a conceptual overview of revenue generators and cost accumulation in a typical organization.

TdABC approach can effectively answer questions such as—Is this product/service, order, customer, channel, or business profitable? If not, what does it take to make it profitable (reduce service, increase price), how does it compare with other businesses? etc. (Everaert et al., 2008)—given its accurate revenue and expenditure matching.

10.6.2 Integration with Lean

Lean is built on the core philosophy of separating waste from value addition. A process comprises multiple activities, and each activity at the unitary level is either work or waste. Keeping with this, from Lean perspective, any expenditure is either (legitimate) cost or waste.

$$\text{Activity} = \text{Work} + \text{Muda}$$

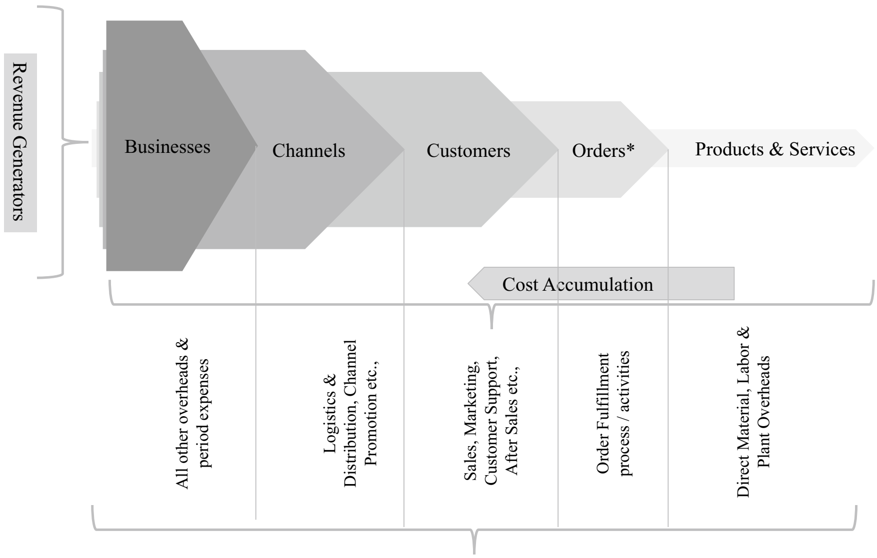

Fig. 10.3 Revenue generation and cost accumulation in organizations

$$\text{Expenditure} = \text{Cost} + \text{Waste}$$

Cost is the amount of expenses (actual/notional) incurred on or attributable to a specified thing or activity. Cost is not by default "what is incurred", in its entirety. It should reflect only purposeful spending on value-added activities. Rest of the expenditure are all "*Waste*".

TdABC proponents recommend that it is better to be approximately right than being precisely wrong. TdABC requires two parameters: the cost per time unit of the activity and the time required to perform an activity (Somapa et al., 2011), which are captured by direct observation or by interacting with process owners. The VSM exercise by all the Lean organizations is a ready source of much of the information that is needed for TdABC. Further, once the required interface (between traditional accounting transaction database and the TdABC database) programs are developed, organizations will have the advantage of evaluating the performance of their value streams on a dynamic basis.

First among the difficulties in implementing TdABC is the effort involved in recasting the general ledger financial data to the supporting and then to operating departments. Allocations are usually hard coded in the ERP systems, and rewinding them requires some manual effort (Siguenza-Guzman et al., 2013), at least the first time. Second challenge is to have the team members agree to be observed or interviewed with consultants, which may not truly reflect the long-term performance in terms of time equation coefficients due to behavioural biases (Cardinaels & Labro, 2008). However, in a Lean intervention, the second challenge is overcome as direct observation of the process is mandatory for making the VSM, and most of the relevant data such as cycle time, manpower, and machine time is being captured at this juncture. Lastly, some process variants may be so rare that they may not occur during the observation period of the consultants, leading to missing them altogether.

10.7 Summary

In this chapter, we presented some of the emerging business philosophies, methods, and technologies that have the potential to provide the requisite thrust to Lean organizations to take their performance to the next levels. The functional initiatives, viz., Six Sigma, Theory of Constraints, Industry 4.0, and TdABC, support operational performance, whereas an overarching sustainability initiative helps the firm develop and maintain a long-term perspective. A brief overview of each of these opportunity areas was provided, followed by some suggestions on how SMEs can plug these methods into their existing Lean implementations.

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11 Leveraging Lean to Tackle Uncertainty

11.1 Introduction

The pandemic of COVID-19 has heightened the importance of building resilient organizations that can not only recover from the debilitating supply chain disruptions quickly, but also leverage the crisis to their advantage.[1] Even during the years leading to the pandemic itself, there has been a steady rise in the disruptive events globally.[2] This predicament is expected to continue like this due to a myriad of interlinked reasons such as environmental deterioration, networked economy, shifting political forces, and shorter product life cycles, each of which is not only a potential disruptive force, but also feeds others, potentially multiplying the overall impact.

Some management thinkers believe that Lean deteriorates the organizations' ability to respond to disruptions. This is only true, only if all that is done under the umbrella of Lean is to drive out inefficiencies or redundancies (buffers such as capacity, inventory, time) without due regard to underlying uncertainties. The fact that the truly Lean firms such as Toyota continue to survive disruptions rather graciously as against those firms which implemented Lean only as a mixed-bag of tools or slogans, should tell us how misguided this judgement is. True Lean philosophy is based on the principle that uncertainty/variability is the cause of buffers, and the only way to truly (if at all) eliminate a buffer is by having a complete knowledge (and therefore no uncertainty/variability). Since complete knowledge is impossible, the next best thing is to create an organization that senses, processes, and responds to change quickly—a learning organization. After all, in the first place, Lean as a system was developed to deal with one of the worst disruptions

[1] https://www.mckinsey.com/business-functions/risk-and-resilience/our-insights/the-resilience-imperative-succeeding-in-uncertain-times#.

[2] https://worlduncertaintyindex.com/.

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of past century, the ravaging effect of the Second World War on Japan especially post the atomic bombs. And Lean or TPS proved its mettle as "THE" philosophy to handle uncertainty during the next major global disruption—the 1973 oil crisis. There are always layers of assumptions/beliefs/past conditioning upon which organizational buffers are based on. Whenever something happens to shake these assumptions, Lean management takes notice of it, corrects its worldview, and builds the necessary buffer. Therefore, Lean questions only just-in-case buffer and not the redundancies deliberately designed into organizational value chains, as we will see in some of the snippets in this chapter.

SMEs, most of which are at far end of supply chains, face the maximum brunt of the uncertainties due to well-documented demand signal amplification effect known as "The Bullwhip Effect" (Lee et al., 1997). SMEs therefore are a highly vulnerable sector, who will be at a loss if their organizational design does not help them tide over these uncertainties. Lean management principles aid building flexibility into supply chain design and capabilities, a handy tool in times of unexpected events (Sheffi & Rice, 2005). Lean management helps SMEs to prepare for shocks and adapt quickly to changing environment.

The chapter begins with an explanation of various terms related to uncertainty, in order to bring clarity from among a bewildering array of jargon used in popular press and as well in our day-to-day conversations. We then look at examples of some of the recent supply chain disruptions and their impacts. Finally, a few examples of how organizations have effectively tackled uncertainty by leveraging Lean are illustrated.

11.2 Definition of Terms

We classify various terms in vogue into two groups, viz. sources of disturbance and the strategies adopted by firms. Disturbances could be on account of internal or external situations presented to the organization. Strategies refer to the capabilities the organizations develop in order to cope with the disturbances in a manner that is favourable to the organization.

11.2.1 Sources of Disturbance

Various disturbances affecting organizations are presented in Fig. 11.1. The terms are organized such that the degree of impact on the firm increases as one proceeds outwards from the innermost circle.

We explain these terms from an operations perspective in the following subsection.

11.2.1.1 Randomness

Randomness refers to the unpredictable variation in behaviour of every process, equipment, or system. Truly random behaviour implies variation from

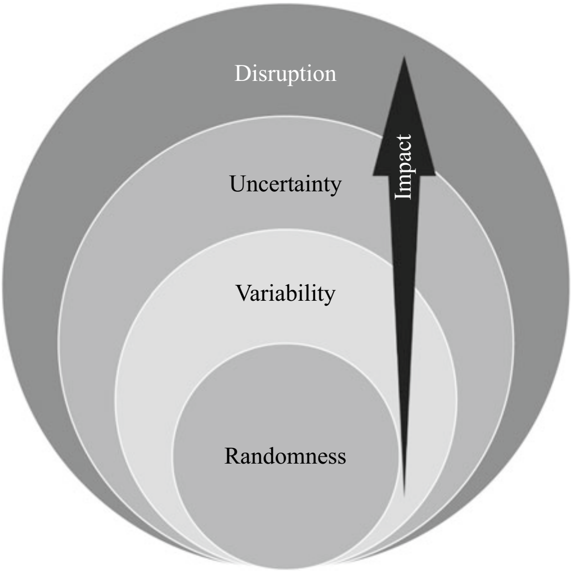


Fig. 11.1 Sources of disturbance faced by firms

mean/expected behaviour with some regularity, but without any discernible patterns such as increasing/decreasing trends or seasonal/cyclical fluctuations. Randomness is also called white noise, which is technically the residual component in any data series, after all other components of variation are explained. With sufficient past data, there are statistical techniques available to measure the extent of randomness in a process and thereby recommend the achievable control limits.

11.2.1.2 Variability

The explainable component of variation in mean/expected behaviour over time can be called as variability of the process. From this definition, one can expect predictable patterns such as increasing/decreasing trends or seasonal/cyclical fluctuations in the operations data such as demand, production quality, and raw material quality. Presence of a pattern helps organizations perform root cause analysis, so that it can either take corrective actions or be better prepared.

11.2.1.3 Uncertainty

Incomplete knowledge, understanding, and articulation (typically about future) are referred to as uncertainty. While the term uncertainty implies both favourable and unfavourable possibilities, we are concerned with unfavourable possibilities and would like to cover from them. Uncertainty results from our inability to see future, or understand/process the information objectively, or due to high complexity of the system/environment.

Consequently, uncertainty can be reduced by reducing the lead time since keeping the horizon short negates our inability to see the future to some extent. Lead time is defined as the time required by the organization to get the product into the hands of the customer from the time order is received in the make-to-order supply chains, whereas it is defined as the number of days ahead of which different entities of the supply chain have to forecast in the make-to-stock supply chains. Lead time can be reduced by improving the quality and timeliness of information collection, processing, and propagation within and through the departments and as well to the entities outside the organization. Lastly, reduction in the complexity of systems and processes also significantly contributes to reduction of uncertainty. The extent to which the lead time cannot be further reduced determines the present irreducible uncertainty. However, with improvement in processes, understanding of the environment, technology, and practices, organization can continue to keep reducing their uncertainty.

11.2.1.4 Disruption

A completely unexpected and a rather sudden happening, such as a pandemic breakout, Suez Canal blockade, and natural calamities or accidents, can be termed as disruptions. There are always events happening across the world all the time, which the erstwhile organizations were insulated from because the impact of such events was localized and did not touch organizations' network. However, with increase in the interconnectedness of the world, either the supply, demand or both ends of the organizations supply chains are increasingly getting impacted with such happenings (Coe & Yeung, 2015). If the impact is on the supply end, it is called a supply shock and a demand shock when the impact is on the demand end. A survey of supply chain professionals conducted by World Economic Forum (WEF) found that the top five sources of disruption are (1) reliance on oil, (2) non-availability of shared data/information, (3) fragmentation along the value chain, (4) extensive subcontracting, and (5) poor supplier visibility.[3]

11.2.1.5 Risk

Typically, individuals/organizations want to protect themselves against the unfavourable events, and so efforts are made to quantify the expected impact of these unfavourable events. Such a quantified measure is called risk. There are measures of risk pertinent to all the levels, viz. randomness, variability, uncertainty, and disruptions. Popular risk measures are variance, standard deviation, value-at-risk, etc.

A collection of practices that improve the preparedness of organizations to meet uncertainty and disruptions is referred to as supply chain risk management. Most common approach of risk management involves assessment of probability of occurrence of an unfavourable event and its impact rating (on some nominal scale such as 1 to 10, higher the rating, higher the impact). The product of these two values is called as risk score, and organizations establish a threshold for such

[3] https://www.weforum.org/agenda/2020/03/covid-19-coronavirus-lessons-past-supply-chain-disruptions/.

risk scores. Any event with a risk score higher than the threshold is actively monitored, and sensors /indicators of such events are put on a high alert mode. Alternate plans are created that get triggered as soon as the symptoms are sensed. Organizations create a cadence to review and modify their risk assessment matrix including addition/modification/deletion of events and adjustments to the probability/impact values.

11.2.2 Strategies

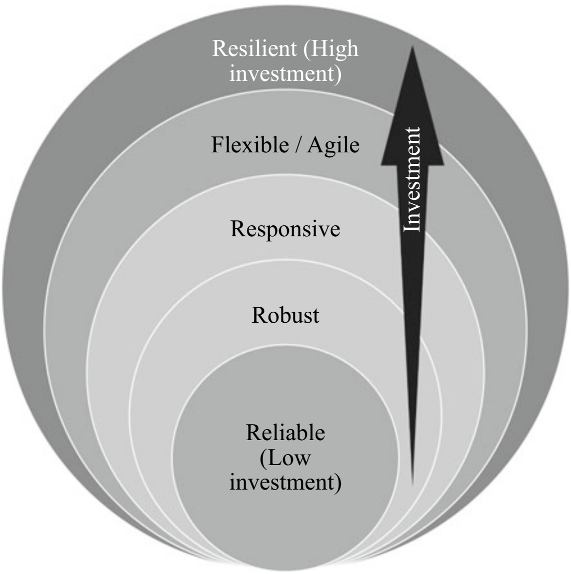
Strategies that can be adopted by firms to tackle the source of disturbances are presented in Fig. 11.2 in the order of additional investments by the firms. The innermost circle presents the least investment, and the outermost, high investment in building deliberate redundancies in capacity. It is to be noted that the sources of disturbance (Fig. 11.1) and strategies (Fig. 11.2) do not necessarily correspond in a one-to-one mapping, but some alignment exists. It is logical to improve capabilities from the inner to outer circle, for higher-order investments stick well when lower-order capabilities are firmly in place.

We explain these terms from an operation's perspective in the following subsection.

11.2.2.1 Reliable

A process is said to be reliable when it operates within the specification limits, i.e. the capability of the process defined in terms of its upper and lower control limits should be well within the customer specified upper and lower limits, respectively.

Fig. 11.2 Strategies to be adopted by firms



Various statistical quality control techniques including Six Sigma have been developed and implemented successfully to monitor process reliability. We encourage the reader to refer any of the foundational statistics books on the subject matter for additional details.

11.2.2.2 Robust

A process is said to be robust, when its outcome (signal) continues to be within acceptable limits even when the environmental conditions (noise) change substantially. Genichi Taguchi, a Japanese engineer, had developed statistical methods which involve Design of Experiments (DoE), Taguchi Loss Function (TLF), etc., collectively called robust design methods. DoE helps the designer to develop an optimal number of parameter settings, with which one can estimate the relationship between inputs and outputs. TLF helps assign customer (dis)satisfaction value to the extent of variation (deviation from expected value) in output. TLF value rises slowly when the variation is small, but rapidly rises beyond a threshold. TLF serves as a motivation to continuously endeavour to reduce the variation. Robust engineering goes a step beyond reliability in the sense that it takes active control of process design, so that the output stays within desirable levels.

11.2.2.3 Responsive

A firm is responsive, when it is able to meet the alternative delivery requests from the standard delivery options offered by the company. The alternative delivery request can be in the form of product features, quantity, delivery lead time, location, or lot size, etc. Ability to cater to such non-standard requests involves deliberate cushion building in the organization's supply chain such as signing up with costlier suppliers, logistics service providers, keeping inventories at various echelons, having quick access to spare capacity. Responsiveness is an effective organizational strategy to meet uncertainty, if its products are innovative, enjoy high margins and have short life cycles or fixed selling seasons (Fisher, 1997).

Zara: A Responsive Organization

Zara, a Spanish fashion retailer, is a case in point. It takes less than 6 weeks for a new product from design stage to be positioned in its retail shelves. Contrast this with the industry average of six months. Just like Toyota, every process, infrastructure, and information technology investments, supplier and distributor agreements are all tuned towards keeping this lead time as low as possible, rendering Zara one of the most responsive supply chains. The results are evident—in an industry where most of the players sell only 60% of their production at full price, Zara is able to sell more than 85%, positively impacting its profits.

11.2.2.4 Flexible/Agile

Flexibility is a reactive capability, i.e. the organization is able to quickly change to meet the changing environment, whereas agility refers to the organizations' proactive capability to capture the opportunity presented by the uncertainty faster than its competitors. Organizations can build flexibility into their plans by regularly undertaking a segmentation analysis of their products, component parts and creating an operations plan consisting of a mix of standard, optional, and rare products right from design to delivery.[4] The mixed model production capability recommended in Lean management improves the organizational flexibility and agility (Duggan, 2018; Takahashi et al., 2007). There are articles that place agility as a strategic capability, under which flexibility is an operational capability (Abdelilah et al., 2018; Lee, 2004). Flexibility and agility are structural capabilities, whereas responsiveness refers to information and process capabilities.

11.2.2.5 Resilient

Despite of best of the systems and processes, disruptions are unavoidable. While responsiveness, flexibility, and agility are all instruments to handle both uncertainty and disruptions, resilience is an exclusive measure of the organizations' ability to quickly restore its normal functioning post-disruption (Ponomarov & Holcomb, 2009). Sheffi and Rice Jr (2005) popularized the notion of enterprise resilience in their MIT Sloan Management Review paper. They recommend that the organizations should endeavour to achieve resilience by investing in flexibility rather than in redundancies. Simchi-Levi and Simchi-Levi (2020) proposed supply chain stress tests that evaluate the time to recover (TTR), time to survive (TTS), and the performance impact (PI) as a measure of resilience for critical supplies. As stated in the introduction section of this chapter, COVID-19 pandemic had substantially increased the necessity of organizational and supply chain resilience. This resulted in the release of plethora of consulting and IT solution offerings addressing resilience by providers. The solutions belong to two categories applicable to both upstream and downstream of the enterprise, (1) usage of analytics for better segmentation and risk classification of components and finished products (Simchi-Levi et al., 2014) and (2) improving visibility through enhanced digital connections.[5]

11.3 Recent Supply Chain Disruptions

Global uncertainty has been observed to increase steadily based on an index published using text mining for word, "uncertainty", and its equivalents on 143 country reports published by Economic Intelligence Unit as seen in Fig. 11.3.

[4] https://www.mckinsey.com/industries/advanced-electronics/our-insights/building-a-flexible-supply-chain-in-low-volume-high-mix-industrials.

[5] https://www.mckinsey.com/industries/advanced-electronics/our-insights/reimagining-industrial-supply-chains.

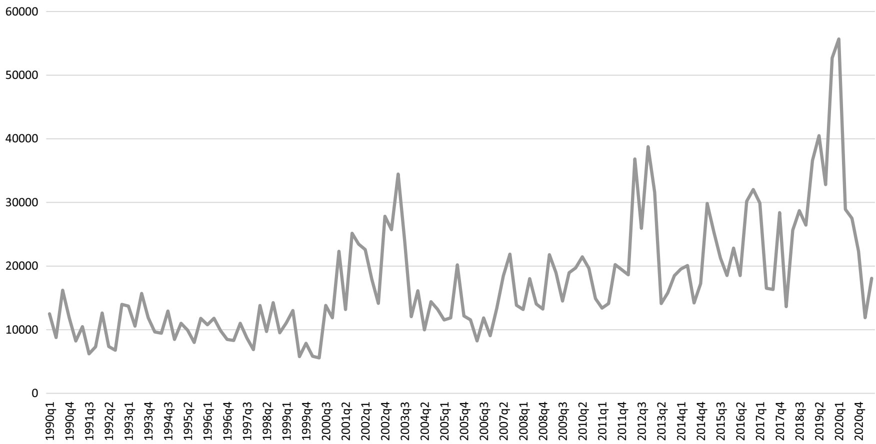


Fig. 11.3 World uncertainty index (WUI) on the raise

While there are numerous disruptive events as seen in the above chart, to set the context, we describe six examples of supply chain disruptions in the recent past.[6] These examples are representative of the lot in the sense they cover natural disasters, accidents, a major sociopolitical disturbance, and a pandemic.

11.3.1 COVID-19

Since the first case of COVID-19 was identified in Wuhan, China, in December 2019, the pandemic took the world by storm. It broke out in waves in different world regions, with every country experiencing two to three waves. Lack of an effective vaccine forced countries to adopt social distancing, quarantining as the only means to prevent the spread of the virus. This led to a series of lockdowns, and countries sealed their borders avoiding goods and people movements. Even within country, logistics was limited to essential goods during lockdown periods. For globalized supply chains, this move was unexpected and devastating. Added to the supply side challenges, due to extended work from home, the demand patterns of number of product categories have changed substantially (e.g. SOHO equipment demand shot up, and automobiles and component demand dropped). Companies, small and big, stood up to the challenge, figured out alternate suppliers/materials, changed products/production plans, implemented safe operating procedures, and worked with their banks and supply chain partners to tide over the cash deficit period.

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[6] https://www.aptean.com/en-EU/insights/blog/6-events-disrupted-maunfacturing-supply-chain.

11.3.2 Semiconductor Manufacturing Factory Fire

On 19th March 2021 at 2:47 AM, a fire broke in the N3 Building (300 mm line), Naka factory (Hitachinaka, Ibaraki Prefecture, Japan) of Renesas Semiconductor Manufacturing Co., Ltd.[7] An electric malfunction has resulted in a fire, which was put off by 8:12 AM. The fire burnt down production equipment and damaged the sensitive clean room. The company could resume its original production levels only by 24 June 2021 resulting in production loss of approximately 100 days.[8] The company commands a market share of nearly 30% of worldwide semiconductor sales to automobile industry. The loss of production of such a critical supplier was a double blow to the automobile industry, which was already reeling with semiconductor shortages induced by pandemic. A few companies (Nissan, Honda) had to change their production plans completely to cope up with this supply disruption.[9] The company exhibited an extraordinary alacrity in identifying alternate production options, rapidly sourcing replacements to damaged equipment, and kept all the stakeholders regularly updated about the status of recovery.[10]

11.3.3 Brexit

Britain's exit from European Union (popularly called Brexit) began in 2016 and culminated in the Trade and Cooperation Agreement (TCA) between both the parties on 24 December 2020.[11] This agreement finally brings to rest months of uncertainty for supply chain partners on either side of the English Channel. The agreement also brings clarity on how taxes will be applied on goods based on the country of origin, requiring firms to operate transparent supply chains.[12] One of the most evident short-term impacts of Brexit has been the increased lead time and transportation (includes clearance) costs between UK and EU, requiring firms to overhaul their supply chain planning, execution, and monitoring systems.[13] EU is the largest supplier and customer base for UK enterprises. Considering the deep interconnectedness of trade between UK and EU for several major industries, McKinsey Consulting recommends that firms should (1) redefine their sourcing strategy, (2) revise their supply chain footprint, (3) review inventory build-up

[7] https://www.renesas.com/us/en/about/press-room/notice-regarding-semiconductor-manufacturing-factory-naka-factory-fire-summary-updates.

[8] https://www.renesas.com/us/en/about/press-room/update-10-notice-regarding-semiconductor-manufacturing-factory-naka-factory-fire-production-capacity.

[9] https://www.reuters.com/business/autos-transportation/renesas-says-plans-restore-full-production-fire-damaged-chip-plant-by-end-may-2021-04-19/.

[10] https://www.renesas.com/us/en/about/press-room/update-6-notice-regarding-semiconductor-manufacturing-factory-naka-factory-fire.

[11] https://www.chrobinson.com/blog/the-direct-impact-of-the-brexit-deal-on-supply-chains/.

[12] https://www.pinsentmasons.com/out-law/analysis/brexit-deal-supply-chains.

[13] https://www2.deloitte.com/nl/nl/pages/tax/solutions/the-impact-of-brexit-on-your-supply-chain.html.

strategy, (4) prepare for changes in demand, (5) adjust product portfolio, and (6) strengthen capabilities and talent.[14] We find these recommendations are useful to manage all supply chain disruptions.

11.3.4 Suez Canal Blockade

Containerization of cargo is perhaps the single most contributor to huge increase in worldwide logistics. The growth in cross-border logistics led the shipping industry to build bigger and bigger vessels. The biggest among the class of container ships is called as Ultra Large Container Vessels (ULCV), which can carry more than 20,000 TEU containers.[15] The ULCVs can cross Suez and Panama canals. Suez Canal is the main artery of global logistics with nearly 50 ships crossing it in a day, contributing to nearly 12% of global trade.[16] Suez Canal is the shortest shipping route between Europe and Asia. When the "*Ever Given*", a 20,000 TEU ULCV, ran aground due to strong headwinds on 23 March 2021, it effectively choked this artery. A 24×7 recovery effort by a number of experts resulted in clearing of the ship six days later, after a trade loss of nearly $9 billion every day.[17] Shippers used the alternative route around Africa via Cape of Good Hope with an increase in transit time by 2 weeks.[18]

11.3.5 Drought in Taiwan

Semiconductor chips are ubiquitous. They are there practically in every consumer durable product around us. With the increased drive towards smart "everything", the usage of semiconductors is going to keep increasing. Manufacturing of semiconductor chips involves serially binding many layers of silicon wafers one on another to create Integrated Circuits (IC). Given the miniaturized manufacturing with high precision, the raw materials, WIP and the finished chips need to be thoroughly cleaned of any residuals. This cleaning is done by what is called as Ultra-Pure Water (UPW). A single IC made on a 30 cm wafer may require about 2200 gallons of UPW to get desired levels of cleanliness. Further, deionizing approximately 1500 gallons of regular water produces 1000 gallons of

[14] https://www.mckinsey.com/featured-insights/europe/brexit-the-bigger-picture-rethinking-supply-chains-in-a-time-of-uncertainty.
[15] https://en.wikipedia.org/wiki/Container_ship.
[16] https://www.cnbc.com/2021/03/29/suez-canal-is-moving-but-the-supply-chain-impact-could-last-months.html.
[17] https://lloydslist.maritimeintelligence.informa.com/LL1136246/Suez-blockage-extends-as-salvors-fail-to-free-Ever-Given.
[18] https://www.bbc.com/news/world-middle-east-56538653.

UPW.[19] Additionally, water is required for running the plant for purposes such as AC cooling towers. All these make semiconductor industry one of the largest industrial dependents of water. Normally, Taiwan is a country with abundant rainfall/typhoons. However, in 2020, it faced a worst drought in 56 years. Taiwan Semiconductor Manufacturing Company (TSMC) is the world's largest semiconductor manufacturer, single largest contributor to Taiwan GDP, a user of about 150,000 tons of water per day, was diverted with much of the water available in the country's reservoirs, at the cost of other sectors, notably agriculture.[20] Regardless, a worldwide semiconductor crisis ensued that may take a long time to recover from, as setting up of alternate production facilities is at least a 3- to 4-years-long capital-intensive project. Serious efforts are underway to increase the water recycling ratio to reduce water consumption in semi-conductor manufacturing by many researchers around the world.

11.3.6 The Texas Freeze

Texas suffered one of the worst winters in 2021, brought about by three successive sever winter storms that swept the Americas during February 2021.[21] So harsh was the impact that the power grid failed, resulting in power outage lasting for days in the state. Texas is home to a number of industries such as semiconductor manufacturing, oil and gas, petrochemicals, food and agriculture, and aerospace and defence, besides being a transportation hub.[22] Samsung, Infineon, and Texas Instruments are some of the large semiconductor manufactures in the state that were affected by the outage, exacerbating the already delicate semiconductor situation.[23] The industries using the by-products of petroleum refineries such as plastics, adhesives, and chemicals were also significantly affected. Total economic losses from this disaster were estimated to be $130 billion (Busby et al., 2021). The catastrophe is yet another example of how one event in one place causes ripple effects in different supply chains.

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[19] https://www.chinawaterrisk.org/resources/analysis-reviews/8-things-you-should-know-about-water-and-semiconductors/.

[20] https://www.forbes.com/sites/emanuelabarbiroglio/2021/05/31/no-water-no-microchips-what-is-happening-in-taiwan/?sh=368aa62d22af.

[21] https://en.wikipedia.org/wiki/2021_Texas_power_crisis.

[22] https://www.ismworld.org/supply-management-news-and-reports/news-publications/inside-supply-management-magazine/blog/2021/2021-03/the-texas-freeze-repercussions-and-risk-mitigation/.

[23] https://www.forbes.com/sites/willyshih/2021/02/19/severe-winter-weather-in-texas-will-impact-many-supply-chains-beyond-chips/?sh=1b10fbc2358a.

11.4 Lean: Counter to Uncertainty

Where Lean differs in philosophy vis-a-vis most management approaches is to understand the sources of variability and initiate efforts to reduce/eliminate/manage these variations. While this approach is more fundamental, active and involving in nature, passive approaches that take variability, lead time as given are more common, perhaps due to the ease they promise in implementations. And yet executives are taken aback, when an unknown/unexpected variation occurs, and their current set of tools is not equipped to handle the situation. As noted by Spearman and Hopp (2020) in their case for unified operations science, time as a buffer is interrelated with inventory and capacity choices. Conventionally, organizations countered variation with high lead time (time buffer), or inventories or capacity buffers. Ford and others managed by cutting the demand side variation by choosing to serve a narrower and stable slice of demand, and Sloan and other mass producers managed by creating a massive capacity and inventory investments. These approaches are increasingly getting untenable with the fleeting nature of today's market demand for most products. So, time is also a response measure that can define capturable demand.

In this context, we highlight a few examples how Toyota (Iyer et.al 2009) prepare themselves for disruptions, and upon the occurrence of disruption, measures they take to rebound. While most of these disruptions occur suddenly, yet there are also real disruptions that are slow, such as environmental or technological.

11.4.1 Fire at Aisin Seiki Plant (1997)

When the lines producing p-valve, a machined product, at one of the supplier plants, located at Aisin Seiki was gutted down on 1 February 1997, any other organization would have taken weeks, if not months to put together a plan-B, but not Toyota. Within hours, some 62 suppliers responded to calls by Toyota to produce one or more of the many types of p-valves that were needed by Toyota in the months to come. P-valve being a standard part, Toyota maintained only 2–3 days of production worth inventory in the system, implying that the entire production not just that of Toyota, but also that of suppliers who depend on Toyota's orders were to come to a grinding halt, unless the situation is not addressed immediately. Decisions were made quickly on which supplier will make which type of the valve, and the corresponding manufacturing designs were faxed by next day. Within a day or two, prototypes of the assigned valves started arriving at Toyota for approval, which were mostly given the same day. Standardized processes as recommended by Lean management are the most important reason as to how these companies were able to design and produce completely new parts. By 8 February, volume production of p-valves has commenced at about 50% of the responded suppliers. Key takeaways from this incident for SMEs would be that (1) it helps if they are part of an ecosystem, instead of being solo, (2) respond very quickly to any crisis calls, and put together a response team, and (3) stay with the Lean management process to steadily gain lost productivity.

11.4.2 Strike at the US West Coast Ports (2002)

Unlike the previous fire example, trouble was brewing for a while between the US West Coast port union workers and the ports from early 2002, which finally resulted in a lockdown of ports starting from 29 September 2002. Sensing this challenge, Toyota took the following measures to keep its North American plants up and running despite the lockdown: (1) built inventory for the imported parts through the period leading up to lockdown, (2) book air cargo capacity ahead, and (3) kept the option of re-routing ocean cargo alternate ports such as Mexico and Canada. This example clearly illustrates the willingness to relax Lean norms such as low inventory or frequent shipments in times of crises. Further, a hallmark of a Lean-oriented firm is that it always has its ears to the ground and acts quickly.

11.4.3 Manufacturing Problems at Freescale (2005)

Freescale, a manufacturer of semiconductor chips, was having capacity problems at its France factory during 2005. Semiconductor capacity enhancement takes years to set up. Automotive boom was at its peak during 2005, implying that the chips shortage could potentially dampen the overall sales. In addition to placing its own team at the supplier's premises to help them improve productivity and resorting to air shipments to reduce pipeline inventory, Toyota this time realigned its production mix such that the supply of chips to fast selling models was prioritized. This is an example of how a leading Lean organization shifts its managerial focus depending on shifting bottlenecks and change the practices as the situation demands.

Many other large firms such as Walmart, South West Airlines, and Seven-Eleven have implemented some or all principles of Lean management successfully and hence better prepared to meet uncertainty.[24]

11.5 Summary

In this chapter, we clarify various terms related to uncertainty and the strategies adopted by firms to deal with the same. We also indicate a logical order for these terms and also a recommended sequence of implementation of various strategies. We looked at a few devastating supply chain disruptions of the past decade. Finally, we saw how Toyota, the pioneer of Lean management tackled uncertainty, by deliberately and knowingly relaxing its Lean norms. Such a relaxation holds good for only as long as the danger of uncertainty is clear and present. Once the event passes, the buffers will be gradually removed.

[24] https://iveybusinessjournal.com/publication/going-lean-as-a-solution-for-navigating-uncertainty-and-a-crisis/.

With all positive public press, it might be tempting for the reader to imagine that Toyota's Lean journey was a bed of roses. On the contrary, the company met with obstacles/challenges at every turn of this arduous but very rewarding journey. And some very serious wake-up calls too, notable among these are the Japan Earthquake (2010) and the accelerator pedal-related recall in North Americas (2010), both resulted in this great company to pause and reflect. Toyota, in fact, has a name for this phase of Lean implementation (*hansei*: pause and reflect). The learnings from *hansei* from every Kaizen event make the organization more aware of its own capabilities, and the environment it operates in. The essence of removal of wastes by a Lean organization improves its visibility by that much more than its non-Lean peers. With this improved visibility, a Lean firm can assess the impact of disruption, look at alternate options, and trigger them as appropriate, better than its counterparts.

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Case Study 1: Seeds of Growth

Background

PAN Seeds (PAN) has established a strong presence in the rice dominated eastern belt of India. The main seed processing plants are located in West Bengal, the largest rice-producing state in India, with an estimated production of 15 million tonnes per year. The company commenced operations in a small way in a few decades back and subsequently expanded both its field production and seed processing to multiple plant locations. PAN sells both basic and premium varieties of paddy (rice) seeds catering to farmers in West Bengal and its neighbouring rice-producing states.

Mr. Alok Marodia, the founder, has handed over the day-to-day sales and operations functions to his two sons and spends his time on Research and Development and other organization building activities. Anshuman (the elder son) takes care of operations and is always on the lookout for ways and means to improve operational performance. With their progressive mindset, PAN has already implemented and is regularly using an ERP for all its functional transactions. In addition, the management has set up a system of measuring, tracking and analysing performance on select key performance indicators (KPIs) on Google spreadsheets. Weekly review cadence with functional heads aid performance monitoring and timely decision-making.

An invite to a one-day seminar on Lean management sparked Anshuman's curiosity. Though he could not attend, he received the presentation material from the seminar and went through it. Impressed at the operational improvements reported at various case study companies, he called for a meeting with the Lean *Sensei* (Ganesh, one of the co-authors) from the seminar.

The two met up in person in February 2020, in which Anshuman introduced himself and PAN and asked Ganesh "What can you do for my company"? Ganesh laid out a general approach to implementing Lean management in a seed processing plant. However, he said that a more specific approach could be presented only after a diagnostic visit and an interaction with the key people at the plant. The

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first week of April'20 was decided as ideal for this visit, as plant operations for *Kharif* season would be in full swing (See Fig C1.1). In most parts of India, the monsoon rains arrive in June or July and farmers sow their major crop during this period, called *Kharif*. Post harvesting, a second smaller crop is sown in the *Rabi* season that occurs in the winter months. April would therefore be the best time for observation and assessment of current operations. And then COVID struck the world, resulting in massive lockdown and travel bans. By the time the restrictions were removed, *Kharif* season was over. Persistent that Anshuman is, he ensured that the initiative was back on track by July'20.

The Seed Industry

Lean is a universal philosophy but for successful application of its concepts one needs to understand the features of the industry. Seeds are an agricultural commodity and as such of a highly seasonal nature. The seed industry is quite unique in many respects as against regular manufacturing in the sense that different production and distribution processes must happen at specific times of the year as shown in Fig. C1.1.

It therefore becomes critical that all the resources are aligned such that the narrow window of opportunity is not lost. The key aspects to be considered when designing Lean improvement initiatives in this industry were:

- High peak load coupled with a short window of opportunity of planting season implies entire downstream plant output needs to be made available during two to three months of *Kharif* season and one to two months of *Rabi* season.
- There are no permanent workers. Seasonal workforce come to work in the plant only in the operating months while rest of the year they work elsewhere either on the fields or doing other jobs.
- The plant executives and supervisory staff are permanent employees but without active engagement for several months of the year. This fixed cost is unavoidable, and to keep it to a minimum, employees are hired from nearby villages and towns, are relatively less qualified, and with almost no exposure to industrial set-ups.
- Machines run for two months, twice a year with a four months' gap between the seasons. The long idling of plant machinery with sudden spurts of usage is again a challenge from the maintenance of equipment performance.

Every single characteristics of the industry seem to go against every known notion of where would Lean fit. It is with this background that Ganesh had to view Anshuman's question "What can you do for my company" which in his mind translated to "What should be our approach to implement Lean in this industry".

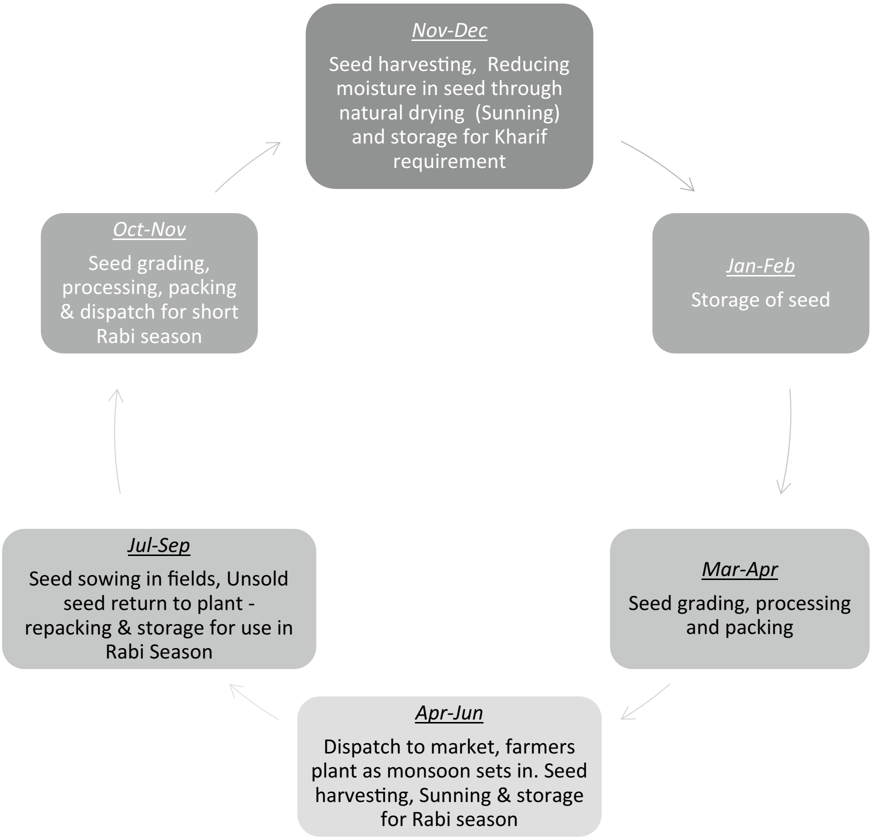


Fig. C1.1 Annual cycle of seed process

Approach to Lean Initiative

Given the unique characteristics of this industry, there were understandably doubts on the applicability and usefulness of Lean management. Specifically, the questions that needed to be answered while designing the approach were:

- How can Lean thinking be applied in an industry where there is no production for eight months and peak production during the remaining four months?
- Standards are a key foundation for improvement—where there is no fixed workforce, how will we get them to standardize? How will they take ownership of the process?
- Inventory is the biggest *Muda* as per Lean, but here storing of seed is the norm?
- Even if we do manage to design the initiative and implement Lean concepts, will there be any significant tangible business benefit?

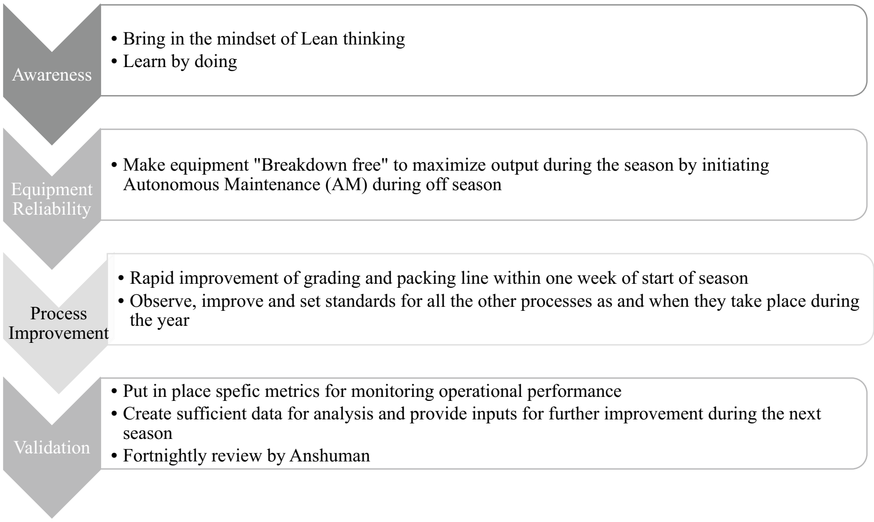


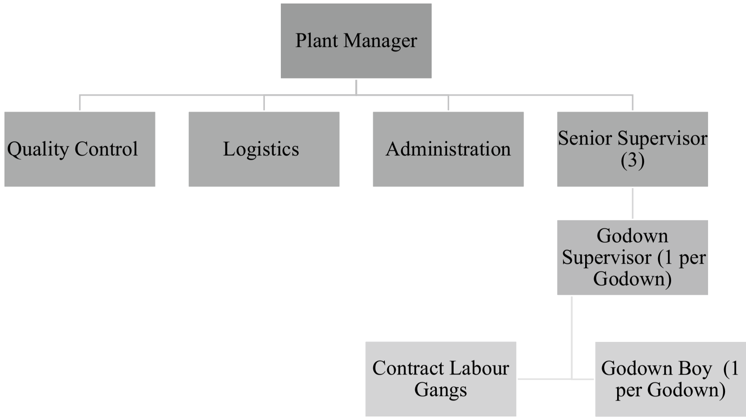
Fig. C1.2 Broad roadmap for Lean

Lean involves looking at processes through the philosophy of "Doing more with less". Tools and techniques can always be adapted. Keeping in mind the above factors, it was decided to dive straight into the implementation rather than follow the conventional diagnosis, roadmap, and implementation approach. With the understanding of the nature of operations, a four-stage roadmap was formulated at the outset to implement Lean at PAN Seeds as shown in Fig. C1.2.

The largest plant of PAN Seeds was located at Bardhaman (West Bengal) and contributed about 75% of the seed output. Two more plants located in other districts of West Bengal contribute the remainder. In order to disseminate Lean thinking across all the plant locations, it was decided to involve key people from the other locations in focused improvement workshops to be conducted at Bardhaman. The plant managers of the other two plants would then implement the learnings in their respective plants. Anshuman would review the progress in all the plants during his fortnightly visits. The organization structure for the plants is depicted in Fig. C1.3.

Stage 1: Initiating Lean Thinking

With the four-stage approach decided, the plant teams gathered for a three-day quick improvements workshop led by Ganesh. The goal of this initial workshop was to bring in Lean thinking through working on a few quick improvement projects. Anshuman decided to participate himself as a team member to not only understand the Lean philosophy but also to highlight the importance being placed



Terminology Description

Godown – a shed that includes plant machinery and storage facilities. Bardhaman has 14 godowns of varying production capacities (Tons per hour) with different levels of automation, and storage (Tons)

Senior Supervisor – manages operations of multiple godowns. There are three supervisors.

Godown Supervisor – in-charge of the operations of one godown

Godown Boy – runs the grading and processing plant (a.k.a operator)

Labour Gangs– contracted seasonal workers who load and unload trucks, dump the seed in the grading plant and run the packing lines. They also manage the Sunning.

Fig. C1.3 Organization structure—Bardhaman plant by PAN's management on this initiative. The participants included plant in-charges and senior supervisors from all three plants.

The *Kharif* season having concluded in May, only a few manual packing activities were in progress at the time of the workshop. In one Godown, mustard seeds, a minor product, were being packed and dispatched. In another of the Godowns, unsold market returns were being repacked into gunny bags for storage. Vegetable seed packing was in progress in another plant location at Fatehpur. The rest of the plant locations were in complete shutdown. (Refer Fig. C1.1).

Day 1—Awareness

Initial orientation was provided to the team on core Lean concepts such as customer focus, internal supplier–customer relationships, and how to observe a process through the eyes of the customer. Value addition and the wastes known as *Muda*, *Muri,* and *Mura* (3 M) were discussed. Three cross-functional and cross-plant teams were then formed from among the participants. Each team then went to observe one of the three packing processes under the Lean paradigms. Teams shared their observations in the end of day session.

Day 2—Understanding

The teams were encouraged to think about "why" the observed wastes happen. A second round of detailed observations was done to understand the Whys. In addition, concepts of cycle time measurement and productivity calculations were introduced and applied to the running processes. *Ganesh then challenged each team to increase productivity by 50% in these simple manual packing processes.*

Day 3—Excitement

Teams took up the challenge and applied the concept of waste elimination and immediate countermeasures to improve flow. Study and fine-tuning of line imbalances after establishing basic flow involved adjusting worker positions and number of workstations. By evening—a huge result! All three teams reported in excess of 50% increase in productivity and hourly line output after making improvements. Mr. Alok Marodia, the MD, had been invited for the closing session and presentation by the teams and was pleased with the enthusiasm of team members and excited by the results shown.

This three-day action-oriented learning workshop served to motivate the key people, enabling them to gain confidence through their actions and brought in the faith that Lean works. More importantly, it created the enthusiasm among the participants to pick up the later stages of Lean implementation with jest.

Stage 2: Making Equipment Reliable

Preserving the germination properties of seed is critical to productivity of the farmers (customer). Hence, the grading, processing, and packing is done just when seed is needed in the market. This means a narrow 45–60-day window for completing

Table C1.1 OEE computation

Regular OEE computation formula	Rough OEE Computation Formulae used at PAN
OEE is a measure of the percentage of total available time that a machine spends in actually adding value to the customer. It is computed by removing the six major losses from the total available time, categorized as below: *Availability:* total time minus breakdowns and changeovers *Performance:* available time minus short stop and speed losses *Quality:* produced quantity less rejection and yield losses *OEE:* availability % × performance % × quality %	Daily plant stop—start time = Available Hours (AH) Grading (supplier rated) capacity = G Theoretical Output in Available Hours (TO) = G x AH Raw seed dumped (charged) = RM Grading Loss (undersize, husk, foreign body) = L Actual Plant Output (AO) = RM–L Overall Equipment Effectiveness (OEE) = AO/TO

the plant activities in the main season. Any time lost due to plant breakdowns implies poor product availability in some markets. In Lean parlance, this translates to a focus on plant Overall Equipment Effectiveness (OEE). However, as is often the case in most SMEs, the data on downtime, short stops, plant performance, and changeovers was not available. The daily data captured in a large register did at least record plant start and stop time and the plant output for each day.

The bias of Lean as we saw earlier is towards action. While accurate OEE data on availability, performance, and quality definitely helps in focusing efforts, the team did not want this to be a roadblock in the pursuit of improvement. Hence, the OEE was computed using a rough formula as against the regular computational method as shown in Table C1.1.

This came to approximately 70% for a few high capacity Godowns with semi-automated packing lines, providing a lot of scope to reach the benchmark level of 85% and above. Most Godowns are dedicated to one or two seed varieties and therefore experience very few changeovers, if any. Hence, the team's focus was on avoiding breakdowns and minimizing short stops. As the plant was under shutdown, it was a good time to kick off autonomous maintenance (AM) activities. Initiated in August'20, AM was developed, implemented, and practised through till the end of the next *Kharif* season in May'21.

The primary purpose of autonomous maintenance is to have the operators develop ownership for their own machines. This is achieved by training them to identify machine abnormalities, rectify (or get rectified) these abnormalities so as to minimize equipment related problems. As we saw, there are no full-time permanent operators in PAN. But it was still essential to have some form of AM in place. The first phase involved training the supervisors and Godown boys. In the *Rabi* season they personally took ownership for the daily CLRI activities, filling up the abnormality registers and corrective actions.

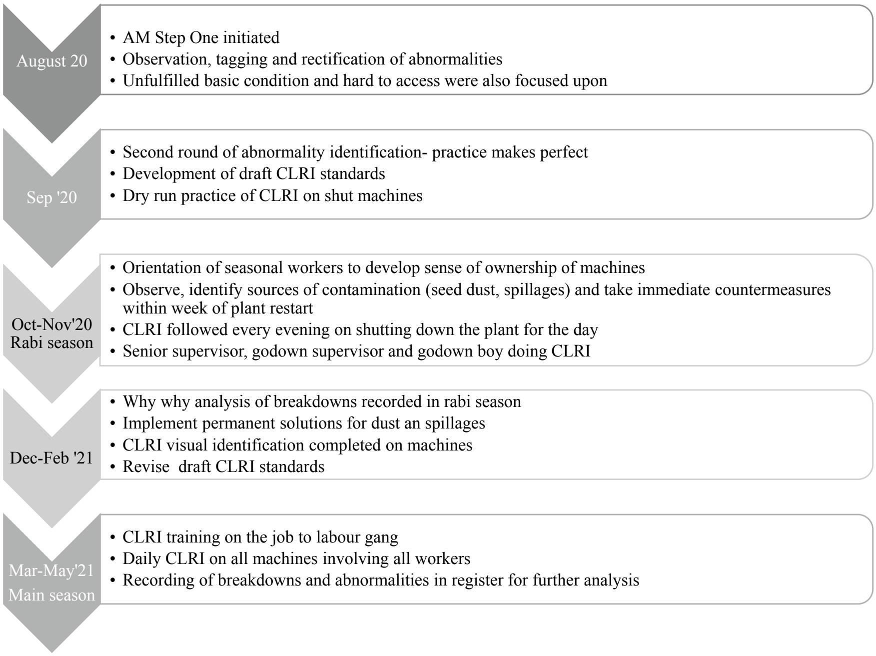


Fig. C1.4 AM implementation schedule

In the next phase, the labour gangs who helped in the grading operations and ran packing lines were trained on the job on CLRI. In the *Kharif* season, daily cleaning and following CLRI was done by entire workforce, and this also enabled slashing the time needed for this activity.

The steps and the corresponding timelines involved in AM implementation are shown in Fig. C1.4.

By end of the May season, the plant teams had embraced CLRI whole heartedly. Every evening, the team members religiously clean and inspect their respective machines. In fact, when Anshuman asked the team at the end of a year of Lean implementation on which aspect they learned from the most, the unanimous answer was "CLRI".

In June, data was compiled to understand the impact of CLRI on plant performance. OEE of the main Godowns had risen to 85% as a result of significant reduction in breakdowns and short stops. The grading plan was completed ahead of schedule even though the output was higher than in the previous year.

Stages 3 and 4 Process Improvement and Validation

The entire cycle of operations in the seed processing plant repeats twice a year, once each for the *Kharif* and *Rabi* season, respectively. As discussed earlier, the

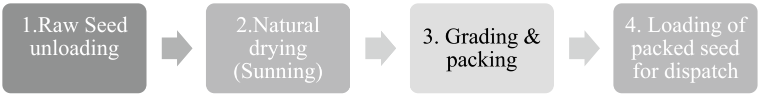


Fig. C1.5 Plant process sequence

operations are sequential such that different processes are performed at different points in time. Hence, we are compelled to take up each process for improvement, as and when it is running and complete the improvement and standardization cycle simultaneously given the short window. Hence, Stages 3 and 4 of the roadmap were happening together throughout the year. The overall sequence of plant processes is depicted in Fig. C1.5; each box was taken up as a separate improvement project within the Lean roadmap.

Given that the Lean initiative commenced in July, the seeds for *Rabi* season were already in storage after drying. Grading (3) is done through a mostly automated set of equipment whose improvement was taken up through the equipment reliability project. We therefore commenced our process improvements with the packing line (3) in October, followed by unloading of seed (1) and sunning (2) in November month. Peak dispatches happen in summer months, and we focused on loading and dispatch (4) in April' 21.

Packing Line Improvements

One of the major constraints for a seasonal industry such as PAN Seeds is the inconsistent availability of workforce. The plant operates with contracted labour gangs, each gang being allotted one or more Godowns. The members are involved in all the activities of the Godown right from unloading incoming seed, sunning related activities, operating packing line, and loading packed product. In the peak season months of November and April–May, gangs were often found shifting from one activity to another leading to disruptions in the packing line output. Data of the past season highlighted multiple line stoppages as the entire gang went to help out in sunning or dispatch loading.

The team was set with a goal of establishing packing line operations free of Muda and Muri, such that the line could meet the target output with the minimum "fixed" workforce. Then these workers would continue to run the line while the other gang members would work on the other activities in parallel. The initial workshop had already exposed the plant team to the concept of 3 M and waste elimination. As *Rabi* season plant operations commenced in early October, the team was dedicated to improving packing line within the first week of operation. The typical seed packing process flow is depicted in Fig. C1.6.

There are three types of packing lines across the PAN Seeds plants.

1. *Manual:* All the activities are done by hand.
2. *Semi-automatic:* Mechanized conveyor line but a man has to support by holding the bag in place for filling, sealing, stitching, etc.

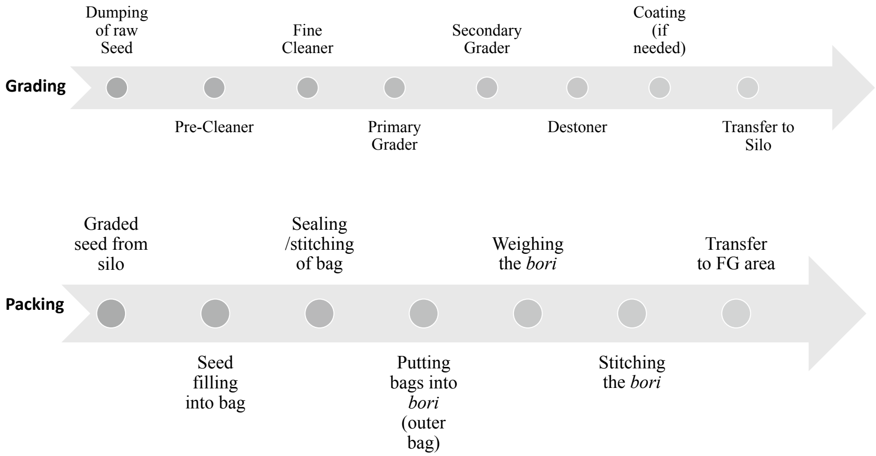


Fig. C1.6 Seed grading and packing process flow

3. *Fully automated FFS line:* Operator involvement is minimized to machine setting and outer bag (*bori*) operations.

However, irrespective of the type of packing line, the Lean concept to be applied was one and the same—single-piece flow. Hence, three teams were formed, one for each type of packing line and the teams executed the improvements in parallel during the first week of the *Rabi* season. The approach taken to implement and refine flow is detailed below.

Step1: Calculate *Takt* time

The packing line has the target of packing whatever has been graded. Hence, grading capacity determines the *takt* time for the packing line. The team for each Godown first computed the respective *takt* times.

Example:
Godown 11 Takt time
Grading capacity = 4.5 tonnes/hour
Pack size = 6 kg bags
Target = 45000/6 = 750 bags per hour
Actual working time per hour @ 85% effectiveness = 50 mins
Takt time = 50*60/750 = 4 seconds per bag

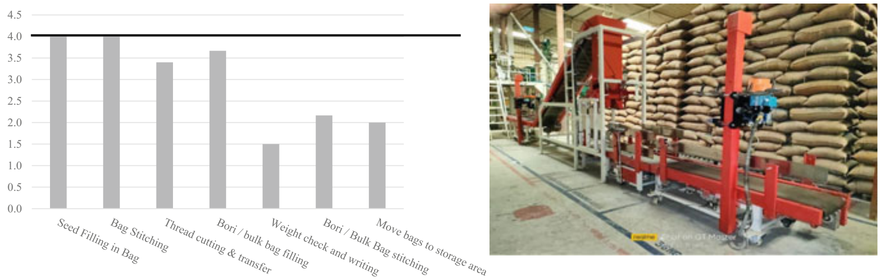


Fig. C1.7 Cycle time study of semi-automatic line

Step 2: Observe current operations

Team then observed the current line operations—and measured the cycle times of each of the operations. The cycle times are depicted pictorially in Fig. C1.7.

The simplest way to identify bottlenecks in the flow is to observe where material is piling up. In this case, the team observed that several bags were waiting in line for operation 2: bag stitching. Every now and then, operators had to stop the filling machine and remove the extra bags from the conveyor, and later during breaks, they would put them back at the stitching station and stitch.

Step 3: Countermeasures

Ideas were discussed on improvements that could be done to reduce the waste in the bottleneck operations using the Eliminate, Combine, Simplify, and Rearrange (ECSR) principles. Solutions implemented include.

- Reduce incoming variability: In this case, it was observed that four filling heads were in use with cycle times varying from 9 to 12 s. The filling head settings were adjusted to ensure uniform cycle time of 9 to 10 s. Since the *takt* time if 4 s, one filling head was put into standby mode. With three filling heads, the cycle time was 3.3 s which ensure smooth flow. The smooth flow of bags resulted in cycle time of the stitching operation also reducing to 3.5 s as operator was undisturbed by bags piling up.
- Short cycle operations of weight checking, writing, and *bori* stitching were combined such that a single operator could do the same. Each *bori* has 36 kgs, i.e. 6 bags of 6 kgs each. Hence, the *takt* time for this is 4 s per bag $\times$ 6 bags $=$ 24 s. With workstation arrangement and reducing distance between the stages, one operator was able to complete this set of activities within the *takt* time with minimum strain.
- In the manual line, a *bori* fixture to hold the bulk *bori* into which individual packets are filled—a single operator is now able to stitch the bag and drop into the *bori* held by the fixture. See Fig. C1.8 for the improvement done in *bori* packing.

Fig. C1.8 Improvement in *Bori* filling

Step 4: Validate results

The packing lines thus improved in the first week of the *Rabi* season were operated with the new methods for the rest of the season. The smooth flow with the minimum required workforce was thus confirmed, and the outcomes measured showed a clear improvement in terms of both productivity and reduction in wastage. As the short season concluded towards the end of November, the plant team was confident of sustaining the new process in the next season.

Step 5: Making standards

Based on the data collected during *Rabi* season, process standards were drawn up for the *Kharif* season. The standards were made product SKU wise for each Godown packing line and incorporated the target output rate, resources (man and machine) to be allocated, preparation activities to be done before start, and the quality checks to be carried out. Following the standards over the *Kharif* season of 2021 helped realize productivity gains across all the lines as shown in the Table C1.2.

Table C1.2 Comparison of packing line performance

Parameter		Manual line	Semi-automatic	FFS
Number of people per line	Before lean	11	11	6
	After lean	7	9	4
Seed wastage (average)	Before lean	60 kg per day	100 kg per day	200 kg per day
	After lean	<10 kg per day	18 kg per day	60 kg per day

Sunning Improvements

West Bengal is a warm and humid place. Most of the seeds are harvested post-monsoon and arrive at the plant in November and December. These seeds are processed and packed only in April for farmers to sow by June. Seed has to germinate only when planted; hence, this property has to be preserved for over half a year. Moisture content (MC) of the seed is the single most important parameter to control germination and needs to be below 12%. Incoming seeds may have up to 18% MC, and a natural drying in the sun is used to reduce this to acceptable level. In past seasons, the team recorded that over 15% of incoming lots had to undergo at least one "resunning" as the required MC level could not be reached in one day of sunning. Sunning process depicted in Fig. C1.9 involves a lot of manual labour and therefore additional cost if it has to be redone.

As per Lean paradigm, the only value-adding activity here is the process of spreading exposing the seed to the sun for drying. Observing the process, the team noted that spreading was generally completed by 10.30 am, and the seed is again collected in heaps by 2.30 pm and repacked by 3.30 pm. This was due to the winter months having early sunset; by 4.30 pm, it is dusk, and dew formation is a threat to the moisture content of exposed seeds. Early morning fog also has the same impact, and seeds cannot be spread before 8 am. For effective sunning, the two main targets for process improvement were therefore to ensure that:

- Seed should spend maximum time in the sun.
- Maximum surface area of all seeds should be exposed to the sun.

The team implemented two major changes based on core Lean concepts.

Step 1: Seamless flow in the cycle of activities from bringing the stored seed to spreading thereby reducing the "throughput" time for spreading. Table C1.3 compares the earlier and improved processes and their outcomes.

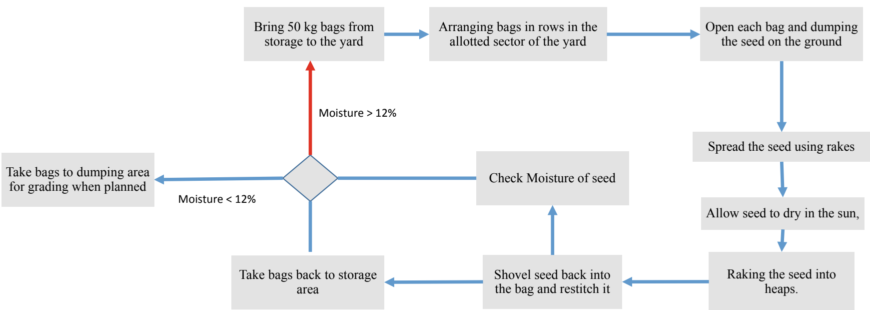


Fig. C1.9 Sunning process

Table C1.3 Throughput time of sunning process

Earlier process		Improved process	
Schedule	Activity	Schedule	Activity
8–9.30 am	Labour gang lays out bags of seed in the yard	7.30 am	First lot of bags brought out by labour gang
9.30–10.30 am	Women workers cut open the bags; gang will start dumping the seed in parallel. Sample collected and moisture checked after complete cutting of bags for the lot	8.00 am	Women cut open first lot, second lot brought out by gang in parallel. Moisture check done as soon as first row of bags of a lot are cut open.
10.30–11 am	Women rake the seeds of all the lots one after another	8.15–8.30 am	First lot of seeds dumped in tandem with cutting open the bag. Raking done immediately for each lot before moving to next lot
Lot sunning begins from 10.30 to 11 am		Lot sunning begins from 8.30 to 9.30 am	
Average hours in the sun = 4		Average hours in the sun = 6	

Step 2: The second target was to expose maximum area of seeds to the sun. However, the yard area was limited and needed to be optimized. For two weeks, data was captured on the depth of the spread seed layer and the incoming and reduced moisture content. Through analysing this data, a correlation was established—higher input moisture content seeds need more exposure to sun which can happen through wider spreading to lower the depth of seed layer. Through further trials, the team could establish a standard table which gave the depth (inches) to be maintained for each range of incoming moisture.

But each lot has different quantities. So how do we know to what extent the seed should be spread to maintain the recommended depth? For this the team divided each yard into rectangular sections of standard 12 feet width, visually marking off the length at 5 feet intervals as shown in Fig. C1.10.

For each depth, the square feet per kg of seed was computed based on practical measurement of the spread seeds and standards fixed. The standards ranged from 2 to 5 inches layer depth, with increments of half an inch. For example, seed with incoming 14–15% MC should be spread with a layer thickness of 3 inches. The formula developed is based on kgs of sheet per square foot for a particular layer thickness. Using this calculator made available on each Godown supervisor's mobile, he easily computes the surface area of spreading needed for the specific lot quantity. Now since the width of each section is fixed at 12 feet, area/width gives the length of the yard section to be occupied by the lot. Based on this he instructs his gangs to first place a line of bags at the end to mark the border for the lot. The gang then evenly spaces out the rest of the bags in the lot within the boundary and once spread they cross-check and confirm the layer depth.

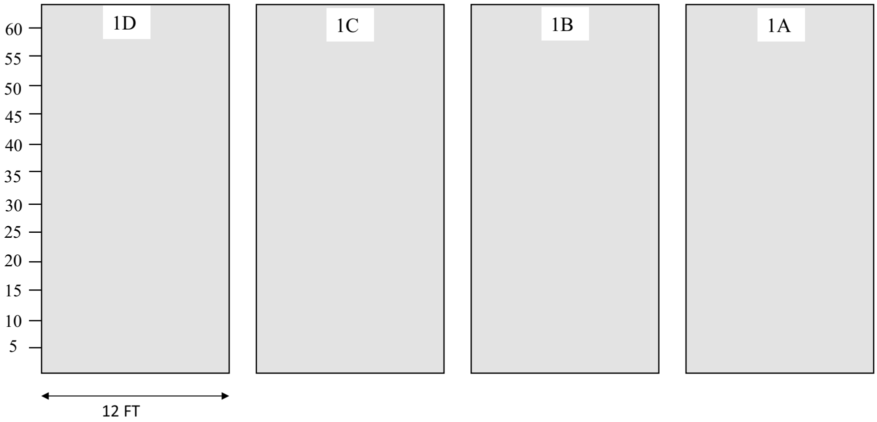


Fig. C1.10 Yard marking

A small change in the procedure being followed for moisture checking had to be done to enable this new method to be followed. Earlier, samples would be collected after all the bags were opened before seed is dumped out and the moisture checked later. Now, as soon as the first row of bags is placed, they are immediately opened, moisture checked, and the area calculation done immediately so as to give the labour gang clear instruction.

The outcome was validated within the months of November and December. *The resunning quantity dropped from 9% in the previous year (2019) to less than 5% in the current year (2020). Only abnormally high moisture content batches needed a second round of sunning.*

The team has standardized this improvement to the extent that they revalidated the entire standards for the Sunning which happens in May. The hot and humid conditions of May are different from the cold and drier December. Tweaking of the standards followed and now there are two sets of standards, one for each season.

Loading and Unloading Improvements

May is a hectic month for the plant. Most of the activities are going on simultaneously and are at peak load; unloading of raw seed and Sunning (for *Rabi*), grading, packing, and dispatches for *Kharif*. Since the same labour gangs are more or less involved in all the activities, there is a lot of firefighting in allotting and monitoring work. One major concern was truck movement and handling. On any given day, more than 50 trucks are found in the plant premises either for unloading raw seed or for dispatch of finished product.

A cross-functional team of senior supervisor, plant manager, and logistics executive was formed to observe, analyse, and improve truck related operations. While in Lean language, the entire operations are *Muda* as they involve only handling and transport of material within the factory, it is a necessary part of the supply chain. The main purpose of the activity is therefore deemed as value adding. In

Table C1.4 Comparison of truck TAT

Unloading truck TAT (minutes per MT)	Before	24
	After	19
Loading truck TAT (minutes per MT)	Before	12
	After	7

this case, it is either "unloading" or "loading" which occurs when a bag of seed is either removed or placed in the truck. So only that part of the time when people are doing this is considered value adding.

The team observed the entire truck turnaround process (TAT) for both receipts and dispatches and tabulated these in the form of operations analysis tables.

The observations showed that the actual unloading time was about 4 min per tonne which was comparable to the benchmarks for such manual operations. However, 40% of the total time spent by a truck in the plant premises was for other activities including security check, waiting at various places such as the weigh bridge (before and after) and for documentation at logistics department.

The team brainstormed and came up with several actions that were implemented within a couple of weeks. Major improvements in work flow and processes are seen in eliminating duplication of documentation and streamlining the weigh bridge operations.

Physical observations also highlighted a few bottlenecks in the infrastructure. In a couple of places, trucks were unable to pass when there is already a truck being unloaded or loaded. The roads were modified with small changes while a second weigh bridge was installed considering the increased volume of operations spanning 14 Godowns. The docking point in some of the Godowns was modified with extension platforms such that two trucks could be placed and handled at the same time as compared to only one being handled so far. All this enabled reduction in the waiting time of trucks thereby improving the TAT as shown in Table C1.4.

Some Outcomes of One year of Lean

Some tangible gains

With the completion of *Kharif* dispatches, PAN had been through one entire cycle of implementing Lean concepts in various seed processes occurring at different points of time. The plant team tabulated the impact of this intervention on key metrics that are being regularly tracked by the management. A comparison with the previous year which was already considered the benchmark year at PAN is shown in Table C1.5.

Empowering people

Given the industry sector, it is no surprise that the plants are located in remote areas with no connection to any industrial zone. The extremely seasonal nature of work means that fixed costs need to be kept to a minimum. Consequently, the team running plant operations are from nearby villages and towns and none of

Table C1.5 Plant performance comparison (paddy seed—Bardhaman plant)

KPI	2019–20	2020–21
Total packed output (MT)	11,411	14,177
Godown OEE	70%	82%
Productivity—labour cost per MT	Rs.967	Rs.880
% rework in sunning	8.91%	4.76%

them are engineers or management graduates. They have never been exposed to other industries or the work practices elsewhere and are cocooned in their own world of seeds. Most of them have risen up through the ranks from being Godown boys to senior supervisory positions.

But what has stood out right from the outset of this Lean journey is their hunger and willingness to learn and try out new things. Having grasped the paradigm of Lean thinking, they soon understood and applied the concepts be it “waste elimination” or “flow” or “autonomous maintenance”. Realizing the benefits of application first hand only served to motivate them further along this journey.

Sustaining and Moving Ahead

Seeing their involvement and interest, PAN rolled out a key result area (KRA) linked incentive model for the first time in the company’s history. The team is rewarded if they sustain the improvements made through the season and achieve these KRAs. And they did it!. PAN’s management has seen the uptick in plant performance and the growth of their people. At the plant, the labour gangs are earning more by expending less effort. So, all the stakeholders see a good reason to keep improving through Lean.

In the 2021–22 year, the plant team have already commenced the next round of Lean activities. The *Kharif* data on plant performance including OEE, breakdowns, and short stops was analysed and specific problem areas identified. Teams have been formed to work on these. For example, the short stops in the FFS packing lines in the plant’s Godown 14 were an area of concern. The team underwent a problem-solving training workshop in August’21 and completed a root cause analysis of the top two reasons for short stops. Actions have been taken and the results are being validated during the November ’21 *Rabi* season run.

Pre-*Rabi* season, the team was engaged in strengthening the AM activity by working on the repeated abnormalities, sources of seed spillage, and dust observed in *Kharif* season. The CLRI sheet was fine-tuned and visual controls on the grading and packing machines are enabling the CLRI time to be reduced. The target for next season is to do it in less than ten minutes every day.

And most recently in December ’21, the plant has formally launched 5S activities starting with the stores. The packing materials, machinery spares and consumables and the chemical stores have all been taken up for improvement.

Anshuman is now in the process of extending Lean to other aspects of the business starting with the corporate functions of HR, finance, and logistics.

Case Study 2: Business Transformation Through Lean

Background

Linkwell Telesystems has been operating in the electronics industry for over three decades and has managed several product lifecycles since its inception. The company's strategy is to develop potential high volume products typically ordered through government tenders and supply these in bulk quantities. As a product nears the end of its lifecycle, Linkwell's strong R&D is ready to roll out and scale the next product. Through this timely new product development (NPD) and launch strategy, Linkwell was able to enjoy the fruits of telecom boom of the 1990's and early 2000s. Linkwell pioneered the point of sale (POS) devices in early 2000s and is currently riding the energy meter wave owing to the rapid and sustained growth of household and commercial establishments in the country.

While energy meters have been in the market since the past decade, there has been a significant spurt in demand from 2017. That year, Linkwell had to ramp up production fivefold from about 100,000 units to 500,000 units per month to meet the requirements of the numerous contracts that it won in rapid succession. This rapid growth was managed mainly by lateral expansion of production lines, addition of facilities and developing multiple subcontractors. However, this being a competitive and low margin business, the company's bottom line was under pressure in spite of the large growth in top line. Secondly, the product was expected to soon reach the end of its life cycle as the next-generation smart meters were expected to enter the market, rendering some of the investments in capacity expansion useless. In early 2019, Linkwell's top management started to feel the need to improve profitability by reducing unwanted expenses while at the same time create an operating model flexible enough to match the fluctuating demand conditions.

Way back in 2008, Linkwell had undertaken a pilot Lean intervention over a six-month period under our guidance, in its coin operated phone assembly lines. While the intervention gave a significant boost to the throughput, the Lean journey was not continued then, due to various internal considerations of the plant management. But this glimpse of the power of Lean remained ingrained in the mind of Ms. Radha, the Executive Director. And so it happened that her team once again

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G. Mahadevan and K. C. Chejarla, *Lean Management for Small and Medium Sized Enterprises*, Management for Professionals,
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reached out to us by the end of 2018. A preliminary visit to understand the current state of operations in April 2019 was quickly followed up with an agreement to embark on a year-long Lean program to streamline the entire manufacturing operations for energy meters.

Diagnostic

We began with the current state assessment of the existing operations across Linkwell's four plants all located within a five-kilometre radius.

- Units 1 and 2 are in the main factory complex, covering meter calibration, final assembly to packing, an SMT(Surface mounted technology for Printed Circuit Board <PCB> assembly) line and the main stores.
- Units 5 and 6 have additional lines for product calibration, final assembly, and packing lines.
- Unit 3 makes sheet metal parts while the adjacent Unit 4 produces the injection moulded components.

Linkwell was working with over 40 subcontractors including six for SMT, ten for leaded process (manual component assembly onto PCBs) and more than 20 mechanical assembly units, most of them located within the same 5 km radius of the main units. Subcontractor management was handled in a decentralized manner by respective final assembly units (1,2, 5, and 6). Each subcontractor is linked to specific units. The production schedulers in these units issue schedules, coordinate with the stores for material issues and follow-up (with subcontractors) for the finished items. Oracle ERP's material procurement, inventory, and accounting modules are used while production planning was done on spreadsheets.

The diagnostic exercise brought together functional heads and unit in-charges to observe their respective processes and compare the current state of operations vis-a-vis organization goals and process targets. The cross-functional teams formed comprised of the respective unit or line in-charges, the warehouse in-charges, quality team leaders, and members from support functions including HR, logistics, and stores. These teams dedicated three full days under our guidance to complete the current state assessment and frame an improvement plan for their respective areas.

The existing overall material and information flow diagram is shown in Fig. C2.1. As it an be seen, the flow is quite complex, especially because a number of intermediate processes take place at subcontractors. The complete set of components is received at the main stores. The core of the product is the PCB; this is initially processed at the SMT line at Unit 1 or at external SMT subcontractor units. The PCB is then sent to the stores from where it is issued to various leaded (PCB) subcontractors who complete the PCB assembly, test it for functionality, and then send them to the mechanical assembly subcontractor units allocated by the respective Linkwell unit scheduler. Each final assembly unit (1, 2, 5, and 6) has their own set of leaded and mechanical assembly subcontractors with whom they coordinate. Once the subcontractor has completed the meter assembly, the assembled units are dispatched to the respective Linkwell units for calibration, final assembly and packing. The packed meters are stored in the finished goods areas of the respective units awaiting customer inspection and dispatch clearance. Unit 3 fabricates sheet metal parts that are mainly used by the mechanical assembly units, while Unit 4 provides injection moulded components used both at the subcontractor and final assembly units. All parts made by units 3 and 4 are routed through a separate store located in the same premises. Throughout this case study, we show Linkwell's own units in light grey colour and subcontractors in medium grey colour, in figures and various other exhibits.

The product flow involving interim processes at different subcontractor locations had resulted in non-value-adding material transport, handling, and documentation. In addition, plan follow-ups and coordination required dedicated expeditors who were firefighting all the time. The fivefold increase in capacity within a year had been made possible by adding additional units 5 and 6 and rapidly developing multiple small subcontractors to support them. This sudden scaling up of operations left no time for the management to design and implement ideal process flow. The team concluded their diagnostic exercise with a listing of the major issues identified and framed a Lean roadmap to tackle these issues. With the management's focus on reducinfg expenditure having been clearly communicated, the teams defined the process-level goals as detailed in Table C2.1.

Roadmap

With the above goals in mind, the roadmap was broadly designed to address the overall value stream including the subcontracted processes.

Improve Flow

1. **Focus Area#1 (Downstream processes)**: Connecting operations in flow, line balancing, workstation improvements to enhance productivity.
2. **Focus Area #2 (Subcontractor operations)**: Improve flow, workstations to enhance output per subcontractor. With the above in place, reduce number of subcontractors to simplify overall operations.
3. **Focus Area#3 (Upstream processes,** sheet metal, injection moulding and SMT): Reduce changeover times through SMED and thereby WIP inventories. Do problem solving and Kaizens to resolve specific issues.

Implement Pull

4. **Focus Area #4 (Link up the entire value stream)**: Lean scheduling based on simple pull systems to link these units to their customer lines be it subcontractor or the final assembly lines.

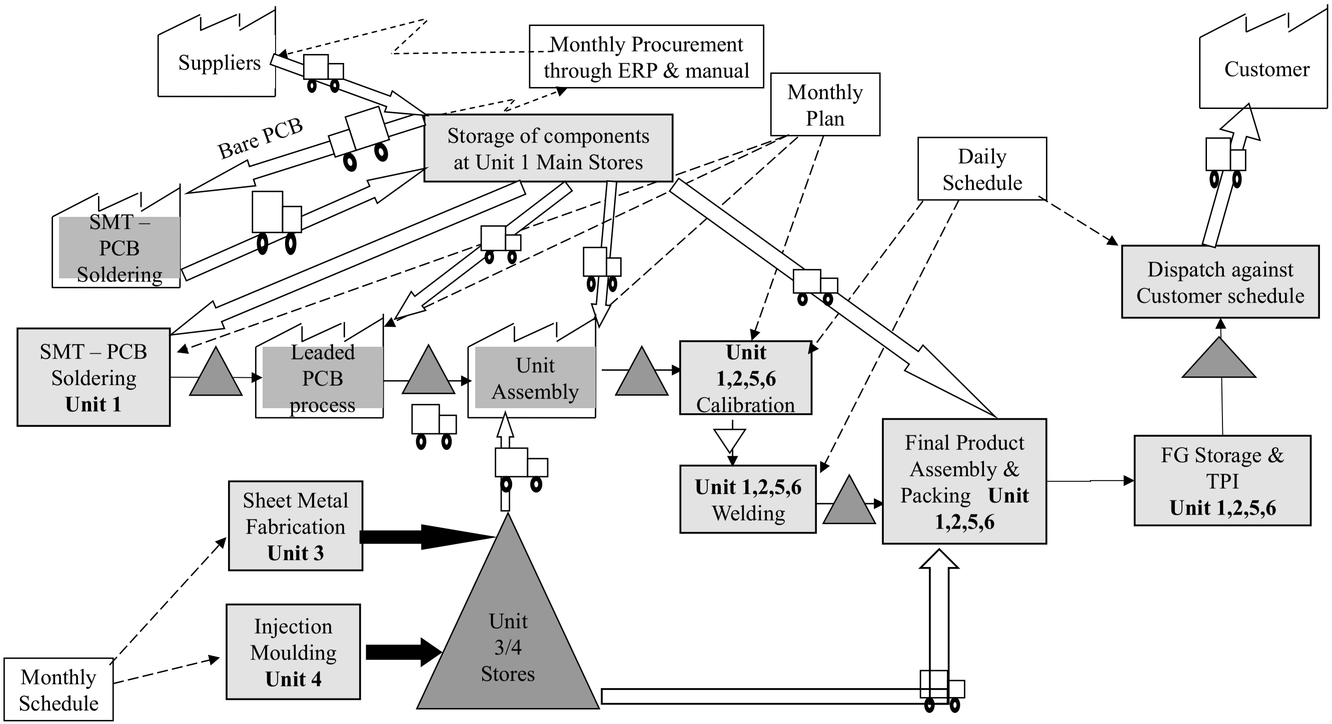

Fig. C2.1 The material and information flow of current process. *Notes* Units 3 and 4 make their own schedules based on the monthly plan requirement for assembly units

Table C2.1 Process goals for lean intervention

Section	Parameter	UOM	Current state	Target
Materials management	Space utilization (CFT)	Cubic feet (CFT)	To be computed	>90%
	Customer service level	Kit issue against JO	<40%	>90%
	Stores management	Visual	No	Search free
Unit -3 (Sheet metal operations)	Material transport	Distance moved (metres)	>50 m	<20 m
	Quality	First time right	98%	>99.5%
Unt -4 (Injection moulding)	OEE	Ratio	70–80%	>80%
SMT	OEE	Ratio	60–70%	>80%
	PCB handling	No. of touches	4	1
Lines (1,2,5, and 6)	People productivity	Value adding %	50–60%	>80%
	Output per sealing line	Meters per day	1600–2000	3000–3500
	Space utilization	VA %	<25%	>50%
	Facility utilization	Distance travelled	250–450 ft	<100 ft
	Rejection	% rework	2%	<1%
Finished goods operations	Space utilization	% Utilized	To be computed	>90%
	Inventory management	Visual	No	Search free

Stabilize Processes

1. **Focus Area #5—Standardize** the improvements done through 5S.
2. **Focus Area#6 (Equipment reliability)** Autonomous and planned maintenance to minimize short stops and breakdowns.

Implementation

The first three months were spent in connecting the process islands through a judicious combination of flow and pull. In accordance with Lean philosophy, Linkwell started the process improvement/waste elimination from the customer end with initial focus on the final processes comprising of calibration, assembly and packing. After packing, the product is stored in the Finished Goods warehouse waiting for dispatch clearance by the customer.

Focus Area#1—Establishing Flow at Final Processes

All the finishing operations of the product are done in-house in manufacturing units 1, 2, 5, and 6. A cross-functional team was formed at each unit to work on improving the existing lines. After a couple of days of observation, the teams made note of the following:

- Most assembly and packing operations are short cycle with less than 10 s cycle time.
- As calibration operates in three shifts, inventory is automatically built up after it is completed—this material searching, handling and transport.
- The meters for calibration come in from the mechanical subcontractors in plastic crates with 72 meters per crate while post calibration 100 meters are placed in a trolley for assembly in order to maintain the meter serial number. Each meter has a unique number that is tracked all the way to the end customer point and it is mandatory to pack the finished meters in the same order.
- The layout is such that there is significant transport of plastic components to the line and assembled meters to the final packing area.
- Any short supply of the meters coming from mechanical subcontractor meant that the calibration and assembly lines remain idle. This was found to occur frequently and was one of the reasons why calibration was operating in the night shift as well, despite having adequate capacity.

Based on the observations, three improvement projects were identified for implementation.

(1) Improving assembly-to-packing flow for better productivity,
(2) Reduce calibration cycle time and thereby reduce the number of shifts,
(3) Link input materials and all processes through visual management and pull systems.

Project 1—Assembly Line to Cell Conversion

Figure C2.2 depicts the basic value stream map (VSM) of the existing process. An assembly line operated by 11 people with a maximum operation cycle time of 12 s was delivering around 2100 meters per day. Process observations showed significant imbalance between operations with inventory piled up at some stations and other stations being idle. Each meter also had to be picked up multiple times and pushed from station to station. This excessive handling not only was a wasteful movement for the operator but also a cause for damaging the product. The team worked over two months in a systematic manner to improve the process layout.

Step 1—Study existing line set-up and identify *Muda*, and *Muri*.
Step 2—Line modified from existing straightline table set-up to a U-shaped table set-up.

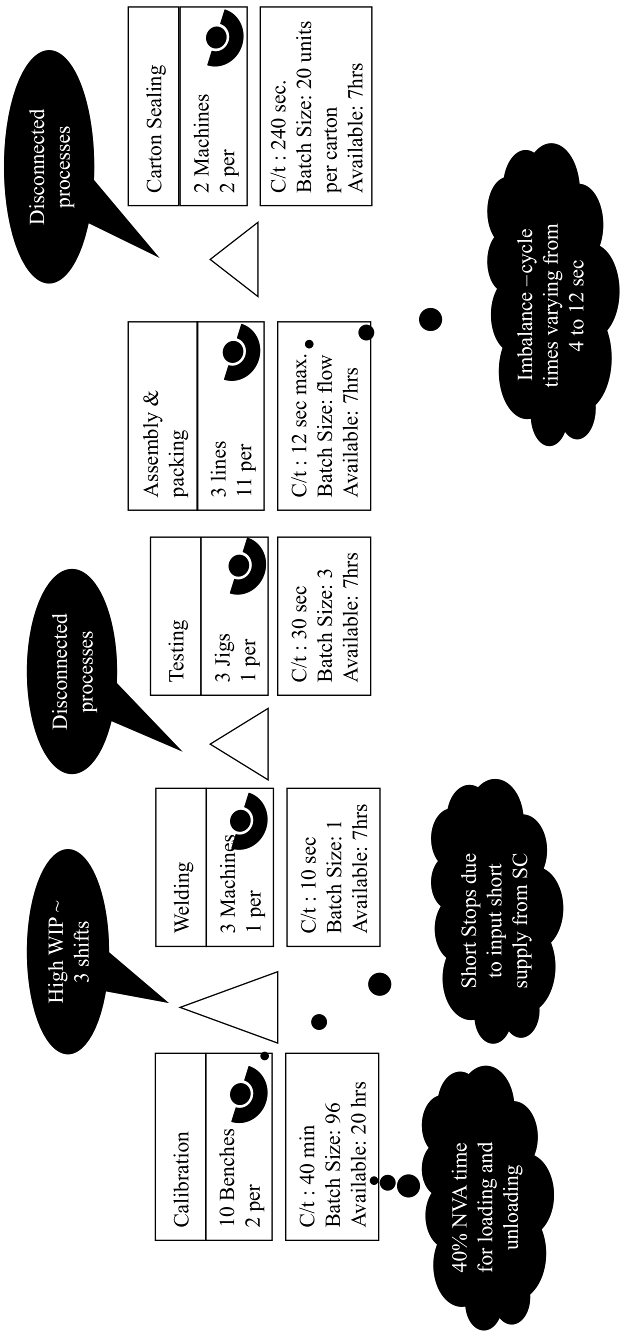

Fig. C2.2 VSM of existing process

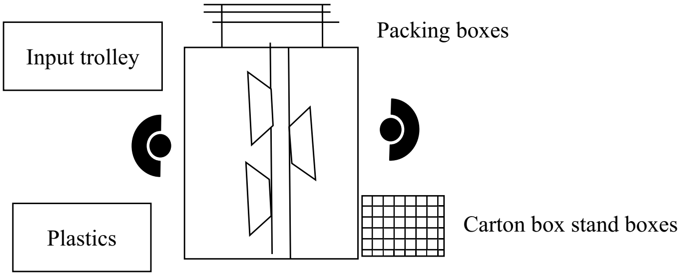

Fig. C2.3 Two-person cell workstation

Step 3—Line balanced and new workstations were set-up to minimize Muri such as, picking up of large plastic components from bin kept on the floor, reaching out for folding boxes for packing, etc.
Step 4—Trial done with two single person workstations on opposite sides of an assembly table with one person assembling and second person packing. The existing operations were redistributed between them to balance the cycle times. Figure C2.3 shows the layout of such a cell.
Step 5—Both the improved line and the two-person cell were run for one month along with the existing lines. The team observed work practices, monitored daily production and quality, and concluded that the cell was most suitable and effective method. Table C2.2 compares the performance of existing line with the cell.
Step 6—Existing workers were retrained for multiskilling so that any of them can assemble and pack the whole product.
Step 7—Two-person cell workstation standardized and replicated to form ten such cells by dismantling the long tables used in the existing lines. This group of ten cells was able to deliver the same output as the three lines in operation before Lean.

The conversion of three long assembly lines into ten small cell workstations necessitated a relook at the overall layout of the assembly floor. The earlier layout depicted in C2.4 had certain other constraints such as zig-zag material movement and excessive material handling.

Only the material planned for immediate dispatch can be stored in the Finished Goods (FG) area shown above. Bulk of the material had to be sent out in forklifts to an adjoining FG warehouse. The plastic product covers are bulky and are transported from Unit 4 in large specially made plastic lined boxes. These boxes are transported by hand trolleys across the factory floor.

Actions Taken

Layout was modified to reduce zig-zag material movements. The major changes here were,

Table C2.2 Comparison of performance of assembly line and two-person cell

Process parameters	Modified line	Cell
Number of operations	Assembly—7 Packing—3	Assembly—6 Packing—4
Cycle times	Min.—4 s Max.—12 s	Assembly—36 s Packing—30 s, plus loading carton box on conveyor every 20 pieces
Pick up and place time	Pick up and place—3 s per operation	Pick up and place—3 s per operation
Total throughput time	120 s	66 s
Pick and place time	30 s = 25% NVA	6 s = 9% NVA
Outcomes		
Number of people	11	2
Output per shift	2100 meters	700 meters
Productivity	190 meters/person	350 meters/person
WIP	At any time at least 100 meters on line due to imbalance	Max. of 5 meters per cell
Rejection	1–2%	<0.5%

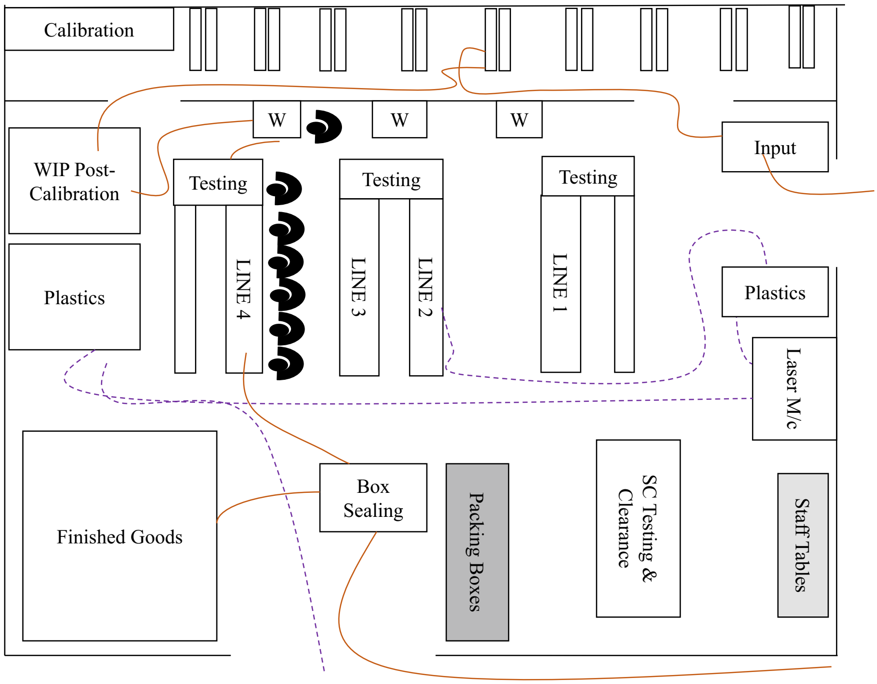

Fig. C2.4 Earlier layout of the overall production unit

- Welding and testing synchronized—the cycle times were more or less balanced and hence it was easy to link these two processes without any further process improvements. Tested meters are placed in movable trolleys in sequence and parked in standard WIP area—marked for 2 h stock (16 trolleys) Further, areas were designated for input, plastic, and packing materials .
- A readily available belt conveyor, taping, and strapping machines which were not in use were renovated and put in place to complete the set-up. Online sealing and strapping meant the carton boxes could be directly moved to FG store thereby avoiding an extra handling.
- With the space freed up by the new layout, almost 75% of the FG produced could be accommodated in the same premises. Only items with delayed or unclear dispatch dates are shifted outside.

The simplified layout and the improved work processes are shown in Fig. C2.5.

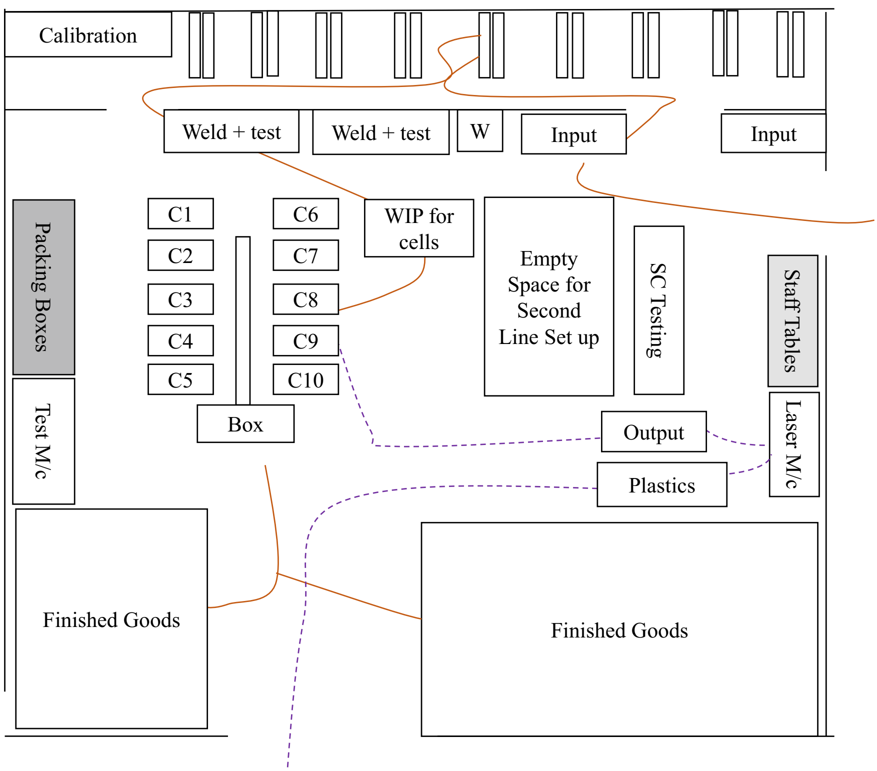

Fig. C2.5 Simplified layout and improved work processes

Project 2—Calibration Cycle Time Reduction

Calibration involves loading of software into the meter and validating. It is a critical process since it determines the proper functioning of the meter post-installation. Each calibration bench, monitored by one operator, has two sides with 48 slots each thereby processing 96 meters per cycle. The team wanted to reduce the cycle time in order to complete more cycles per shift and reduce the number of shifts operated. After observing five running cycles across various benches, the team made an operations analysis table and identified value-added (VA) and non-value-added (NVA) activities as shown in Table C2.3.

As can be seen from the above table, *Muda* activities occupied more than 40% of the 45 min cycle. The team analysed the reasons for this and came up with the following solutions to reduce this *Muda*.

1. Loading the next batch immediately after the activity 4 (instead of activity 6) to start the software loading process. Then complete the sign off of previous batch.
2. All the benches do not get loaded at same time and the operator of the adjacent bench is now roped in to unload and load one side of the bench to which (s)he has direct access.
3. Modifications done to software loading and verification reduced the time from 24 to 20 min.

Outcome of implementing and standardizing the above actions is shown in Table C2.4.

Each bench can now calibrate 15 batches x 96 meters per batch = 1440 meters in a shift. With the available 7 benches, by ensuring 100% input material

Table C2.3 Operations analysis of calibration process

S.No.	Activity	Time taken (min)	VA/NVA *(Muda)*
1	Loading the units from the trolley onto the bench	6	NVA
2	Software loading	20	VA
3	Verification	4	VA
4	Unloading the units onto bench table one by one	6	NVA
5	QC check sign off on each unit	7	NVA
6	Placing the units in sequence back on the trolley	2	NVA

Table C2.4 Comparison of calibration process before and after improvement

Parameter	Before	After improvement
NVA time	21 min	7 min
VA time	24 min	21 min
Total cycle time	45 min	28 min
No. of batches per shift	10	15

availability, the calibration output could match the day's target of 10,000 meters. Calibration operated in three shifts earlier. With this reduction of cycle time, it is now able meet the upstream demand within general shift operation alone, enabling it to go online with the assembly processes. Further, the room has five air conditioners (1.5 T each) which are needed to keep the temperature below 24 °C as per process requirement. Reducing to a single shift operation resulted in significant power cost savings as well as the air conditioners are switched off after the day's work.

Project 3—Visual Management and Defining Rules to Link Processes

In line with the new layout and single shift operation, new material handling norms were defined. All input materials are stored subcontractor-wise. Each SC was allotted plastic bins of a different colour for visual identification. Movements to and from calibration area were done only through numbered trolleys containing 100 meters each. Trolley parking locations were marked with space provided for the defined WIP only.

Focus Area#2—Enhancing Subcontractor Capacity and Linking with the Final Processes

In addition to higher cycle time, another reason for calibration operating all three shifts was variability in lead time in receiving the assembled meters from all of the upstream suppliers (both own units and subcontractors). So logically, the next set of projects taken up by Linkwell were to ensure 100% on time in full (OTIF) delivery by the upstream suppliers to the calibration process (in units 1, 2, 5, and 6). The overall material flow among the own production units and subcontractors leading to the final process is shown in Fig. C2.6.

All the upstream processes in the figure above were taken up for improvement over a three-month time frame. The SMT is a specialized process and as such Linkwell had to depend on large outstation SMT units to obtain its net requirement beyond what was made in house.

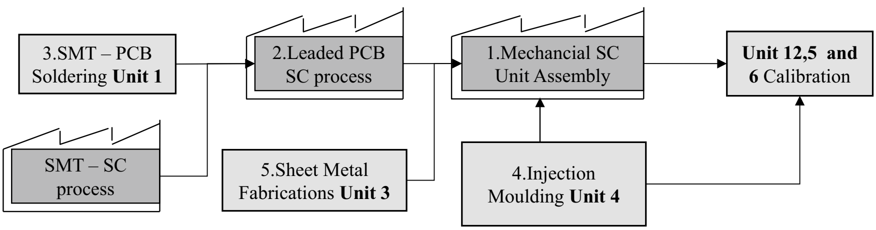

Fig. C2.6 High-level material flow between own production units and subcontractors

Project 1—Capacity Enhancement of Mechanical Assembly and Leaded PCB Subcontractors

The team proceeded to work with the immediate supplier, the mechanical subcontractors, so that they could match the daily demand rate in a synchronous manner. The aggregate requirement was catered to by a cluster of 20+ mechanical subcontractors who were in turn supplied by a group of eight leaded PCB subcontractors. Managing the quality, logistics, planning, and delivery for these many units was challenging and involved a dedicated team of supervisors mainly for coordination and follow-ups. As a pilot, two subcontractors each from mechanical and leaded PCB were selected and cross-functional teams were formed to observe and improve their work practices.

i. Mechanical Unit Assembly.

Typical high-level process VSM of mechanical units is shown in Fig. C2.7,

The *gemba* observations showed testing, last operation, to be the bottleneck with large number of PCBs piled up before it. Secondly, the assembly and soldering operations were set up to operate in flow but the line was not balanced resulting in small piles of inventory in between some of the operations. Soldering was divided into four workstations causing multiple hand-offs of the PCB, one of reasons for product failures detected during testing. The teams worked on each of these areas as described below.

i (a). **Testing**: Complete cycle observed and operations analysis done to identify value-added (VA) and non-value-added activities (NVA) as shown in Table C2.5.

It is seen that the actual testing or value-adding time is only 30% of the total cycle time. Further, PCB was handled multiple times during the test. The team came out with a modified test jig with only three slots and reworked the test software to work with this jig. This jig was now attached to the end of the assembly line *thereby integrating testing into the single-piece flow line.* An added benefit was immediate feedback on the type of failure to the respective workstation enabling a reduction in the percentage of failures. With the new jig, the loading and unloading time has

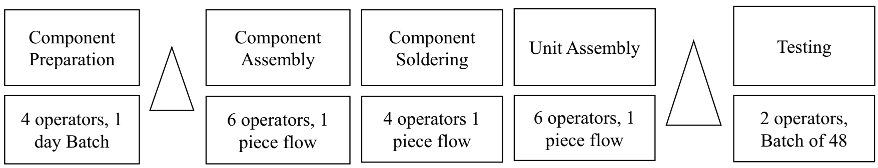

Fig. C2.7 High-level VSM of mechanical units

Table C2.5 Operations analysis of testing process

Sl.No.	Activity	Time taken	Remarks (VA/NVA)
1	Loading the meters from the crate one by one and locking each meter in place	3 min	NVA
2a	Testing 3 meters at a time—moving the probes, connecting and recording parameters, comparing with specs and pass/fail status automatically generated	12 min (1 min per set of 3 meters)	VA time = 6 min NVA time = 6 min
2b	Visual inspection of display—in parallel		VA
3	Unloading the passed meters from the testing machine and placing them into plastic crate	3 min	NVA
4	Moving output to designated area and fetching next input crate	2 min	NVA

reduced further and 3 meters are tested every 36 s. So, the improved process now operates at an effective cycle time of 12 s per meter.

i (b). **Unit Assembly**: For the unit assembly line to be able to operate at 12 s *takt* (time for the *new* testing process), the following changes were made:
- Workstation improvements to enable easy picking up of components,
- Line balancing using Eliminate, Combine, Simplify, and Rearrange (ECSR) principles to ensure flow close to ideal single-piece flow.

i (c). Soldering

Earlier, soldering was split up among four operators as shown in Fig. C2.8.

This resulted in each PCB being handled four times which was detrimental to both the quality, with increased chances for component being detached, as well as to the output with an increased cycle time (due to non-value-added movement of material between operators). The work flow and layout were changed to accomodate single person workstations to enable parallel processing as shown in Fig. C2.9:

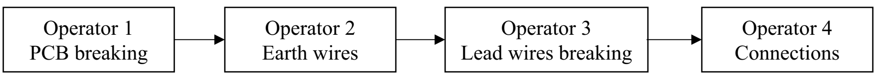

Fig. C2.8 Earlier soldering process

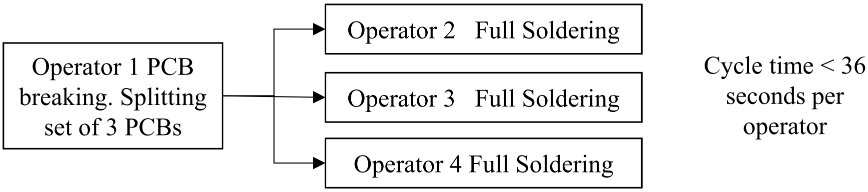

Fig. C2.9 Parallel processing in soldering

i (d). Component Preparation

The workstations were converted from line form to single person workstation tables and shifted to a separate area. Each workstation was given the daily target as per 12 s takt time. Standard inventory of half day was defined for prepared components. While this is being consumed on the line, the requirement for the second half of the day would be prepared and placed in the designated zone.

i (e). Standardization and Outcomes

Implementing Lean lead to a significant increase in the output of the subcontractor units. Having perfected the flow in the two pilot subcontractor facilities, the same was replicated across other selected subcontractors. Linkwell then filtered out the poor performers and reduced the number of subcontractors thereby making it easier to manage the supply chain. Table C2.6 summarizes the results.

ii. Leaded PCB

The through-hole process for soldering components onto PCBs used in the energy meter was being carried out at eight different subcontractor units. The tested and passed PCBs are placed in electrostatic discharge safe (ESD) bins and sent to the main stores at Unit 1. At Unit 1, the PCBs are kitted with other components needed for the meter, and are distributed to the Mechanical Assembly subcontractors. Two PCB subcontractors were selected for piloting Lean

Table C2.6 Summary of improvements in mechanical unit assembly subcontractors

	Before	After
Output per day	900–1000 meters	1500 meters (potential of 2000)
Productivity	40 meters/person/day	70 meters/person/day
No. of subcontractors	20 +	12

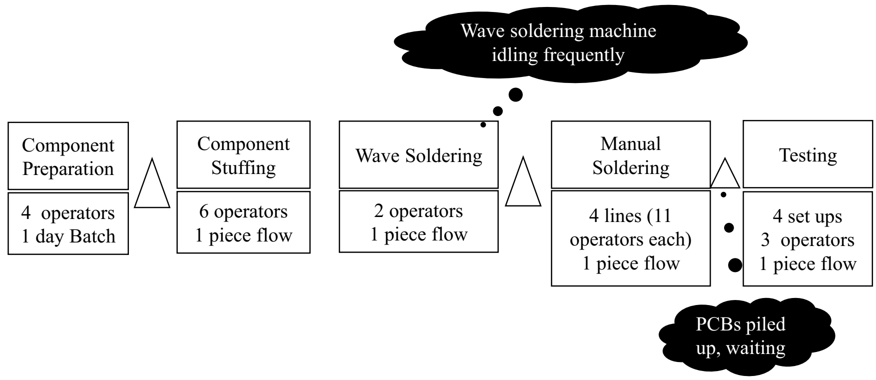

Fig. C2.10 Typical VSM of leaded PCB subcontractor

implementation. The typical process flow and main observations at the largest subcontractor, Lalitha, are shown in Fig. C2.10.

The four manual soldering lines (and attached testing set-ups) were supplied by a single wave soldering machine, which was producing around 4500 PCBs per day. However, the wave soldering machine had an installed daily capacity of 12,000 PCBs. Testing was identified as the bottleneck operation and the team began removing wastes from testing. After resolving this bottleneck, the team worked on improving the utilization of the wave soldering machine.

ii (a). Testing

Testing of PCBs was done on a specially developed jig connected to a PC in which the testing software was loaded. The operator fits the PCB in the jig and gives the test command. All the parameters are checked through the software and green lights show up on the monitor as each parameter is cleared. Once the test is complete, the system alerts the operator whether the PCB has passed/failed and the jig lifts up (error proofed) automatically. The tester signs on each passed PCB and places it in the ESD bin, while failed PCBs are kept separately for analysis and rework. Following were the team's key observations:

- Testing set-up is physically located apart and operates on a standalone basis necessitating supply of PCBs in bins from the manual soldering line to this location.
- The testing cycle time is 120 s for a set of 3 PCBs. This translates to around 750 PCBs per day per jig. Two jigs were allocated to each line but the actual output was around 1200 PCBs per line or about 4500 PCBs in total (from four soldering lines).
- Out of the 120 s cycle time, operator's work was only about 30 s which includes loading, unloading, and signing on each PCB.
- Almost 10% of the PCBs are retested due to failure—actual failures were about 1% while the rest were due to connectivity issues in the jigs. This repeat testing meant a wasted effort.

Table C2.7 Operations analysis of PCB testing process

S. No.	Activity	Time taken (s)	Remarks (VA/NVA)
1	Loading the 3 PCB board on to the jig	10	NVA
2	Testing preparation—erasing memory	30	VA
3	Loading the required protocols	20	VA
4	Testing the parameters	50	VA
5	Unloading the board from the jig	10	NVA

These observations led to immediate Kaizens that could significantly improve the testing process.

- Jigs modified slightly to solve connectivity issues and avoid false alarms.
- Testing jigs attached to end of the manual soldering line so that the PCBs are tested and packed inline and in flow mode. To match the line target output, two test jigs were positioned such that a single operator can handle both test jigs thereby increasing productivity and reducing the handling related *Muda*.

With the above changes, the testing output went up to 1500 PCBs per day per line.

The line target was then increased to 2000 PCBs per day. Line balancing through ECSR-based improvements was carried out and the soldering output started meeting this target. This meant that the testing once again became a bottleneck. The team now conducted an operational analysis of the actual testing activity as shown in Table C2.7.

Interestingly, the proportion of *Muda* was very less in this operation and there was not much scope to reduce the loading and unloading time. The team therefore started probing the value-adding activities and identified two improvement ideas:

(1) Erasing memory did not actually need the test jig. There was a possibility of doing it with a much simpler set-up, which was then designed and implemented.
(2) Some of the testing protocols could be speeded up through tweaks in the software.

As a result, the total cycle time on the jig was finally reduced to 72 s, resulting in an output of about 1050 PCBs per day per jig, i.e. 2100 PCBs per day per line.

ii (b). Wave Soldering

To cater to four manual soldering lines each now operating at 2000 PCBs per day, the output of wave soldering needed to be in excess of 8000 Nos per day. Observations showed that the wave soldering was frequently idle as the rate of output from the upstream process, component stuffing was lower. This manual

Table C2.8 Improvements in output of the PCB subcontractors after Lean implementation

Output per day	Before (PCBs per day)	After (PCBs per day)	Increase in output
SC Unit 1	4500	8000	75%
SC Unit 2	2000	6000 (extra line)	200%
SC Unit 3	1000	2500	150%
SC Unit 4	1800	2500	40%
Number of subcontractors	8	4	Reduced by half

stuffing was done in a typical moving conveyor with six workstations with each operator stuffing (fix) a set of components as the PCB came along the conveyor. Further observations of this process presented the following reasons for the slower pace of component stuffing:

- Frequent movement of the first operator to fetch PCB boards placed a little away from the line,
- Imbalance of the work content of the six operators in the line,
- At stations with a higher work content, the operators were frequently pulling back the boards moving on the conveyor to complete their work.
- Several PCBs had to be reworked after visual inspection due to components being missed out.

To address the issues observed, a single person workstation was created for stuffing where one operator stuffs all the components as per PCB design. The components were placed in front in small bins in order of the stuffing sequence to avoid any errors of missing or wrong stuffing. After completing the operation, the tray was placed onto the conveyor and moved to the visual inspection station. An output of 1600 PCBS per day was achieved at the trial station, and five more such workstations were set up with the sixth operator being assigned the role of a material feeder to ensure each station is supplied with all the components and bare PCB boards.

ii (c). Standardization and Outcomes

To match with the line demand, the output of wave soldering was standardized at around 8000 Nos per day. The improvements done at pilot subcontractor were replicated at other selected leaded PCB subcontractors, and the number of subcontractors was reduced to four. Table C2.8 shows the enhanced capacity.

Focus Area#3—Improving Capability of Upstream Processes

With the final assembly and its immediate supplier processes reorganized along the Lean paradigm with clear improvements, it was time to turn attention on the further upstream processes. As mentioned in the introduction, Linkwell has three major upstream units—the SMT line (surface mounted technology) for production of PCBs, sheet metal fabrication for making child parts such as the meter name plate, fasteners, etc., and the injection moulding unit that made the body parts such as meter casing, outer box, and other plastic moulded parts.

While capacity of these processes appeared to be sufficient to meet the targeted output, their ability to actually deliver the components exactly when needed by downstream processes was in doubt. Examples of these shortfalls are delays in the name plates supplies by Unit 3 or in the injection moulded casings from Unit 4. Further, the SMT line appeared to be overloaded leading to Linkwell planners having to outsource PCBs from external sources located in a different city. The cost of outsourcing (subcontracting charges plus logistics) was higher than the in-house production cost on the SMT line.

As before, cross-functional teams involving the concerned unit managers, customers (assembly line leaders), quality team members and planning cell member were formed, who observed the processes, and executed the following improvement projects.

Project 1—OEE Enhancement of SMT Line Through SMED

The SMT team was already tracking parameters such as down time and quality, and also, the SMT line performance data was also available from the machine software. The Lean team's initial computed Overall Equipment Effectiveness (OEE) was only 60% which meant there was a significant scope for improvement. From OEE analysis, changeover time emerged as the biggest loss, as there was at least one changeover per day taking anywhere between 90 to 240 min depending on the complexity.

The team participated in a three-day Single Minute Exchange of Dies (SMED) workshop under our guidance. As part of this workshop, the team first observed the existing changeover procedure, analysed the *Muda*, *Muri,* and *Mura*, implemented solutions to reduce these wastes and thereby reduce the changeover time. The current layout and SMT line process flow is shown in Fig. C2.11 with the following four main processes:

1. Paste application—done through the printer using a stencil specific to each PCB,
2. Component placement and assembly—two high speed pick and place machines, two semi-automatic machines and one tray feeder,
3. Reflow soldering—done through an oven,
4. AOI visual inspection with predefined reference templates loaded.

The following are the team's observations of changeover procedure.

1. *Changing stencil and paste on printer*—Movement from stencil preparation to the printer location,

2. *Component loading on feeder reels and verification*—Each product has anywhere from 30 to 50 components most of them unique which means loading of 30 to 50 feeder reels per changeover. The component reels are brought from the stores located behind the SMT.
3. Multiple crisscross movements between the jig, rack, and pick and place machines were repeated for each component loading. Each component reel goes to the jig for fixing in the feeder and these feeders loaded into the slots provided in the auto feeder machines
4. After component reels are loaded in the feeder, each component is verified by a quality assurance team member to ensure there is no error during loading. For this, each reel has to be partially removed, the component number checked and noted against the feeder location. These are then verified against the program in the feeder display.
5. Program has to be called at each pick and place station while the PCB template has to be called in the automated optical inspection (AOI) station
6. The first piece inspection procedurecommenced with visual inspection of first board before reflow, then AOI check and clearance followed by passing another four boards through the AOI. After this, clearance for production run was given and this entire process took a good 20 minutes.

The team brainstormed to come up with a series of improvements in terms of layout, method changes, and deploying additional available resources to speed up the changeover process. These improvements included the following:

- Layout of feeder jigs, racks, stencils, and other supporting activities changed to eliminate unwanted motion and strain. Stencil inspection workstation made with provision for paste preparation, and the regularly used stencils were shifted next to it.
- Modification of racks into slim trolleys capable of holding multiple component reels with visual identification. The trolley is filled up with component reels received from the main stores, reels needed for the next changeover are placed in the same sequence as required in external mode, i.e. done while the SMT is running, the trolleys are then moved to ear marked location next to the respective feeders. This eliminated the need to have a component store within the SMT area.
- Verification by line operator eliminated, and it was found adequate to have only one verification process by QA person after loading feeders. In a few months' time, the software provision for barcode scanning of component reel and matching it with feeder location was activated to eliminate manual QA verification.
- *Deploy available resources*—In addition to line operator, AOI operator was also involved in changeover. The component preparation was completed in general shift by supervisor and kept ready for changeovers.
- *First piece inspection*—This was replaced by passing the first five boards all the way to AOI and clearing in one go.

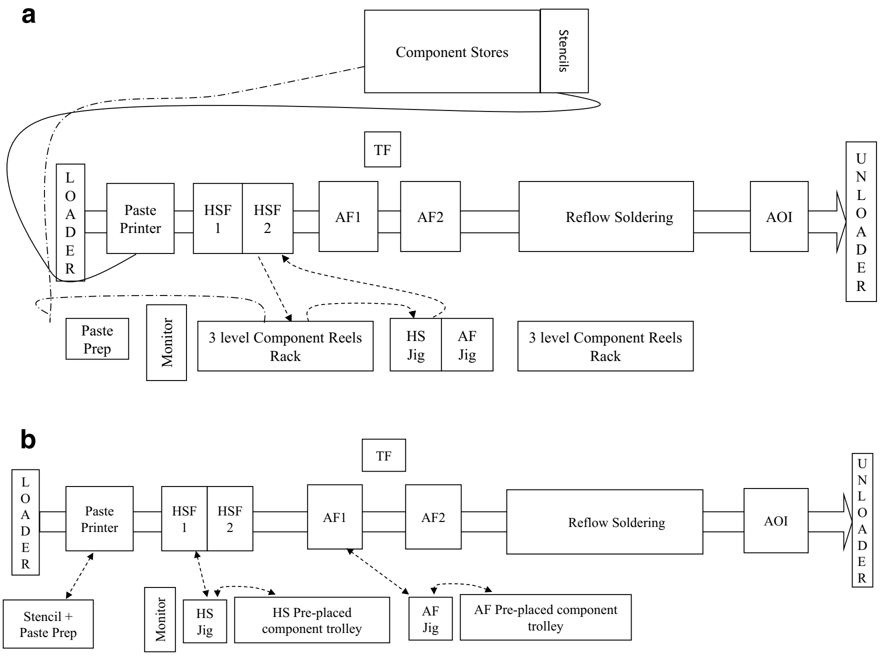

Fig. C2.11 **a** Earlier (above) and **b** modified (below) layout of the SMT line

Figure C2.11a, b depict the layout of the SMT line before and after the SMED workshop. The dotted lines indicate operator movements for doing the changeover activities

Once the benefits of SMED were validated, a changeover SOP and checklist was prepared. Changeover times were displayed on a white board next to the SMT line monitor to ensure visibility. Further additional feeders were procured to facilitate external preparation of reel components.

Outcome

- Average reduction in changeover time by **40–50%**.
- This resulted in increase in **OEE** from **60 to 70%**. Further increase in OEE was later taken up by an improvement project for reducing short stops.

Project 2—Component Flow in Sheet Metal Fabrication Unit

The most critical component made in the sheet metal fabrication unit is the name plate (top/front cover) of the meter. The name plate carries all the product details and a barcode for reading the meter. The process flow for name plate manufacturing is shown in Fig. C2.12.

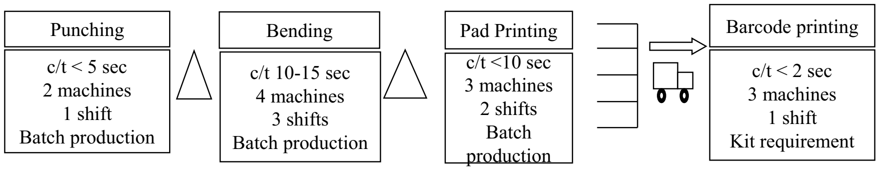

Fig. C2.12 VSM of name plate preparation process

A monthly requirement plan is given by the assembly units (1, 2, 5, and 6). The delivery is coordinated with the mechanical sub-assembly subcontractors who fit the name plates to the meters. There are two name plate models in terms of design and size. At the pad printing stage, customer-specific information is printed and the name plate becomes specific to the specific customer order. The barcode printing machines are located at the final assembly units. After pad printing, the Unit 3 hands over the name plates in plastic crates to their Stores. From stores these are sent in small vehicles to the respective assembly units for barcode printing. The unit coordinators then arrange to send these name plates to the mechanical assembly subcontractors.

The complexity of the current process had resulted in the following major problems:

- *Name plates not available as per requirement*—Unit 3 was manufacturing and printing the name plates as per monthly plan. However, changes in customer delivery schedule would lead to shuffling of the monthly schedule at the assembly lines. But name plates would not be available requiring several follow-ups and expediting with Unit 3 to urgently make the required name plates.
- *High WIP of customer-specific printed name plates*—At times, orders are held up due to financial or other customer related issues and the name plates would lie idle. Reworking of such printed name plates, by erasing the print using a cleaning agent, and reprinting with other customer orders was also a regular practice.
- Multiple handling and transport between Unit 3 to stores then to assembly units for barcoding and onwards to subcontractor for mechanical assembly resulted in complications in terms of material reconciliation, handling damages and constant need to track the items, increasing the logistics cost.

In addition to the above observations, the team also captured the quantitative data of the process in the following Table C2.9.

Based on the above observations and data, the team identified the following areas to focus upon.

- Reducing number of touches, handlings, and transporting of nameplates,
- Minimize generation of defectives.

Table C2.9 Initial performance of name plate preparation process

Parameter	Nos	Observations
Value adding operations	4	Cycle times are very less; bending and pad printing variations in cycle time
Number of direct touches	8	Additional touches for cleaning of printing defects, rearranging at pad printing machine
Handling of crates containing name plates	12	At each stage, output is put into plastic crates of standard size and moved to intermediate storage location. Later, they are taken to next operation when needed. Additional handling at for loading and unloading in vehicle
Distance moved	5 km	Moves to units 1,2 and 5,6 for bar coding
Inventory points	5	After each stage
Defectives	2.5%	Mainly printing defects, pieces are cleaned and reprinted. A separate team of four people were engaged in rework activity

Project 1: Linking Sheet Metal Punching, Bending, Printing, and Barcoding

This future state map of the name plate printing operations was visualized by the team as shown in Fig. C2.13.

The target was to punch, bend, and keep a standard WIP before pad printing since up to this stage, there are only two variants of name plates. Then based on the weekly schedule, name plates would be printed and barcoded inline and shifted to stores. Any changes in priority required one day's advance notice. With this redesigned VSM, material handling and transport would be minimized as the barcoding is also to be done online. Several Kaizens were undertaken, as described below, to help implement the target state VSM.

Kaizen 1: Bending process cycle time reduction

Observation of the bending process showed the actual value-adding time is only about 2–3 s, while there was a lot of variation in unloading time. Figure C2.14

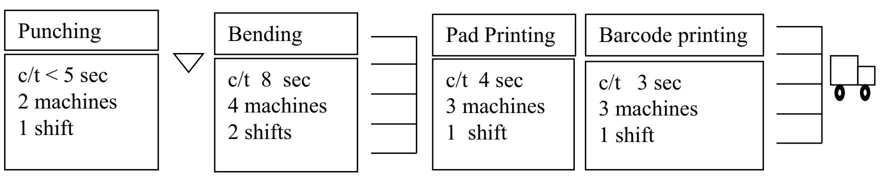

Fig. C2.13 Future state VSM of name plate preparation process shows the operations analysis with value-added (VA) and non-value-added (NVA) processes identified separately.

The team performed a "why-why" analysis as shown in Table C2.10, to understand the root cause of the variation in time for component removal from the machine.

Following this Kaizen, the overall bending cycle time was reduced from the earlier 10–15 s to a consistent 8 s.

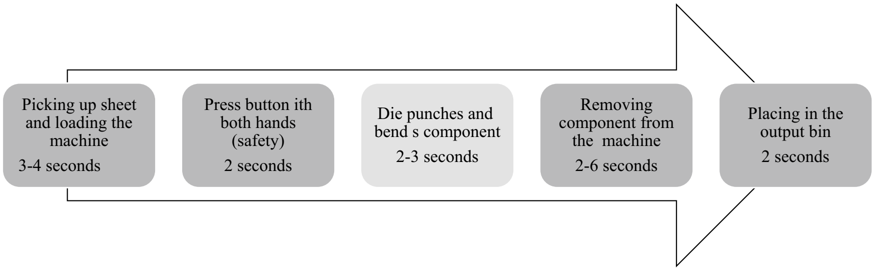

Fig. C2.14 Operations analysis of bending process

Table C2.10 Why-why analysis of process time variation (component removal)

Problem	Unloading time varies from 2 to 6 s per piece
Why	Difficulty in removing piece after punching
Why	Piece getting stuck in locator pins at the bottom face of the die
Why is it getting stuck?	The bent part has to be lifted up and above the locating pins on the bottom die, and this is a little difficult to do due to less clearance
Why are pins needed?	Pins help locate the part for punching
Why have they been designed like that?	No specific reason. So, the height can be reduced if needed
Temporary countermeasure	Finally, it was seen that there is adequate reference provided for centering by the pins at the back of the die and the front pins are not even required. So, the front pins were removed
Result	The part could be removed manually and consistently in 2 s
Permanent solution	A Kaizen done by fixing a flexible air pipe to the machine and connecting it to the available pneumatic line. This was then linked to the upward stroke of the punch. As the die goes back up after completing the punch, the air nozzles blow a short 1 s burst of air that blows out the bent parts directly into the bin now located behind the machine

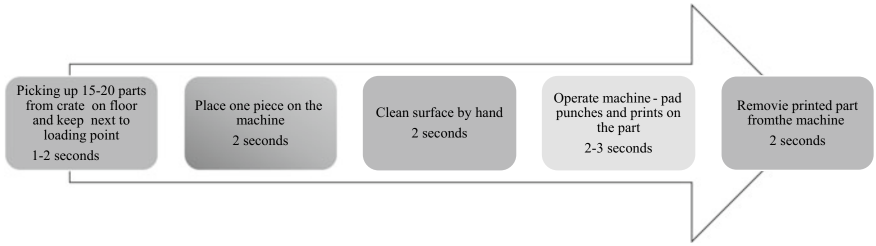

Fig. C2.15 Operations analysis of pad printing process

Kaizen 2: Pad Printing cycle time reduction

As per the proposed process, a supermarket of bent name plate parts would be available for pad printing. However, pad printing would have to work in continuous flow with the barcoding machine which operates through a belt conveyor. This would reduce the multiple handling of printed parts thereby reducing defects as well. In order for this idea to work, it was necessary to reduce the pad printing cycle time so that it can feed the faster barcoding machine synchronously. The team's operation analysis of the pad printing process with value-added (VA) and non-value-added (NVA) processes identified separately is shown in Fig. C2.15.

The above observation led the team to undertake the following two major process improvements:

1. Reconfiguring the workstation to avoid the first activity–the crates were placed on a stand such that operator could directly pick up and load the part without strain.
2. The cleaning of the surface manually with a cloth was consuming time and not addressing the issue wholly. Smudged printing leading to reworks was still happening. A foam roller was developed and attached to the machine itself enabling it to move back and forth linearly as part of machine cycle. Once the part is placed, the roller cleans the part, and as it goes back, the pad comes down and prints on the part.

With these two changes, the cycle time of pad printing came down to below 8 s. On the two pad printing machines, this meant that two name plates are printed every 8 s. In addition, defective generation dropped to $<0.5\%$ as the cleaning became effective. The rework team was no longer needed as the few defective pieces could be easily cleaned and reprinted at the end of the day by the regular production operators.

Kaizen 3: Linking pad printing and barcoding

Now that the cycle times had become manageable, the assembly units were convinced to move barcoding machines with operator to the sheet metal Unit 3. The layout inside the air-cooled printing cabin was changed to bring these two processes in line thereby eliminating several handlings and touches. The earlier and modified layouts are shown in Figure C2.16a and b.

Following two major benefits resulted from making these improvements:

- Avoid 5 km transportation for barcoding (see Fig. C2.12)—also related 4 extra handlings of bins avoided, i.e. loading and unloading of transport vehicle, shifting to location for barcoding,
- Online inspection gives immediate feedback to pad printing operator—eliminated additional inspection in second shift and related handling.

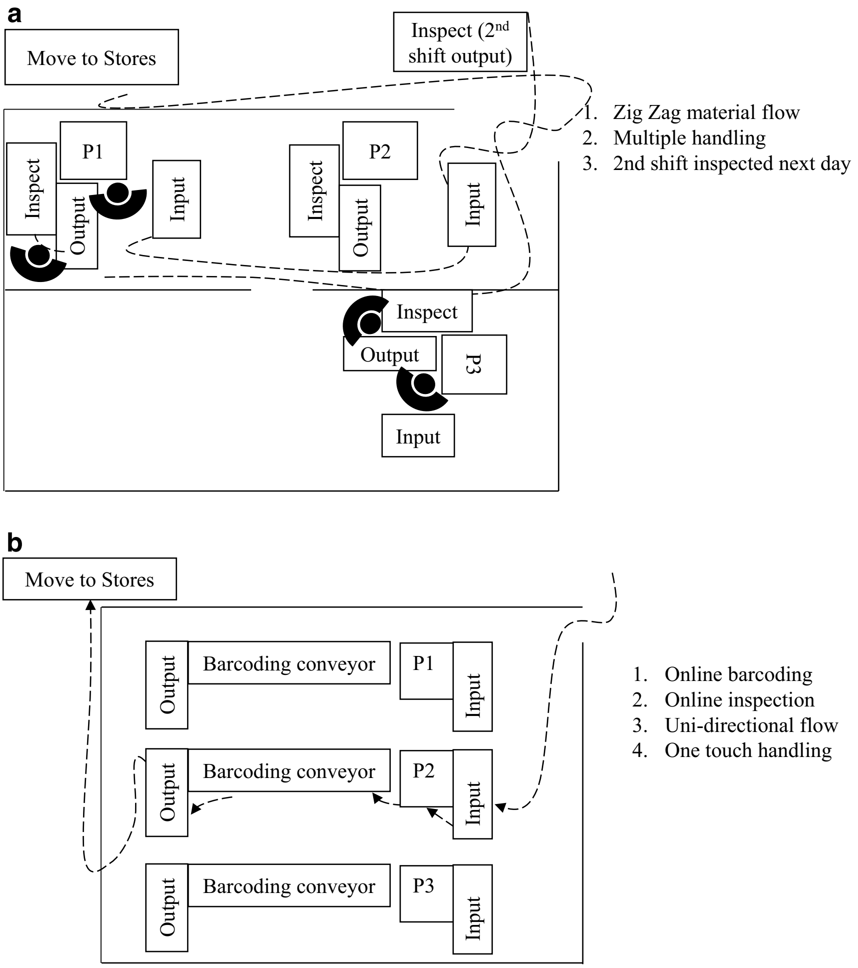

Fig. C2.16 **a** Earlier printing room layout. **b** Modified printing layout

Kaizen 4: Standard WIP and Pull-Based scheduling

With the completion of physical linking of the processes and ensuring line balance, it was time to link up all the sheet metal processes as per the envisaged future state (see Fig. C2.13). Towards this goal, two supermarkets were created with their specific rules as follows.

1. Post bending—Three days' worth of production was to be maintained as WIP for the two variants in proportion to their demand. Bin quantities were fixed (500 Nos per bin) and floor marking for storage was done accordingly. As and when the bins are pulled by the pad printing process and one day slot becomes empty, punching and bending processes operate to make and fill up the emptied slot as per the next requirement in the plan.
2. Printed name plates stock for next three days assembly schedule is maintained in the Unit 3 stores. Here, a separate area was designated and floor marking done for keeping the name plates customer-wise.

With the flow and supermarket pull systems in place, the shortages of name plates were minimized and assembly units were achieving close to 100% of the plan.

Focus Area#4—Linking Up the Entire Value Stream

By now, the physical material flow had been streamlined and the various production stages nearly balanced in terms of daily capacities. To ensure that the flow sustains on a day-to-day basis, it was time to synchronize the supporting activities such as materials management, production planning and quality systems. The next three months were spent on synchronizing all support functions and aligning them with the core process flow. The information flow was accordingly reconfigured.

Project 1: Materials Management—Ensuring on Time in Full (OTIF) Supply of Kits

Linkwell was using a mix of Oracle ERP and excel worksheets for planning production and material procurement. The overall flow of material planning is shown in Fig. C2.17.

The obstacle to flow now was material shortages. The team analysed the shortages and grouped them under procurement and internal stores categories. Further, they brainstormed, identified, and implemented solutions to address the shortages as described below.

Procurement related

Monthly production plan is manually done in excel sheets separately by the assembly units. This was then consolidated in another sheet by the supply chain team. The plan is fed into the ERP and the computer program needs to run in the night to generate shortage report, plan and other outputs. To overcome this delay, the shortage report is often manually prepared by importing the stores stock into a

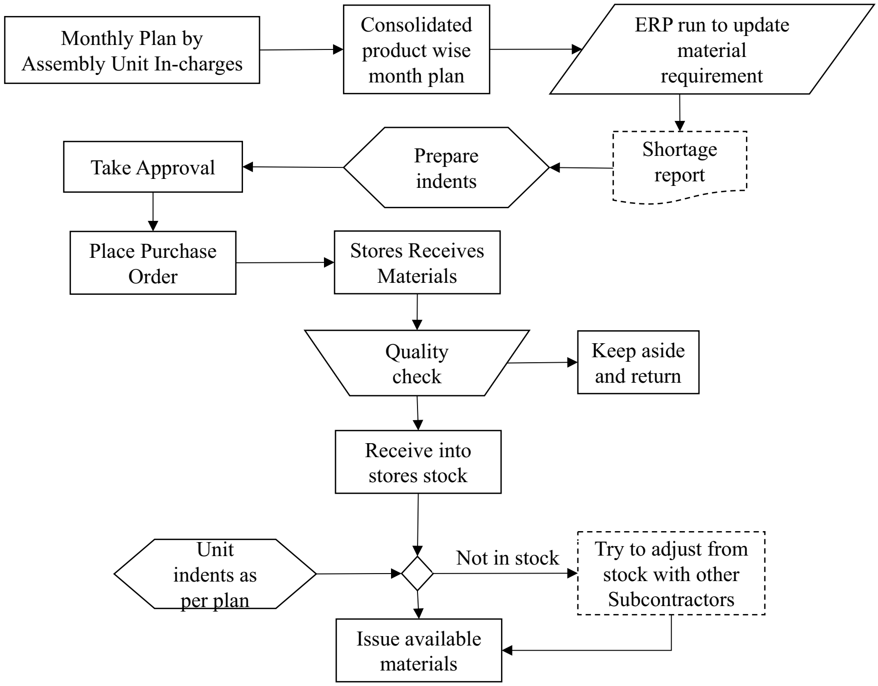

Fig. C2.17 MRP run and execution

spreadsheet and matching against the plan. This method was cumbersome and also error prone and leading to either excess stocks or stockout situations. For example, when the ERP run was made for the July, using the manually generated shortage reports, over 30 items were found to be short. At the same time, several items were found to be in excess of three months inventory.

The systems engineer joined the core Lean team for this project and tweaked the monthly run process, so that the shortage report from the ERP, instead of the manual report, would be the basis for any procurement. For the common items, which are used in most of the product variants, minimum and maximum stock levels were set up in the ERP and triggers were set to alert the supply chain team, whenever stock-on-hand either falls below or exceeds these thresholds respectively. Only select items would be subject to manual intervention and indent approvals post-discussion with the operations head. Even for these, a pop up was provided in the ERP suggesting substitutes. If an item was in shortage, the supply chain team would first look for substitute availability before planning a purchase.

Material Storage and Issue Related

The stores itself had a lot of materials lying without specified location, stocks of material were also outside stores premises. The mechanical items were especially hard to find as materials were stored in a mixed-up condition. As we saw earlier, there are two stores; the main store where all bought out items are received and stored and a sheet metal and plastic components stores for the output of Units 3 and 4. Material was issued in kits to the subcontractors. A kit consists of all the components needed to make the product and kit quantities are generated by the ERP using Bill of Materials (BOM) based on the planned finished product quantity to be entered by the planner. Kit issues to mechanical subcontractors was a complex process—they would collect some items from the main stores, some from the sheet metal unit stores and the PCBs that come in from the leaded subcontractors issued by the final assembly units. This meant multiple handling, transport and coordination among the two stores and the assembly units. Subcontractors were also found making multiple trips using small vehicles resulting in further delay and confusion at the stores. This was mainly because the kit would not be ready and partial quantities had to be picked up for which using a larger vehicle meant higher cost.

To begin with, a physical reorganization of the stores was carried out using 5S principles. The team decided that all mechanical sub assembly items would henceforth be kept in the Unit 3 stores to have a one stop shop for kit collection by these subcontractors.

Step 1(1S)*:* Removed all non-moving, damaged, and unwanted items and disposed them off as per management direction and cleared space in both stores.
Step 2 (2S): Shifted extra racks from main stores to sheet metal and plastics stores and reorganized all the materials on 2 S principles with designated areas for name plates, plastics, bought out items and other items.
Step 3: The kitting area was marked in both stores with provision of up to 3 kits at any time. Kits kept ready in the morning and subcontractors given pick up time slots in the afternoon, thereby minimizing the time spent by each vehicle in the store's premises. Once the full lot of kits was in place, subcontractors were asked to bring larger vehicles to collect entire kit in one shot. The following outcomes as shown in Table C2.11 were realized on completing the stores reorganization.

Table C2.11 Improvement in kit collection time by SCs

Parameter	Earlier	After reorganization
Number of trips	1 trip to Main stores, 2 trips to Unit 3 stores in small vehicle	Single trip to unit 3 stores with a larger vehicle
Distance travelled	40 to 60 km	15 km
Turnaround time at stores	Anywhere from 1 to 3 h	30–45 min

Table C2.12 Why-why analysis for poor OTIF of kits

	Why	Why	Why	Why	Solution
Full kit not available	Specific item shortage	Delay in getting stock	Wrong data	Manual excel working	ERP changes
			SC item delay	SC capacity	Improve SC process
		Issued to other SC	Issued quantity as per month plan	Defined in current SOP	Change SOP

Kitting Practice Improvement

As noted previously, main reason for the delays and fire-fighting to achieve targets was the non-availability of full kit of materials required for mechanical assembly. During the initial diagnostic, it was found that the On Time In Full (OTIF) against these indents was almost zero. Every indent had some or the other material shortages. In many cases, materials were issued in part based on availability, and to somehow ensure production targets are achieved, the unit coordinators were diverting common components from one subcontractor to the other. There was no trace of such material movements in the ERP. A why-why analysis was done to identify root causes and develop actions to mitigate them as shown in Table C2.12.

The changes in ERP have been explained in the procurement-related issues section while Focus Area 2 detailed out the improvements done at various subcontractor processes. We now look at the planning SOP and how the team redesigned the kit planning, issue, and reconciliation process to address this issue.

Existing Process for Kit Planning

Based on monthly plan, unit production planner would split the quantities to each subcontractor and instruct stores to issue them kits in accordance to the same. The stores would issue kits based on the plan and quantities would vary from 10,000 to 25,000 kits—anywhere from one week to entire month production. Since each subcontractor would collect the kit on different days, a subcontractor collecting material at a later date would find a shortage in an item due to less stock in the stores. However, this item may have already been issued in full to another subcontractor. The unit planner would then intervene and transfer part quantities to keep production going at both the subcontractors. This sort of adjustments and firefighting over a period of time had resulted in complete mismatches of stock of various components at different subcontractor locations.

Revised SOP for Kit Planning

To ensure even distribution of kits and better controls, a new SOP was defined as follows, using the “*production levelling*” principle of Lean manufacturing:

1. Kits equivalent of three-day production capacity of the subcontracting unit would be issued. For mechanical kits this would be of 5000 meters and for leaded kits this would be either 10,000 or 20,000 PCBs. This is strictly driven by the weekly schedule given by PPC every Thursday for the next week.
2. Kits would be issued twice a week and when the subcontractor still has a day's safety stock remaining. Different subcontractors were scheduled on different days to level the kit preparation workload at the stores. For example, Unit 3 store has to issue kits to 10 subcontractors which means 20 kit issues per week. The schedule is made for 3 kits per day.
3. The output of the subcontractor units is also routed through stores system. To collect a fresh kit for 5000 meters, the subcontractor has to have delivered to the stores 5000 assembled meters from the previous kit.
4. As schedule and quantity is fixed, kits for the day are prepared in the morning and placed in designated kitting areas. SCs are given time slots post lunch to pick up their kits. So, there is no waiting for them and they are able to carry all the items in a single trip.

Project 2: Lean Production Scheduling

One of the biggest *Muda* seen in the organization was the large number of follow-ups taking place across the operations—emails, calls, reviews, fire-fighting meeting, personal visits to SC premises and interactions with stores. The root cause for this was identified to be the current production planning, scheduling, and monitoring system whose key issues are listed below:

- Upstream units make their own daily schedules keeping in mind equipment changeovers, operator availability, raw material status, etc. They only ensure that they operate within the monthly requirement plan which is also made on a zero base each month. The plan does not factor in the stock of the already produced components lying in the Unit 3 stores.
- As we have seen, the stores also operate independently issuing kits as per monthly plan provided. They do not give feedback to upstream units on stock levels or shortages.
- The assembly unit managers monitoring the final product actuals against the plan are often clueless as to where things have deviated in the whole chain. Sudden changes are made in assembly schedules due to material shortages or customer priority changes and these are not in sync with upstream plants output. Hence, further delays occur in dispatch schedules.

To summarize, all the stakeholders in the value stream be it supply chain, stores, upstream units or final assembly units, were operating in silos once the monthly requirement plan was given by the assembly unit managers. The disruptions, changes, and constraints faced while executing the plan were communicated either through emails or in weekly review meetings chaired by the Operations Head.

Actions Implemented

A two-member production planning and control (PPC) cell was formed consisting of one member each from the stores and production functions. This cell was initially entrusted with supply side planning for a month. After setting this in order, the responsibilities were extended to cover the complete production scheduling, monitoring and coordinating across all the stakeholders to ensure smooth flow of material and information and ensure achievement of 100% against plan. Lean scheduling practices introduced to facilitate their work are:

- Monthly requirement plan is translated into a weekly final assembly schedule,
- This weekly schedule is discussed in a meeting with all concerned unit managers and functional heads, fine-tuned, and released every Thursday evening,
- Stores issues kits to subcontractor unit's according to this schedule; each kit equal to three days output,
- Unit 3 prints name plates from its standard WIP according to this schedule. Recall that three-day standard WIP is already fixed with name plates,
- Unit 4 produces plastic components based on the fixed minimum stock levels (MSL, Kanban trigger). As the components are issued and stock level reaches MSL, a trigger goes to the Unit 4 production in-charge and who then plans to refill the stock with a defined production run for the component,

Outcomes of Improvement in Planning and Scheduling

- OTIF for kit issue increased from < 10% to > 70% within six months.
- Assembly units achieved more than 95% against plan for three consecutive months.
- With central PPC control, the firefighting, follow-up and related *Muda* have been minimized and eliminated the need for multiple coordinators at each unit.

Standardize and Sustain

The last stage of the Lean transformation journey at Linkwell entailed setting up systems and standards that would help the organize consolidate the gains obtained through Lean and ensure sustenance of the Lean process in the long run. An operations excellence team was set up to internalize the Lean approach and be able to take it forward once the consultant withdrew. One of the assembly line managers, Vishnu, had already been given the role of Lean champion following the initial improvement and consolidation of the assembly lines through cell concept. Now, two more employees were added to this team (see Fig. C2.18 for the organization chart) to handle the 5S and maintenance aspects that are part of the stabilization phase.

The next level operational excellence concepts implemented over the last few months were:

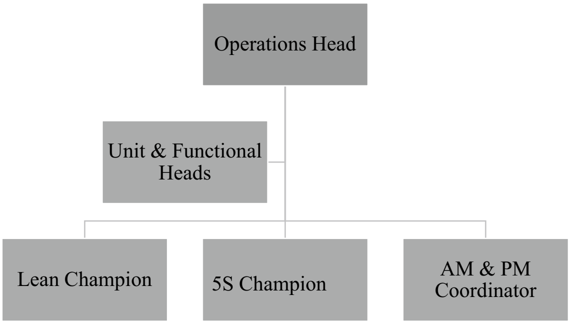

Fig. C2.18 Lean organization chart

(1) Autonomous maintenance across all manufacturing units to reduce breakdowns, quality issues and short stoppages, and
(2) 5S assessment through a comprehensive checklist covering all aspects of Lean implemented till date to enable sustenance and further improvement.

Autonomous Maintenance

With the flow established, quality systems set and pull-based scheduling in place, the core operations were now able to deliver more output at a faster rate while maintaining a minimum standard WIP across the value stream. Changeover times were also reduced to support small lot sizes as per customer demand. But all this could easily be disrupted by either a machine breakdown or variations in machine performance. Hence, it was imperative to maintain the equipment in a reliable condition and aim for zero disruptions. Linkwell implemented the first four steps of *Jishu Hozen* (autonomous maintenance) over a three-month time frame.

Step 1: Initial cleaning and identification of abnormalities were carried out across all the key equipment in all the four units and the utilities supporting them. A total of 940 abnormalities were noted and more than 800 were closed within a month's time.

Step 2: Generation of countermeasures. Some of the abnormalities such as dust in electrical panels or bent connector pins in the calibration equipment were found to repeat across the plants. Why-why analysis was done to identify and arrest the sources of contamination/root causes of the problems.

Step 3: Preparation of CLRI standards.

A cross-functional team consisting of maintenance and engineering staff, unit production and line supervisors brainstormed to prepare cleaning, lubrication, retightening, and inspection (CLRI) standards for their respective equipment. These were then vetted by actual practice on the machines.

Step 4: General inspection.

The CLRI standards were pasted at each machine centre in local language and routines established.

- Operators were trained to follow the standards.
- Every morning before start of work, 10 min was allotted for CLRI.
- Abnormality registers were introduced at each section for operators to note down any abnormalities identified.
- The Lean team audits the CLRI adherence physically once a month.
- To ensure that CLRI standards and machine maintenance activities are regularly inspected, they have been incorporated into the monthly 5S assessment checklist.

5S for Sustenance

Linkwell had already been implementing 5S over the past couple of years and had a core team led by a 5S champion. This team was mainly doing *gemba* audits for housekeeping, unwanted materials and equipment, abnormalities and capturing these with photos. These were then discussed with concerned section heads who would then make an action plan to improve upon the observations. To make 5S, a vehicle for sustenance of the Lean initiative, a new assessment checklist was created and implemented. The entire factory area was divided into zones, each zone with two 5S champions or zone leaders and 5S activities under the Lean initiative were implemented in the following four stages:

Stage 1—Self-Assessment.

Following a training on the checklist and its criteria, each zone leader assessed his or her own zone along with a 5S core team member; they reported the score, observations, action points for improving their score.

Stage 2—Core Team Assessment.

Two core teams were formed, one for the production and another for the support function zones. After a fortnight, these core teams assessed all their respective area zones and reported their own scores and the progress made by the zone teams with respect to the action points.

Stage 3—Consultant Assessment.

A month later, we conducted a formal assessment along with the core team and reported the first official scores for all the zones. The best performing zone in the manufacturing units and best support function were each awarded the rolling 5S trophy by the executive director in a formal get together. Zone Leaders were recognized individually for their efforts. Each zone made their respective action plans to improve upon their performance by the next assessment cycle.

Table C2.13 Consolidated benefits of Lean implementation

Process	Measure	Before	After
Finishing lines	Productivity (per person per day)	180	350
Leaded subcontractor	Output (Nos/day) No. of subcontractors	1500 per line 7	2000 per line 4
Mechanical assembly subcontractor	Output (Nos/day) No. of subcontractors	1000 20	1500 12
SMT line	OEE	58%	70%
Quality	Rejection % (Top 8 defects)	1.23%	0.55%
Overall	WIP inventory (Value Rs. Million)	520	180
	Space utilization		13,000 SFT vacated
Overall cost savings	INR million per month Labour Power Subcontractor Logistics		1.60 0.75 0.08 0.75 0.02

Stage 4—Sustenance.

A roadmap was framed wherein a formal assessment followed by recognition of the best 5 S zones would be done on a quarterly basis. The checklist would help each zone frame a continuous improvement plan till the zone scores and sustains a minimum of 90% for two successive assessment cycles. We anticipate this to happen in about two years after which the checklist could be upgraded and used for further improvement activities.

Conclusion

This relatively short Lean journey of nine months commenced with current state assessment and roadmap framing, went through the improvement phase and culminated in the sustenance phase marked by the 5S assessment. The team is now empowered to continue the journey of continual improvement under Lean paradigms. The team consolidated the benefits of this initial round of Lean implementation over the year as shown in Table C2.13.

The monthly reducing inventory trend (in Rs. million) is shown in Fig. C2.19.

Post Script—The pandemic Era

Within months of the Lean journey detailed above, the entire world was hit with the impact of the Corona virus. Being firmly on the Lean path gave a tremendous boost to Linkwell in battling with the business and operational complications brought about by the pandemic. While our engagement had already ended with the handing over of the initiative to the Lean team, they rose to the occasion to take up the

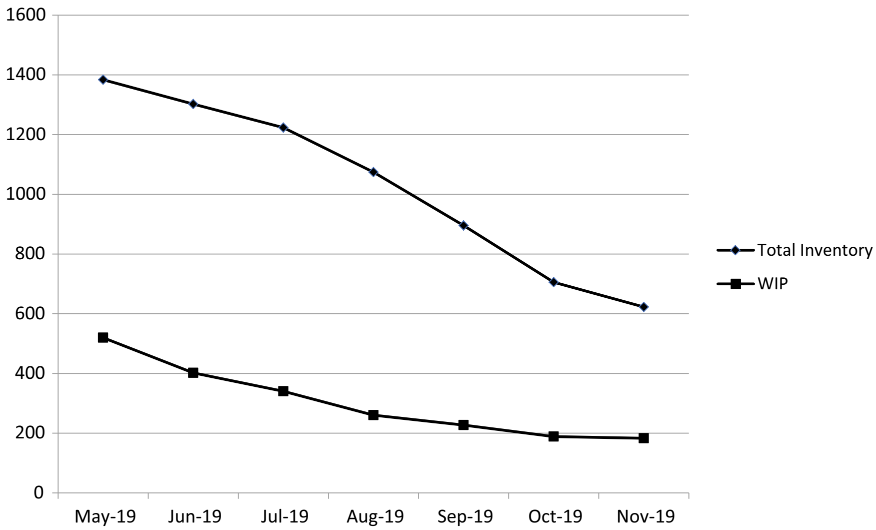

Fig. C2.19 Declining inventory month-on-month

challenges posed by the pandemic situation and worked on further improving and standardizing different aspects of the process.

For instance, they extended the visual management concepts to their file management systems in all the departments such as HR, procurement, administration, etc. that improved the ease of retrieval, reduced the space usage, and reduced filing errors. A number of low-tech, low-cost, but effective poka-yoke-based procedures have been put in place to combat COVID, such as hands-free door opening/closing of all office/wash rooms, visual marks for social distancing, etc. This indicates how deep the Lean-based problem-solving methodology has been ingrained into the thinking process of every employee of the organization. In fact, the daily routines of every department have Lean practices instilled within them, thereby avoiding any notion that Lean is something different from the daily responsibilities of the individuals. Finally, the organization created a performance measurement system that cascades from the top to lower most levels, in which Lean goals are explicitly indicated to every level. In effect, the company has made Lean as a way-of-life in every aspect of its daily operations, problem-solving, learning, decision-making, and managing in internal and external processes.

Case Study 3: The Lean Restaurant—Serving Customers Effectively

Background

Liberty exclusive is a leading hospitality service provider running restaurants (A'la Liberty) and a banquet facility at prime locations of Hyderabad, India. Liberty is well known for high quality vegetarian catering services for a wide range of functions and events. Over the last decade, the restaurant has been adjudged the Best Vegetarian Restaurant in Hyderabad multiple times by the prestigious Times Food Guide awards. Recently, Liberty has opened its first cloud kitchen for takeaways and is planning to expand this as a franchise operation across multiple locations.

Mr. Vishal runs this family promoted business, handles the overall operations and personally manages the restaurant at Banjara Hills. His mother manages the catering services and Rishabh, Vishal's younger brother, handles the day-to-day operations of the restaurant located at the upmarket Tech Park area. Liberty has a loyal and growing customer base and a strong brand image and Vishal saw a huge potential for growing the business and extending the brand to cater to the booming online food delivery business of service providers like Swiggy, Zomato, etc. He also felt the need to improve bottom line as expenses had grown at a higher rate than sales in the restaurants.

Vishal then roped in Prasad, his ex-colleague from Taj Hotels to handle operations and drive improvements so that he could focus on growing the business. To realize the potential, Vishal was looking to strengthen the core operations and delivery processes and establish a standard operating model that can be scaled easily. During a conversation with one of Liberty's regular customers, Vishal was referred to us. After a preliminary meeting, Vishal engaged us to help Liberty improve and standardize its existing operational processes using the concepts of Lean and Kaizen. A six-month time frame was fixed for the first Lean intervention with a focus on the restaurant business segment.

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G. Mahadevan and K. C. Chejarla, *Lean Management for Small and Medium Sized Enterprises*, Management for Professionals,
https://doi.org/10.1007/978-981-19-4340-9

Management Goals

Following a *gemba* walk through of the restaurant facility, we sat down with Vishal and defined the following goals to better the restaurant operations:

1. **Increase resource productivity** of **People (**revenue per employee), **Material** (Zero wastage), and **Space** (revenue per square foot),
2. **To reduce employee stress and strain** while handling the day-to-day operations—avoid "firefighting",
3. **Improve customer experience** by reducing their waiting time from entry to exit, and ensuring consistent delivery of specified and expected quality in food, facilities, and service,
4. **Establish standards** for the core processes and a system for monitoring adherence. The standard practices should help business scale up smoothly and quickly.

The Approach

Unlike manufacturing, restaurant operations are highly variable, with peaks and troughs. Liberty operated lunch and dinner buffets all seven days of the week while also offering guests choice of a'la carte menus. Past data showed that over 80% of the guests prefer the buffet. There was also a marked difference in terms of volumes through the week. Being a family-oriented restaurant, weekends contributed to bulk of the revenues. Additionally, volumes spiked during festival holidays, with guests having to wait for a while to be seated.

A core team comprising of Vishal, Rishabh, Prasad, the customer care manager, floor manager and the head chefs was formed to work with us on the project. The Lean intervention began with a current state assessment during which the entire restaurant operations were viewed through the Lean paradigm of customer perspective. In hospitality parlance, the customer is known as guest and he or she pays for the food and service. The unique feature of the restaurant business is that the customer also participates in the process, specifically in the case of a buffet meal. Hence, the initial observation focused on guest parties such as couples, small groups (4–8 people) and large gatherings (>10 people). The entire value stream was observed from entry of the guest party at the reception desk located at the entrance till the guest party leaves the restaurant after paying the bill, and the table is cleaned and set up for the next guest party.

From this initial observation, the entire set of operations could be sorted into three distinct flows.

- Guest flow,
- Food flow,
- Service staff flow.

The overall process flow of restaurant operations integrating these three flows is shown in following Fig. C3.1.

Obstacles to Flow

After observing each of the three flows, the team was able to arrive at the main impediments to smooth flow and frame a roadmap of improvement projects to address these constraints.

Flow of Guest

Under Lean paradigms, the guest should flow smoothly and seamlessly through the service environment without having to wait anywhere. The following obstacles were identified where guest flow was disrupted and the guest was inconvenienced:

Waiting for table due to.

- Reservation mix ups,
- High table set-up time.

Waiting at the table.

- Waiting for staff to take order, serve water,
- Waiting for soup/starters to be served.

Issues observed at buffet counter.

- Difficulties in picking up items,
- Waiting for crockery (*katoris**, soup bowls, dessert plates) and cutlery,
- Waiting for food items which are stocked out,
- Early arrivals wait as some items are not yet ready at buffet.

**A katori is a small bowl used for items like lentils, curd, etc.*

Flow of Service

Majority of the delays for the guests were due to non-availability of service staff near the tables. The team observed that the staff were busy either getting starters from the buffet area or crockery/cutlery from the washing areas. Starters are generally prepared on order and served hot; they include a mix of Continental, Chinese, and Indian items. All crockery and cutlery used by the guests are transferred to the dish washing area periodically, where they are rinsed, washed and dried before being returned to the buffet counter or guest tables. It was felt that addressing the

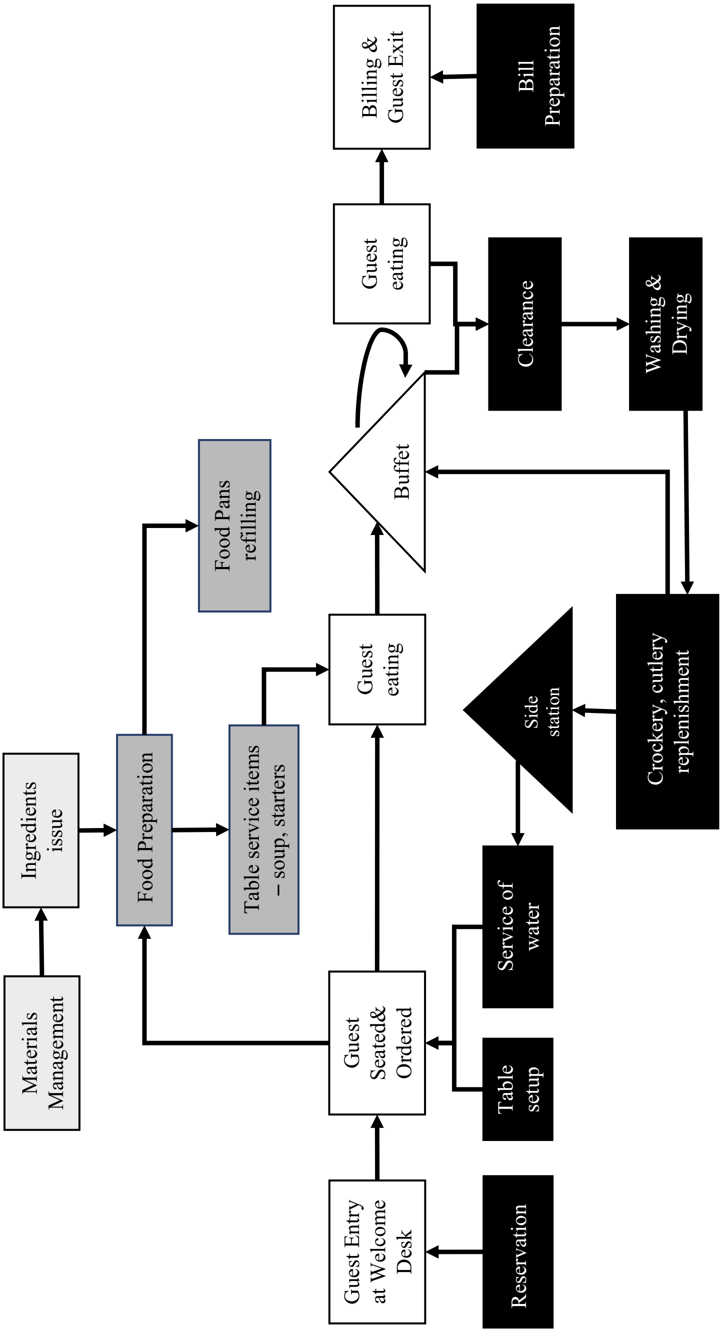


Fig. C3.1 Guest, food, and service staff flows in restaurant operations delay in starter preparation and speeding up washing process would free the service staff to attend the needs of the guests in a timely manner and ensure better guest service levels.

Flow of Food

Cooking of food as per recipe is the core value-adding process of a restaurant. The team observed the activities that make up this process and identified the following impediments to flow.

- Delays due to non-availability and late issue of ingredients from the stores,
- Time lost in searching for items in the kitchen,
- Constraints in starters preparation process in the live kitchen.

Implementation

The obstacles identified were analysed further to arrive at the root causes and a four-month roadmap was formulated prioritizing the focus areas for improvement. Lean focuses attention on the customer experience, and hence, the first priority was to improve the service levels through ensuring increased staff availability and attention to the guests. How Liberty achieved these major operational improvements are discussed in the following sub-sections.

Increasing Service Staff Availability at the Guest Tables

A simple why-why analysis was helpful in identifying the reasons behind guests waiting for service. Table C3.1 describes the analysis.

Based on the above analysis, the following process improvements were identified;

1. Streamline and ensure flow of the cutlery and crockery from point of use to the cleaning and back—one touch concept,
2. Early warning of stockouts of the cutlery and crockery at the buffet counter and refilling through pull-based replenishment using tray *Kanban,*
3. Redefine roles of service staff—separated focus on guests, buffet and washing areas.

We present the process of analysis, deriving the required changes to be made to achieve the improvements, implementation, and the resultant outcomes in the following sub-section.

Table C3.1 Why-why analysis

Issue	Why	Why	Why	Why	Why	Why	Solutions
Guest waiting for steward/waiter to order		Gone to eat lunch	Lunch (for staff) not ready before 1 pm	Chef cooks food after preparing buffet rice	As per existing practice		Revised staff lunch preparation time to 12 noon
	Staff not available near the table area	Gone to the soup/starter pick up counter	Responsible for serving these items to the guest	Roles as defined by restaurant management			Redefined roles of service staff (see below)
		Gone to the washing area for fetching cutlery/crockery	Delay in getting clean cutlery/soup bowls	Delay in drying of washed cutlery	Multiple handling and strain water between washing, drying and taking the items out(?)	Batch system for washing & drying; NVAs in method followed	One touch handling and flow in washing and drying
Guest waiting to pick up items at buffet	Waiting for crockery and cutlery	During rush time, crockery not available at the buffet counter					Pull based replenishment using trays
	Item stockout in pan	Delay in refilling food pans	No mechanism to check stock level	No specific Person assigned			Redefined roles of service staff (see below)

One Touch Handling Method and Flow in Washing and Drying

The current flow of crockery and cutlery is depicted in Fig. C3.2. The process operates in a batch mode with no fixed schedule or quantity. Each section works to complete whatever is available with them at the time, when it is free. Hence, multiple stacks of crockery are observed in between the processes.

Preliminary observation showed stacks of dirty crockery waiting to be washed and this made it clear that washing was the bottleneck and was not able to keep up with the demand, especially during peak hours. An in-depth observation revealed that the existing layout of the washing area was leading to multiple touches (handling) and crisscross movement of staff. Please see Fig. C3.3. Dotted lines and dark grey boxes show glasses flow, and the solid lines and light grey boxes show the other crockery and cutlery flow.

The glasses were washed in a separate line as they needed to be handled in a delicate manner. These were mainly used for juices and water, and there were no delays observed in availability. However, both the ceramicware (crockery) and stainless-steel cutlery were being handled in the main washing line. While only four operations—clean, rinse, wash, and dry are done, it was seen that each item was touched about 10 times. The washed crockery is stacked on a shelf in the order they are washed. This meant a mix of bowls, *katoris* and plates which have

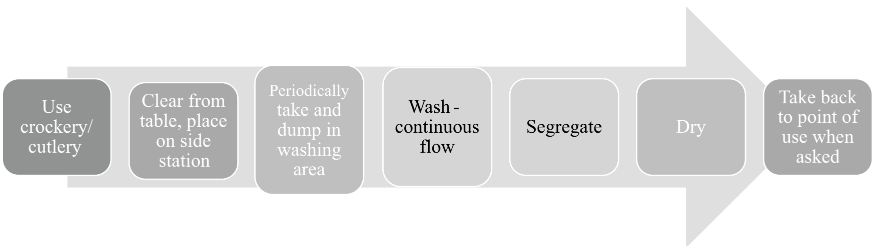


Fig. C3.2 Process flow of current operations

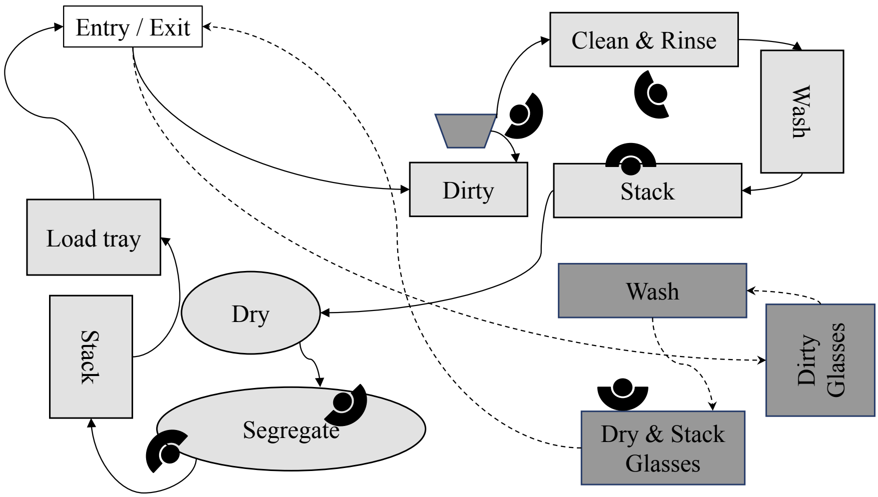


Fig. C3.3 Existing operations flow and layout

to be again segregated when they are unloaded into a basket. This basket is placed on the floor. A staff member, sitting on a low stool, picks up one piece at a time, dries and places it in a stack on another table. This stack is then placed in a tray by one of the restaurant staff and carried to the buffet counter where once again it is removed from the tray and stacked.

Using Lean flow principles, the team changed the layout to improve flow and drastically reduce handling, movement and employee strain. In the new layout, the table for placing dirty crockery was shifted adjacent to the rinsing sink thereby avoiding the need to lift and move crockery. An additional table was located next to the stacking location. The washing staff were now asked to place the items in separate baskets or drying stands as they are removed from the washing process. Another staff member, stands at the drying table, and continuously dries a set of items from one basket placing each dried item directly on trays meant for transporting the item back into the restaurant. The filled tray is then placed at the buffet counter and an empty tray brought back to the drying stand for the next set of washed items. Now all operations are carried out at waist height thereby avoiding the need for staff to bend down or sit in uncomfortable postures. Modified operations flow and layout is shown in Fig. C3.4.

Pull-Based Replenishment Through Trays

Crockery relevant to buffet such as soup bowls, *katoris*, dessert plates, and juice glasses are kept in the shelves of the buffet counter. In line with industry norms, Liberty had crockery of about 1.5 X (times) the restaurant capacity, in circulation. At peak times (say 1.30–2 pm on a weekend lunch hour), there was a lot of firefighting to restock the washed crockery resulting in guests facing a delay at the buffet counter. The restocking additionally inconvenienced the guest as the service

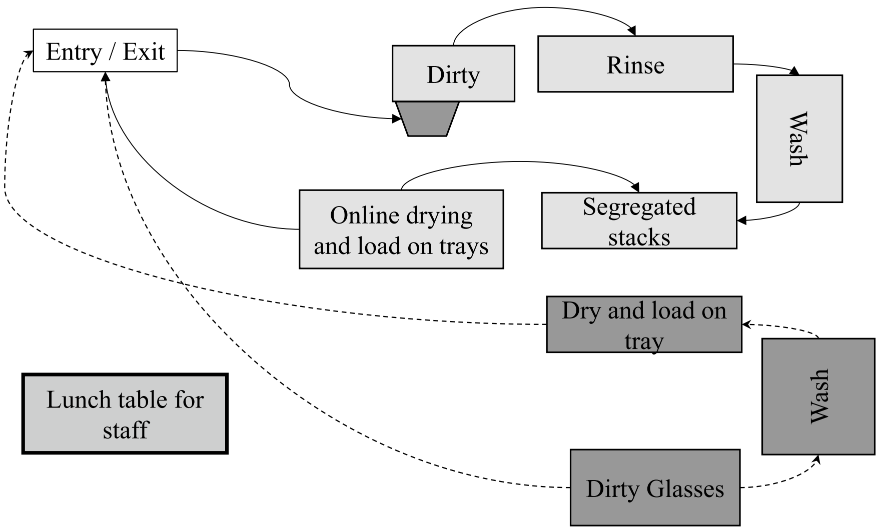
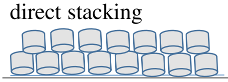
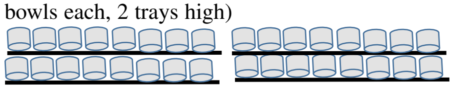


Fig. C3.4 Modified operations flow and layout

staff was found to be blocking the guest movement to pick food; he would take about five minutes to stack soup bowls or *katoris* one by one at the earmarked location. The team worked out a solution to reduce this time taken to replenish crockery at the buffet counter thereby minimizing the inconvenience to guests. Table C3.2 summarizes the improvement done.

The stock position of the crockery item and call for replenishment is based on visual observation by the floor supervisor at the buffet. As a tray gets empty, he signals the waiter to get a filled tray from the drying station. An empty tray left at the drying station is a signal for the back-end staff to dry and place 24 fresh

Table C3.2 Existing and improved cutlery replenishment processes in the buffet area

Existing process	New process
1. Random number of Bowls brought in a tray from the washing area 2. Waiter crouches down at the counter and places each bowl from the tray onto the shelf 3. On completion waiter takes empty tray and leaves it on a side station#	1. Fixed number of 24 bowls bought in a holding tray 2. The waiter bends down momentarily, removes empty tray, and replaces with full tray 3. Takes empty tray and returns it to the drying workstation for replenishment
Maximum number of bowls stacked: 64 (2 rows × 16 × 2 high) height restricted due to direct stacking 	Total number of bowls stacked: 96 (4 trays × 24 bowls each, 2 trays high) 
Cycle time per tray: 5 min avg	Cycle time per tray: 30 s

#Each service section has a side station (cabinet with table top) used by the staff for supporting all their work bowls in the tray. A similar system was fixed for *katoris* and plates each with its own defined quantity.

Service Staff Roles Realignment

The why-why analysis has shown that current attempts by the service staff to somehow fulfil their duties is also a reason for the delay in serving guests. We stationed ourselves at the door leading from the restaurant to the back area (kitchen and washing) for about ten minutes during peak hour and observed that the door was opened more than a hundred times in just these 10 min. Almost every member of the staff—steward, waiter, chef, and even the restaurant manager walked in and out multiple times during this period. The fact that the service staff including the section steward and floor manager keep disappearing into the kitchen area meant that they were often not found by the guests when needed. Not only was this leading to poor service to the guests but also affecting the kitchen hygiene as multiple people kept trampling in and out. The staff were also under a lot of strain due to this constant movement from their service area.

The restaurant layout below gives us a picture of the extent of motion and non-value-added activities taking place. The movement of one set of staff serving Section B is shown—the other section staff also have a similar set of movements for service, food pick up, and clearance. Existing layout and staff movement is shown in Fig. C3.5.

To reduce the movement and increase the service staff presence in the dining section for the guests, the roles of some of the staff were redefined. One senior

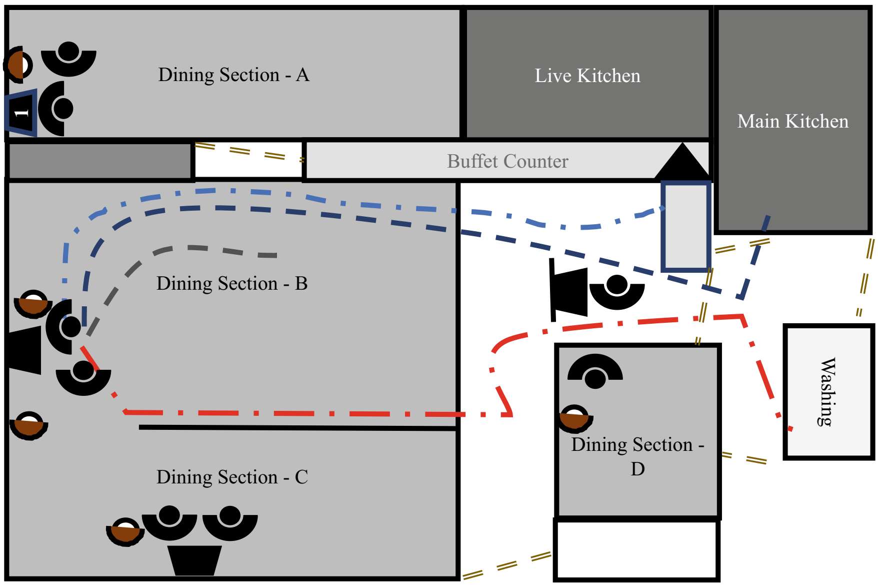


Fig. C3.5 Existing layout and staff movement

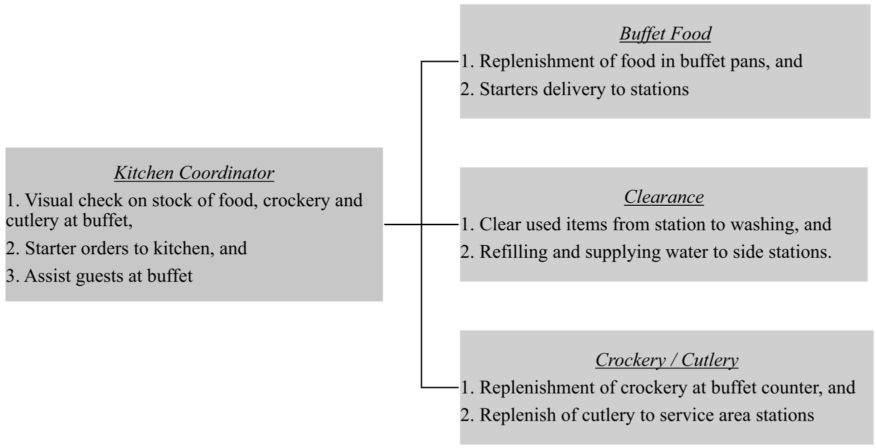


Fig. C3.6 Redefined responsibilities of coordination team

captain and two stewards were pulled out from their respective service sections and were formed into a separate team. The role of this captain or kitchen coordinator was to synchronize the kitchen, washing area and front end (dining sections) seamlessly. The roles were redefined such that only three people were allowed to pass through the door into the kitchen area thereby freeing up the section service staff to be in the vicinity of their guests. One person each was allocated to clearance from side station, for replenishment of food and replenishment of crockery and cutlery, respectively. The new team structure is shown in Fig. C3.6.

Following this realignment of staff roles, the movement of the section service staff was hugely minimized as none of them were expected to enter the kitchen area. All their movements were up to the nearest side station only. Figure C3.7 shows this improved flow with movements of section service staff and the newly created coordination team.

Reducing Guest Wait Time for Table

On an average, the restaurant can service two parties of guests per table. The lunch/dinner time is for about 3 h, and data shows that one party of guests occupy a table for about 75–90 min. The guests who have made reservations for the latter time and the walk-in guests are often found to be waiting at the reception area for up to 30 min. Sometimes, to placate the irritated guests, the hostess would hurriedly have them seated at the table while the table setting process was still incomplete.

Part of this delay was attributed to time taken to clear and set up the table after the previous party has finished their meal. Persistent observation revealed that the

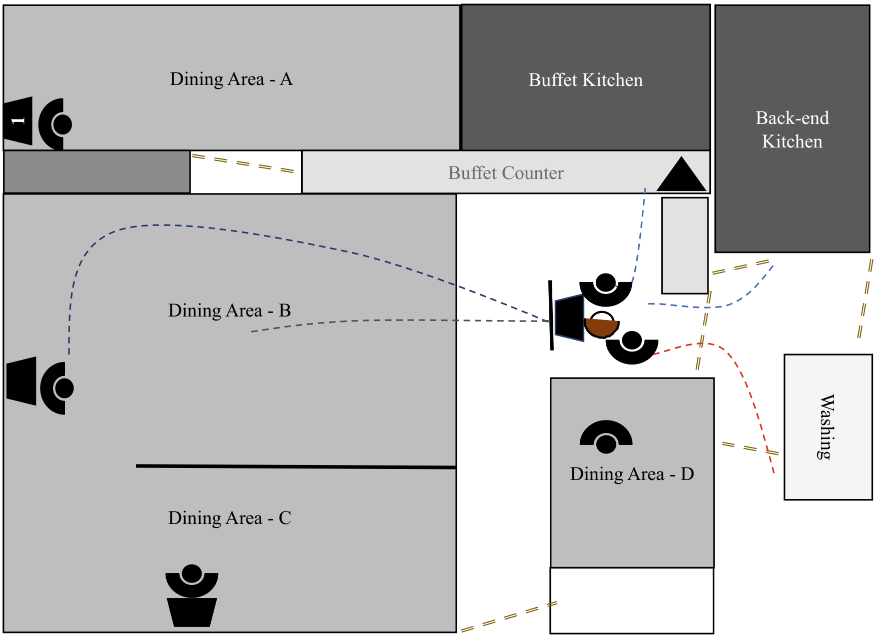


Fig. C3.7 Post-improvement staff movement

speed of the table setting activity was affected by two things and the team worked on improving both these factors that were causing a delay in table setting.

Unavailability of All Required Items in the Section Side Station

Each service section has a side station (cabinet with table top) used by the staff for supporting all their services. The Lean core team went through these side stations and observed the following:

- Variation in type of item and quantities from one side station to the other,
- Items found in mixed-up condition,
- Unwanted/unused items occupying the drawers,
- *Muda* of motion due to non-availability of certain items. For example, hand wash bowls are available but the steward has to go to the kitchen area for hot water.

The team used 5S to improve and standardize the side stations:

1S: The side stations were completely emptied and unused and unwanted items were immediately discarded.

2S: The service team brainstormed and decided on the list of items that are mandatory for each station. It was decided to stock the following items and the corresponding quantities:

- Crockery and cutlery: 1.5 times the number of guest covers#
- Table cloths, napkins and other items: 2 times the number of covers
- Housekeeping items—cleaning sponge, dry cloth, spray, etc. one set per station

#A cover is one seat on a table.

This was to ensure zero delay in resetting up of the table after one party of guests leave.

- The side station has three levels—table top, drawer, and cupboard below. A place for each type of item was fixed based on the frequency of use, size and weight of the item and space available for fitting in the required quantity. All items were placed as per labelled location only.
- A master list of items to be found in the side station with required quantities was made and stuck to the inside of the cupboard door.
- Hot water kettle procured for each side station—this can be used both for hand wash bowl as well as for guests who ask for warm drinking water.

3S: Daily morning practice of cleaning the side station and checking the contents instituted.

Cleaning and Table Setting Procedure

The Single Minute Exchange of Die (SMED) technique was adopted for improving table setting process. Firstly, a video of the entire process of cleaning and setting up a typical 6 cover (seater) table was shot. The whole process was then observed in detail with the concerned staff and analysed for *Muda*, *Muri,* and *Mura*. Some key observations made by the team members are:

- Variation in practice from person to person,
- Variation in sequence of activities from one set-up to the next,
- Cleaning done by housekeeping staff and table set-up by steward. There was waiting time for in between both activities as concerned people were doing other jobs.
- Shortage of some items—stewards moving to other stations and sometimes to the kitchen area to get the items (glasses/plates/cutlery),
- Time taken to refold each napkin—it is placed in the side station as received from laundry but while placing on table the orientation has to be changed.

The team then zeroed on the following improvements:

- Side station reorganization (as detailed in previous section),
- Defining best and simplest way of setting table and having the service staff practice the same,
- Napkins pre-folded by laundry service provider as per Liberty specification.

Outcome

Earlier table set-up time recorded was about 7–8 min for a six-seater table; after the improvement it was reduced to 3–4 min and clear communication protocol extended between the steward and the front desk to ensure that guests are sent into the restaurant for seating only after the table set-up is completed.

Speed and Efficiency of Food Preparation

While Liberty had won multiple awards for food quality and taste, customer feedback highlighted issues with respect to delay in service of food. Having worked on and enhanced the service staff attentiveness to the guest, the core team next turned its attention to this issue, and was able to observe and identify the few specific causes that were contributing to this delay. *Kaizen* projects were drawn up and implemented to address these issues.

Delay in Service of Common Starter Items

There are some starters which are on the menu every day without exception. Pizza is one such item with only the vegetable topping changing from day to day. Observations made during the buffet peak time showed delays in supplying the pizza slices to the pick-up counters. Stewards and captains would often be seen waiting for the pizza, and customers repeatedly asking them on why they have not yet been served. The Lean concepts of VSM and material flow were used to better understand the issues related to the pizza preparation and delivery process.

Process Analysis, improvement, and implementation

Analysis

At the peak hour about 60 people would be having starters at the same time. Past data analysed showed an average consumption of 1.5 slices per person which translated to peak requirement of 90 slices or 15 pizzas. 1.30~2.00 pm is peak time. Delivering 15 pizzas in this half an hour implies a takt time of 2 min per pizza. The value stream map is shown in Fig. C3.8. Each oven can accommodate 2 pizzas side by side and can therefore bake 1 pizza every 90 s which is less than takt time of 120 s.

The above data and observations show that there is sufficient capacity to deliver the peak requirement. However, the actual output was constrained by the following:

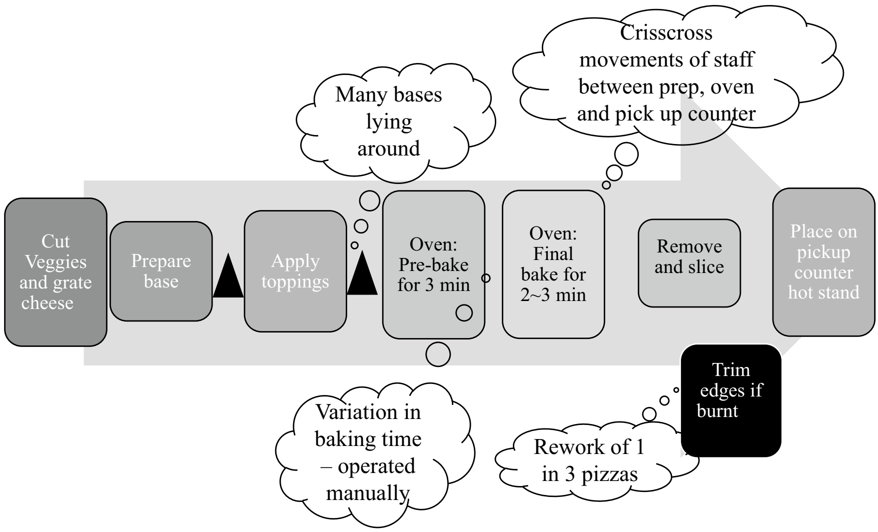


Fig. C3.8 Value stream of pizza making

- Multiple movements of the chef and assistant to prepare and deliver a pizza—also this movement was clashing with the chefs preparing fried starters and *tandoor* snacks.
- Mismatch of base preparation and oven baking results in inventories of prepared bases or stockouts. Inventories cause loss of freshness and stockouts cause idle time on the oven.
- Variation in baking time due to exigency—at times 3 pizzas are stuffed in the oven resulting in low quality (underbake). Other times, there is only one pizza or temperature is turned up to speed up the baking leading to burnt edges. This in turn resulted in additional rework activity of trimming the edges causing further delays.

Improvements

(1) **Flow**—The starter area layout was modified to reduce movements of chefs and their assistants and streamline the flow of starter preparation and delivery to pick up point from where the service staff would collect their starter orders. In the existing layout there was a crisscross movement of the assistant chef for baking the pizza, again taking it across the room for slicing and moving the sliced pizza to the pick-up counter. Similar movements for preparing *tandoor* (a mini earthen oven) snacks as well as cold cut vegetable preparation can be seen in Fig. C3.9a (Earlier layout diagram). Since the pick-up point for starters was located right in the middle of the buffet, the guests picking up their food were forced to go around the service staff waiting at the pick-up

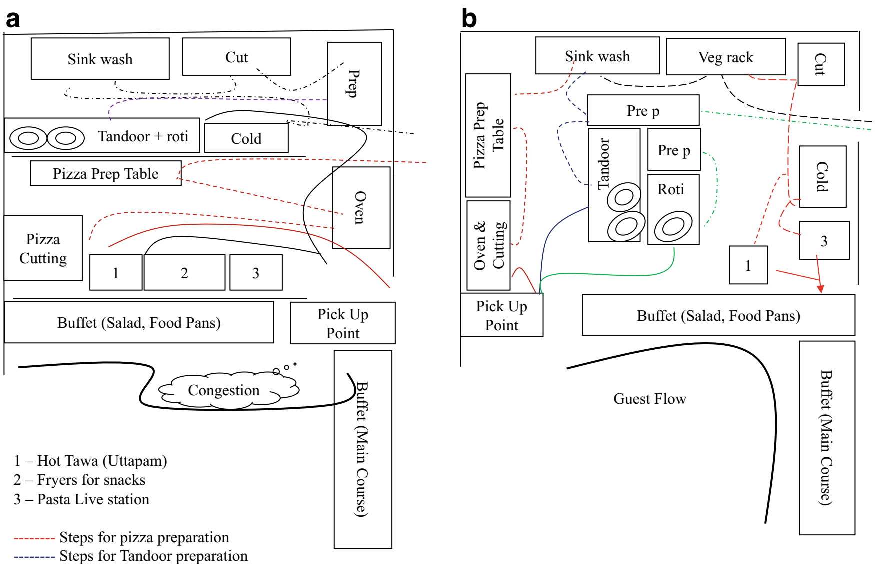


Fig. C3.9 **a** Earlier (Left) and **b** improved (Right) layout for live kitchen

counter. The congestion here was also inconveniencing guests picking up food items kept close to the pick-up point.

With the layout modification, smooth flow of work for all the starters made in the live kitchen was established while reducing strain on the chefs and their assistants. The *tandoor* snacks and rotis were also now delivered in tandem with customer requirement by adding one more *tandoor*. As the diagram shows, the new layout has also helped ease the congestion at the buffet counter and reduced inconvenience to the guests who were picking up their food. This set-up of smooth work flow for pizza enabled the implementation of the concept of customer pull.

(2) **Pull—**The oven is divided into two plates—one is used for pre baking and the other for finishing. Each plate can accommodate 2 pizzas side by side and gives a consistent quality. Hence, a simple FIFO lane-based pull system was put in place with a fixed quantity of two pizzas. This ensured that no unnecessary WIP of pizza bases builds up and no pizzas are baked in advance and become stale. This visual PULL mechanism is shown in Fig. C3.10. At any time, two sliced pizzas are on the hot plate at the pick-up point. Two pizzas are baking in the oven, if the hot plate is not empty, these pizzas remain in the oven in warm mode. As the hot plate becomes empty, the assistant chef removes two pizzas from the oven and transfers the two from pre-bake to bake while putting in two new prepared pizzas into pre-bake oven plate. He slices the removed pizza, places it on the hot plate, and then turns his attention to preparing two pizza bases to replace the ones shifted into pre-bake oven.

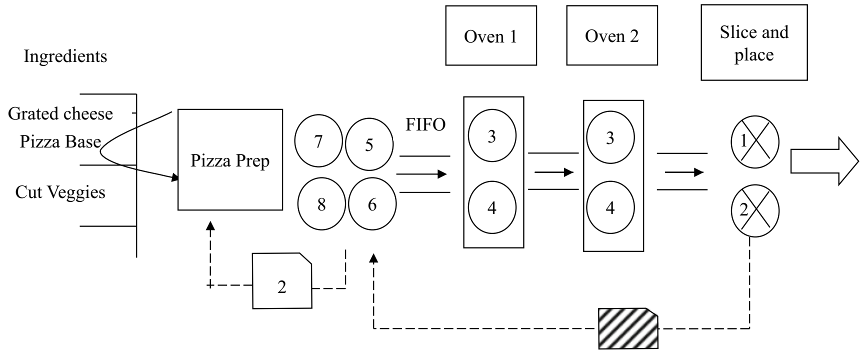


Fig. C3.10 FIFO-based pull of pizzas

Through this combination of layout change and establishing a visual FIFO lane, the team ensured that hot pizza slices are available at the pick-up point at all time.

100% Item Availability at Buffet at Restaurant Opening Time

Guests coming in just after the restaurant has opened were seen to wait as some of the food items were not yet ready in the food pans at the buffet. While the guests were not happy, their table occupancy time was going up reducing the time available for serving the next party of guests. The team first prepared the process flow as in Fig. C3.11 for the kitchen activities and then observed each activity to identify the constraints and reasons for delay in food preparation. The main factors contributing to this delay were receipt of indented material from the stores, or incomplete indents by the chefs. This led to last minute rush to stores to get the missed-out ingredients resulting in delays in pre-cooking activities. The team came out with solutions to address each of these issues and implemented them to good effect, as detailed in the following sections.

Delays in Kit receipt from stores

This was identified as the root cause for delays in food preparation. The Liberty kitchen is structured on food type basis—separate chef teams handle Continental, Chinese, Indian, *tandoor*, sweets, and deserts. Each kitchen chef places an indent for all the items needed for the next day's cooking as per the agreed menu. The items are picked off the racks and placed in a basket by the store's assistant; each basket is a kit for the respective kitchen. The assistant chef arrives at the stores by 9 am to collect the kit meant for that day's cooking. The team identified several gaps in the material procurement, storage, and issue processes and acted on each of them to improve the on time in full kit availability. These are listed in Tables C3.3 and C3.4:

The kit issues system is set such that each kitchen's kit items are placed in a basket and the baskets placed on a rack at the stores entrance. At 9 am, the assistants pick up their baskets, check the items against their indent and move on

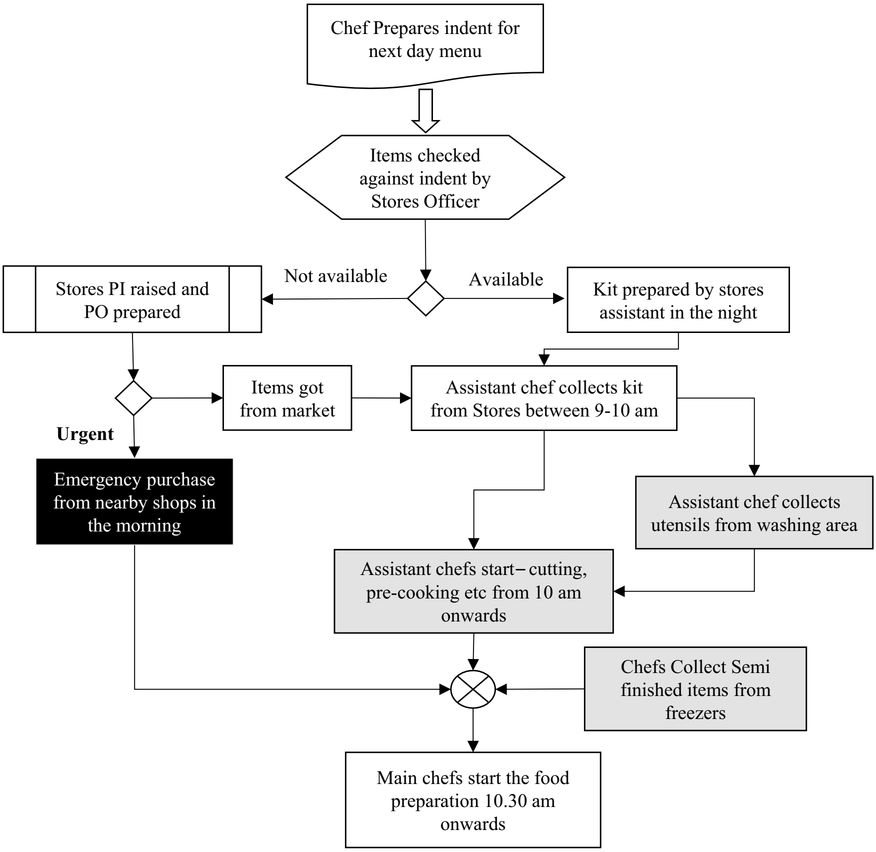


Fig. C3.11 Food preparation process flow

Table C3.3 Stock availability-related issues

Observations	Actions taken
• Many items stock not available in the stores, and this is not monitored in advance • Stock data not updated in the system—in some cases stock is available and its location known only to the stores assistant • After issue, stock is updated on paper and this data is latter re-entered into the software. There were several instances when this update is missed out	• Introduced reorder levels and defined the same in system with 10-day time based replenishment • All the items in the stores master list were sorted kitchen-wise with procurement lead time, typical daily consumption, number of days of stock to be maintained • Daily online updation every evening

Table C3.4 Storage and issues of Kits

Observations	Actions taken
• Items found mixed up in racks and cupboards and several items are found on the floor as racks were overfull • The procedure involves weighing of major ingredients before issue against the indent given. In practice, the staff found it strenuous to bring heavy flour bags from its location to the weighing scale, lift them on and take them off for issue • For several items, the indented quantity has to be made up from bulk quantity pack received from the supplier. This involved additional handling of bulk bags to and from weighing scale, transferring part quantities to the smaller bags and tying up these bags to avoid spillage • Kit preparation takes up a lot of time and effort—the assistant has to move around the entire store 6–7 times to fetch the items for one kit	• The entire stores was first reorganized to make it search free, count free and strain free while enabling FIFO as the items are all of perishable nature • Out of 12 racks, three racks removed and replaced with pallets for storing bulk items like rice, sugar, and flour • Change in layout of weighing scale to facilitate weighment and sealing • Pre-preparation of bulk pack items to smaller 1 kg/500 gm packets during the non-busy afternoon hours using bag sealing machine • Change in storage method—instead of item type wise the racks were reorganized kitchen-wise (see Figs. 12 and 13 for new store layout below)

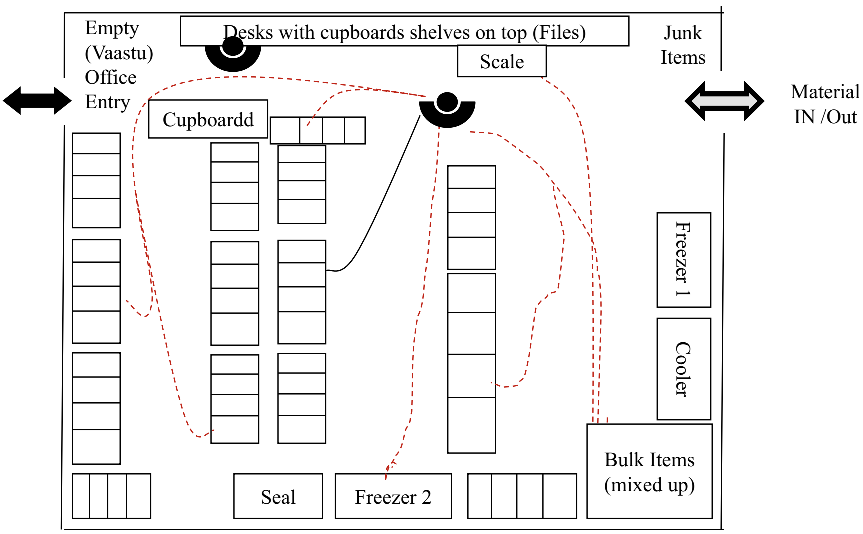


Fig. C3.12 Stores layout and an example kit preparation for one Indian kitchen

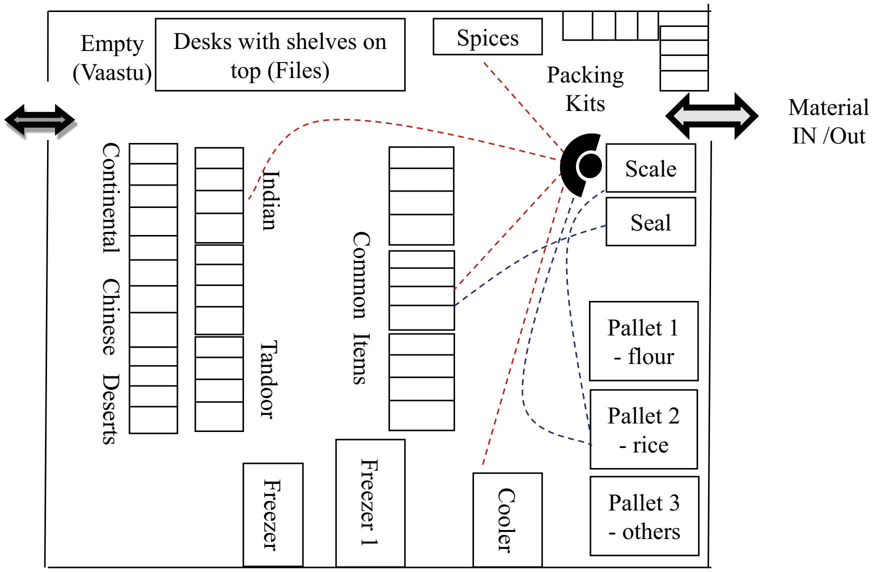


Fig. C3.13 Revised layout (blue dotted line indicates repacking into small packs which is done during non-peak hours)

to their kitchen to start food preparation. The reorganization of the stores layout helped reduce the movement of the stores assistant for getting the kits ready and simplified the process thereby enabling him to have all the kitchen kits ready well in time. The layout change was done keeping in mind *Vaastu* considerations; *Vaastu* is an ancient Indian convention of planning spaces within building structures. Figures C3.12 below shows the earlier lay-out and material movement path and C3.13 shows the revised lay-out.

The following results were seen after implementing the above improvements.

- It took just about 15 min per kit and motion reduced to less than half.
- Item stock-outs and emergency purchases reduced by more than 50%.

Incomplete Indents

Incomplete indents are second major source of delay at the time of food preparation. It was observed that the chef would miss out on a particular ingredient in the indent and realize that it is not available with him only at the time of food preparation. An assistant chef would be sent rushing to the stores to get the item issued; in case of stockout, an emergency purchase had to be initiated further delaying the cooking process.

Most recipes have been developed in house by the chefs and a lot of information is in their minds. Especially for menu items that appear irregularly, it is quite possible to miss out on the ingredients while preparing the indent. Vishal would

Table C3.5 BoM for example recipes

S. No.	Item	No. of covers		10	Basket
		Kitchen	UOM	Std Req	
1	Herb guava	Juice	ML	500	Guava juice, guava crush, chilli flakes, tabasco sauce, oregano
2	Manchow soup	Chinese	ML	1000	Ginger, garlic, green chilli, beans, cabbage, carrot, coriander, salt, pepper, sugar, soya sauce, corn flour
3	Corn *samosa*	*Tandoor*	PCS	35	American corn, capsicum, coriander, green chilli, jeera, red chilli, coriander powder, *paneer*, *maida*, and oil
4	Italian mushroom salad	Continental	GM	500	Mushrooom, bel pepper, balsamic vinegar, salt, pepper, crushed pepper, salad oil, chilli flakes, oregano, and basil
5	*Aloo Chana Chaat*	Indian	GM	250	Potato, *chana*, tomato, onion, chat masala, chilli powder, cumin powder, lemon, coriander, salt

work closely with the head chef in the menu setting and development of new recipes and he realized the importance of having the recipes on paper.

The team spent several days in developing a Bill of Materials (BOM) master using Microsoft Excel. As each day's menu was decided, the team sat down to list down the ingredients in details. The chef would do a dummy run through of the preparation and each ingredient was placed on the table in front of him in sequence to create the recipe. These details were inputted into the master sheet and a drop-down menu was created to link the master sheet with the menu sheet.

Now, as the day's menu is made, the ingredients needed for each item automatically appear next to the item. The sheet has a provision to add the estimated number of covers (guests) and calculates the food quantities to be made. Using this ready reckoner, the chef only needs to verify/input the quantity needed and prepare the indent. Table C3.5 shows a few sample entries from one of the menu sheets.

Time Wasted in Searching for Semi-Finished Items Kept in Freezers

A standard practice of the food industry is to prepare in bulk, certain semi-finished items and stores them in freezers. These items are taken out as per required quantities, thawed and used in the final preparation. This reduces the daily work and speeds up cooking without compromising on quality. Some examples include

Indian gravy, chutneys, pre-cut veggies, etc. Every morning, once the chefs begin their work, they send their assistants to get the required items from the common freezers located at a corner of the kitchen.

The core team observed this set of kitchen activities and listed the *Muda* below:

- Assistants have to walk some distance through the kitchen to reach the freezers.
- They search for the item and are able to locate it after having to remove various other items in the compartments.
- Several times the chefs had to come over as the assistants could not find the required item.

A meeting was held with the head chefs, and on their advice, a common training session was held for all the kitchen staff on 5S and visual management. After this, the core team in conjunction with kitchen staff implemented the following actions:

- Re-layout of freezers to reduce movement distance
- Within a freezer, a set of compartments was allocated to each of the kitchen sections, for e.g. Indian, Chinese, Continental, etc.
- Each section cleared out the unwanted/non-moving items from the compartments
- Each kitchen then segregated the required items within the allotted compartment shelves in the following categories:

  a. Unprocessed items such as cheese, vegetables, milk packets,
  b. Semi-finished (cooked) items such as gravy, *chutneys*, etc., and
  c. Finished (excess) items to be reheated and consumed on the same day.

To prevent accumulation of unwanted items again in the freezers, the food management system was defined clearly with the two SOPs explained below.

Replenishment of buffet to avoid food wastage—Time and quantity-based replenishment was defined. At 2 pm during lunch and 9.30 pm during dinner, the restaurant manager and head chef check the food available in the food pans. Based on the reservation position and this food stock, a decision is taken on which items should be replenished and in what quantity. This is then communicated to the kitchen and only those items are cooked again while the remaining semi-finished items are put away into the freezers. Special care is taken for items that cannot be stored at all such as, juices and certain cooked items that cannot be reheated. A leftover management was created (sample in Table C3.6) to update the stock of finished items.

Daily work checklist made and put up in respective section—This is especially critical for the Deserts section as some of the recipes involve overnight setting. The checklist sheet has the plan which is filled up by the head chef and actual completed work is updated by the section chef. A sample is shown in Table C3.7.

Table C3.6 Leftover management board

Date: 30-Oct					
Prep date	Item	Quantity	Exp date	Action plan	Status
29-Oct	Pineapple pastry	1/2 kg	2-Nov	Consume in buffet on 31-Oct	Pending

Table C3.7 Work checklist for deserts

		Date	29-Oct			
Activity	No	Item	Shift	Plan	Actual	Status
Preparation	1	Baked *rasgulla*	1	120 Nos		
	2					
Finishing	1	Chocochip tart	1	100 Nos		
	2	Chocochip tart	2	80 Nos		
	3					
Advance prep	1	Pineapple pastry	2	2 kg	1.5 kg	Material shortage
	2	Pineapple pastry	2	2 kg		
	3					
Dispatches	1	Chocochip tart	1	150 Nos	120 Nos	Shortage of base
	2	Orange cheesecake		3 kg	3.2 kg	OK
	3					

Food Preparation Time

Once all the items have been brought from the stores and required utensils are in place, the assistant chefs start the preparation which includes washing and cutting of vegetables, boiling/cooking of rice/noodles/pasta, and preparing spice mixes. Among these, the maximum time and effort is spent in vegetable cutting. A number of non-value-added activities (*muda and muri*) were observed in this process.

- Moving to and from the sink to wash and clean vegetables,
- Scraping, throwing away the outer skin and other waste etc., and
- Variation in cutting speed from person to person.

To reduce the time spent by chefs on this activity and free them up for the more value-adding cooking work, a preparation section was formed to cut vegetables, with two assistants drawn out from the existing kitchens. The layout was modified to make a cellular arrangement as shown in Fig. C3.14.

Each kitchen notes their requirement of cut vegetables in a register maintained in this preparation cell. Based on priorities given by head chef, the two-member team wash and cut the vegetables and place them in the cut vegetables rack from where the respective kitchen assistant chefs collect them.

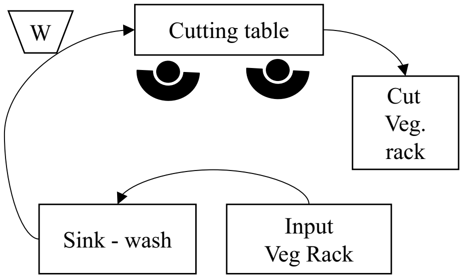


Fig. C3.14 Preparation cell—vegetables cutting

By combining the *Muda* done by each section into one preparatory section and reducing this *Muda* further through cellular layout about **half an hour time** was freed for each kitchen chef.

Standardization of Operations

Once the improvements were completed, new standards which would help in sustenance of improved processes were created. Following standards were developed and implemented:

- *Restaurant audit checklist*—A weekly checklist using 5S as the base, this was used to check the level of cleanliness, organization, and service level of each section. The highest scoring section was recognized.
- Roles and responsibilities were clearly defined for the restaurant manager, hostess, kitchen coordinator and head chef so that they can function in tandem without duplicating or interfering in each other's functions. In line with Lean philosophy, their primary function is to support the value adders such as, chefs and service staff.
- *Restaurant closing SOP*: The process of closing at night is one of the most important factors that affect the setting up of the restaurant the next morning. The restaurant closing process was observed in detail on a peak weekend night and several improvement actions identified. To standardize the whole process, a restaurant closing checklist was also prepared and implemented. Within days the closing time had reduced from 90 min to less than 60 min with complete cleaning and quality checks.

Overall Outcomes

The success of any process improvement is determined by practical measurement of defined metrics which in turn would result in the improvement in the stated business goals mentioned earlier. While we discussed process level outcomes in each section, here we mention two key overall business-related gains seen in this project:

1. Record increase of turnover per day by 40% was achieved without firefighting and not adding a single resource,
2. Improved guest service which is reflected in 20% rise in customer satisfaction levels measured through feedback forms and online reviews.

Conclusion

Lean and the standardized processes that emerged out of the intervention have given Liberty the confidence to expand their core kitchen business. In the pandemic year, Liberty has already opened their first cloud (takeaway) kitchen to great success; the kitchen SOPs are based on the same principles of speed of service (order to delivery time) while maintaining the famed Liberty taste and quality of food. Within months, Vishal has started looking at franchise owned kitchens to expand the Liberty brand.

Case Study 4: Lean Design for New Product Manufacturing

Background

While FS (original name disguised) is a well-known toy brand in India, the domestic segment is actually a small part of its operations. The major portion of its operations is devoted to third-party manufacturing for some of the world's leading toy brands.

The two manufacturing units located in the western and southern parts of peninsular India have been in operation for more than 25 years. Both the plants were operating pretty much at full capacities especially during the peak season. In 2017, a US based global toy retailer approached FS to manufacture and supply a new range of plastic moulded toys designed based on a popular cartoon show. This range of toys were expected to sell in large volumes in the global market and was currently catered to by suppliers in Vietnam and China. The global toy major was now looking to develop an alternate source to counter the effects of the escalating trade conflicts between USA and China. After several months of discussion and negotiations, FS was finally contracted to supply the range of toys to be made in a new factory, to be built to as per customer standards.

In a recent plant visit to the existing factories, the chairman of FS did not mince his words on the current state of operations there. He was upset about the excessive material transport, piles of inventories, haphazard movements, and chaotic layout of the existing factory. His communication to the top management was clear—unless the new facility was designed to work efficiently and look world class, he would not give permission for the new project. The CEO was negotiating at the time to finalize a new site which had a newly constructed but unused factory shed. He had to now live up to the Chairman's expectations in the design and execution of the new factory. A chance meeting with a former employee led the CEO to be referred to us.

The brief to us was clear—study the existing plant to understand the plastic moulded toy operations and then work with the new product development team

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in designing and executing the layout, process flow and systems at the new factory. By the time we were engaged, the team had already completed a lot of the preparation,

- The product development team had already started its work. They had, enabled by the customer, visited an existing supplier site in Vietnam and understood the manufacturing process requirements of the product range. The product range comprised a set of 6 different toys of a single product family; each toy had its own variations in terms of colour, features, and functionalities.
- The site with pre-existing building was finalized and all factory compliances taken—it was now available but had to be made ready for operation since it had been unused for a few years.
- Some of the key machinery had already been ordered based on approximate capacity calculations done with inputs from the customer.

Now, the challenge was to get the plant operational within four months for the pilot production run. Once the customer approved this, the bulk production would have to start. FS management could allot only limited funds for the site work as the company was having working capital constraints. Hence, the goal was to design and set up the operation within the pre-existing shed with minimum infrastructural enhancements.

The Challenge

The brief was to design a layout and implement process flows for a new product which was being manufactured for the first time. Hence, there was no past data or experience to help the team working on this project. What it had were a few samples of the six toy variants, some videos, and notes of the manufacturing activities from the team's Vietnam visit.

The team commenced the design with the available information. Firstly, the sample toys were disassembled and put back to understand the components and the assembly steps involved. Each of the six toy variants had two main parts—one part was a vehicle such as a car, truck, helicopter, etc. and the second part the rider of the vehicle. Each toy variant was unique in terms of both vehicle and rider with different colours, designs, and functionalities. With this understanding, they proceeded to the initial stage of process flow design.

Step I—Process Flow Design

Define Product/Service Groups Through Product—Quantity (P–Q) Analysis Based on Projected Business

P–Q analysis helps identify runners, repeaters, and strangers which have a major implication on process and layout design. In this case, the six toys of the product family were analysed in terms of customer demand projections. The peak quantities during season (Table C4.1) were considered in design capacity computations.

Table C4.1 P–Q analysis with *Takt* time (for moulding)

S.No.	Toy variant	Demand	*Takt* time (Sec)
1	Blue	4000	15.8
2	Red	4000	15.8
3	Grey	2000	31.7
4	Yellow	2000	31.7
5	Green	1500	42.2
6	Orange	1500	42.2
Total		15,000	

Calculate Takt Time and Check Feasibility of Dedicated Flow Lines

Table C4.1 shows the demand data and the corresponding *takt* time. Moulding was the preliminary and time-taking process, and hence was planned as a three-shift operation. 22 planned working hours and OEE target of 80% were assumed for the moulding. For the rest of operations (manual intensive) single shift was planned which meant that the *takt* time was one-third of the moulding *takt* time. The monthly demand was used to a compute the daily moulding production requirement as shown in Table C4.1.

For example, the blue toy had a daily requirement of 4000 units.

Available time per day = 22 h @ 80% OEE = $22 \times 60 \times 60 \times 80\%$ = 63,360 s.

Takt time = Available time/Demand = 63,360/4000 = 15.8 s.

From the table, it was evident that there was no one runner (volume leader) product, and in fact monthly customer demand projections showed that the proportions of the six toys varied from month to month. Therefore, the option of creating dedicated flow lines (for runners) was not feasible. So, the team decided to dig deeper and identify process/resource commonalities by making use of product-process (P-P) matrix for the entire family of toys.

Prepare Product-Process (P-P) Matrix and Group Resources for Products with Similar Flows

The P-P matrix helps group the set of machines/workstations/processes that are needed to make a group of products and helps identify the operating cells that can be formed to process them. The key process flows for the components are shown in Fig. C4.1.

The exercise now involved detailing the product-process linkage for each component. This being a new product for FS, there was no historical process data available. Hence, each sample toy was carefully dismantled into its constituent parts and for each part the possible process sequence was brainstormed and identified through team discussion. The inputs of the project manager and design member based on their visit to the Vietnam plant helped in clarifying doubts about the process. Estimated cycle times based on either observation in Vietnam or based on similar operations being done for other toys were then filled into an easy to

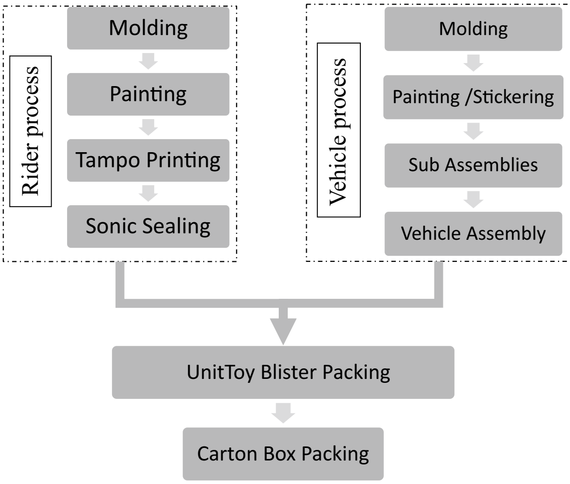

Fig. C4.1 Typical process flow chart for toy manufacturing

understand P-P matrix in visual format. The matrix for one variant (Blue Toy) is shown in Table C4.2.

The numbers in the cells represent these estimated cycle times, and the colour of the cell is the actual colour of the paint or design print at the respective process. While the base colour of the toy is blue, both the vehicle and rider have designs of different colours that are either painted using spray painting in booths or printed using Tampo (pad) printing machines. For example, a rider component such as head, may have brown face and black hair done through painting while the finer work of black eye balls is easier done through printing. A paint booth can be used for any operation or colour. Paint and mask (used to mask the not-to-be-painted parts of the component) have to be changed and spray gun cleaned for every component change-over. Similarly, pad printing machines can also be used for any component by just changing the pad and colours. These cycle times helped in the computation of number of work stations required for manual activities such as painting, assembly, and packing and machine requirement for machine centric processes such as moulding and Tampo printing.

Let us consider an example. As we saw in Table C4.1, the blue toy has a takt time of 15.8 s for a three-shift operation which translates to a *takt* time of 5 s for the single shift painting operation. This toy has multiple components and we take as an example the equipment planning for the rider components named Body RHS and Body LHS. For each of these components, the estimated cycle time for each of the four painting operations is about 10 s which means these four operations can be planned in a single-piece flow line comprising of four paint booths located adjacent to each other. One line would deliver one painted component every 10 s. Since the *takt* time is 5 s, we need to plan for two such lines or eight paint booths for Body LHS and eight paint booths for Body LHS.

In this manner, the P-P matrix gave the team complete clarity on the line balance requirements for flow and enabled the team to move on to the next step of calculating machinery requirements.

Machinery Requirement Calculation

We take the example of injection moulding machines to illustrate machine requirements calculations. Moulding machine capacity required was determined based on the mould given by the customer. For the car body component of the blue toy, daily production requirement is 4000 units per day in a 22-h operating window, and thus a *takt* time of 16 s (approximate) (Table C4.1). From the P-P matrix (Table C4.2), the estimated cycle time for moulding car body is 40 s and the mould has two cavities. So, 2 units per 40 seconds means an effective cycle time (ECT) of 20 s which is about 20% more than the desired *takt* time of 16 s. However, the team was confident of reducing the cycle time further along the way to meet the *takt* time. Hence, one 150 T moulding machine was deemed to be adequate to meet the demand of this component.

In a similar way, the machine requirements were calculated for all the moulded components. A specific parameter to be kept in mind is the moulding machine capacity (tonnes); larger machines are used for the bigger/heavier components. After this, the parts were mapped to machines and a weekly schedule drawn up to verify that all parts can be produced as per required quantities using the computed machinery. Table C4.3 gives a snapshot of the first two days schedule for different components. By the end of the week, all the components had been covered for the week's requirement. The best combination of machine configurations that minimize investment was finally selected by the team. Two insights emerged from this working.

1. Ten machines were adequate to meet the target; 150 T——5 machines. 120 T—3 machines and 80 T—2 machines. The layout could now be made for these machines.
2. Up to a week's inventory of moulded components may need to be stored in racks, the number of racks to hold this needed to be calculated and space provided in the layout.

Other process machinery requirements such as Tampo printing and paint booths were also computed in a similar fashion.

The final processes were the assembly of the vehicle part of the toy, followed by unit blister packing. Each pack contains one vehicle and one rider and these packs are in turn packed in carton boxes for dispatch. While dismantling and reassembling the sample toys, the team had been able to record approximate assembly (fitting) time. The toy was designed for press fit by hand or by using simple jigs and hand tools. In addition, there were design stickers to be hand pasted onto the vehicle body. The team felt that since assembly and packing were totally manual, the processes could easily be designed, implemented and fine-tuned once the plant operations began. It was enough at this stage to just earmark the

Table C4.2 P-P matrix for "model blue toy"

Product - Process Matrix

<u>Note:</u> All values are in Seconds. Colors of the cell indicates paint color. Cell Merging implies combination of the component

Product Name	Parts	SN.	Components	Moulding: Ups in no's	Moulding: 180T	Moulding: 150T	Moulding: 120T	Moulding: 80T	Decorations: Painting 1	Decorations: Painting 2	Decorations: Painting 3	Decorations: Painting 4	Decorations: MH Tampo-1	Decorations: MH Tampo-2	Decorations: Tampo Printing 1	Decorations: Tampo Printing 2	Component Assembly: Glue/Sonic 1	Component Assembly: Glue/Sonic 2	Component Assembly: Heat & Fix	Component Assembly: Gluing	Component Assembly: Stickering	Component Assembly: Stickering	Fin. Assy.: Snap Fit	Fin. Assy.: Tampo - BC	Packing: Blistering	Packing: Fix Vehicle	Packing: Box Forming
Model Blue Toy	Vehicle	1	Car body	2		40			10	16	10										20	20	80	8	25	25	40
		2	Chassis	4		40																					
		3	Drive cab handrail	8			40		10																		
		4	Outer Wheels	4		40																					
		5	Keylock																								
		6	Wheels hub	4			35																				
	Rider	7	Hat	8				35	10	10										15				8			
		8	Head front	16				35	10	10			15	15				15									
		9	Head rear	16				35																			
		10	Body LHS	4			40		10	10	10	10			8	8	12										
		11	Body RHS						10	10	10	10			8												

Table C4.3 Moulding machine requirements for 'blue toy'

Sl. No.	Moulding M/C ton	Day 1			Day 2		
		Shift 1	Shift 2	Shift 3	Shift 1	Shift 2	Shift 3
1	150T	Car body	Car body	Car body	Car body	Car body	Car body
2	150T	Chassis	Chassis	Chassis	OW and Key	OW & Key	OW and Key
3	120T	Drive cab handrail	Drive cab handrail/TC*	Wheels hub	Wheels hub	Wheels hub	
4	120T	Blue toy body LH/RH	Blue toy body LH/RH	Blue toy body LH/RH	Tool change and cushion	Water bomb	Water bomb/cushion
5	80T	Blue toy hat	Blue toy hat/TC	Blue toy head front/TC	Blue toy head rear/TC	Red toy hat	Red toy hat/TC
6	150T	Car body	Car body	Car body	Car body	Car body	Car body
7	150T	Chassis	Chassis	Chassis/TC	OWF, OWR & Key	OWF, OWR & Key	OWF, OWR & Key
8	150T	Llad/DecLH& RH/Hand	Llad/DecLH& RH/Hand	Llad/DecLH& RH/Hand	Llad/DecLH& RH/Hand	Llad/DecLH& RH/Hand	Llad/DecLH& RH/Hand
9	120T	Whe Hub F/Whe Hub R	Whe Hub F/Whe Hub R	Whe Hub F/Whe Hub R/TC	Red toy body LH/RH	Red toy body LH/RH	Red toy body LH/RH
10	80T	Head F/R	Head F/R/TC	Long pin/short pin/TC	Rotate arm	Rotate arm/TC	Fan blade/TC

work area for assembly and packing operations as a block in the layout drawing. Assembly would be done on tables and the number of tables; its orientation and other aspects could be worked out during the pilot production and ramp up stages.

Process Flow Design—Flow and Pull

Now, the team was able to move on to the final step of freezing the entire process flow design. The key question that needed to be addressed was the location of segments for continuous flow and supermarket pull. The process-wise considerations that went into this decision are listed below:

- Constraints on investment, limited the number of **moulding** machines, which meant multiple changeovers to provide all the parts needed for a toy. There was therefore a need to produce and maintain a small batch of most parts before doing the changeover.
- **Painting** is a manual operation and the cycle times are similar or adjustable through line balancing and hence it would be easy to maintain smooth flow.
- **Tampo printing**, though a machine operation, is simple and cycle times easily balanced. So, machines could be grouped into cells that can be allotted to one or more toy variants in sequence.
- **Assembly** needs all the parts, i.e. entire kit for a toy to be readily available; these parts come from multiple sources including moulding, painting, printing and directly from stores as well. Hence, it was necessary to have a supermarket from which compete kits can be issued to the assembly lines.
- **Packing** was a manual process that could be easily linked on line with assembly lines and hence it was proposed to have continuous flow

With these considerations, the rough future state VSM was drawn as shown in Fig. C4.2.

Two supermarkets were defined in future state with the following rules:

Super market 1—Two days inventory of moulded components based on weekly customer order schedule. As parts are pulled by the painting/printing/subassembly operations, the racks are refilled with the next item in the schedule—this is a sequenced pull situation.
Super Market–2—Supermarket for kitting—all parts required for the toy are placed one day prior so that assembly goes ahead as per schedule.

Since there is continuous flow from assembly onwards, the daily schedule is planned at this "pacemaker". Supermarket 2 triggers the production of upstream processes.

Step 2—Freezing the Layout

Now that the process flow had been defined and the type and number of machines/workstations for each operation fixed, the team then moved on to freezing the layout design. Since this was a new facility, the team had the advantage of starting with a "blank slate"—a built up but empty shed and the land around it. The goal was to arrive at the best possible physical material flows through the plant in accordance with the process flow design. This meant that the following aspects needed to be kept in mind while making the layout:

- Minimum material transport distance,
- Minimum material handling—number of touches,
- Sufficient storage facility for peak requirement—raw material and finished goods,
- Incorporate global customer specifications and requirements.

Inspect Physical Location (Built up Area/Land) on Site

The team arrived at the site to examine the site's condition and noted the actual dimensions, positions of doors, windows, and entry and exit points. The location for provisions for electricity, water source and existing drainage were all marked on the layout drawing. In addition, office block, land slope, and height with respect to the shutters were all marked.

Compute Space Requirement

After making the calculation for all the facilities required, the space occupied by the machines and workstations were calculated. To calculate the space the machine foot print was taken (the machine size along with the working clearance). Since most of the machines were still on order, the suppliers were contacted, and this

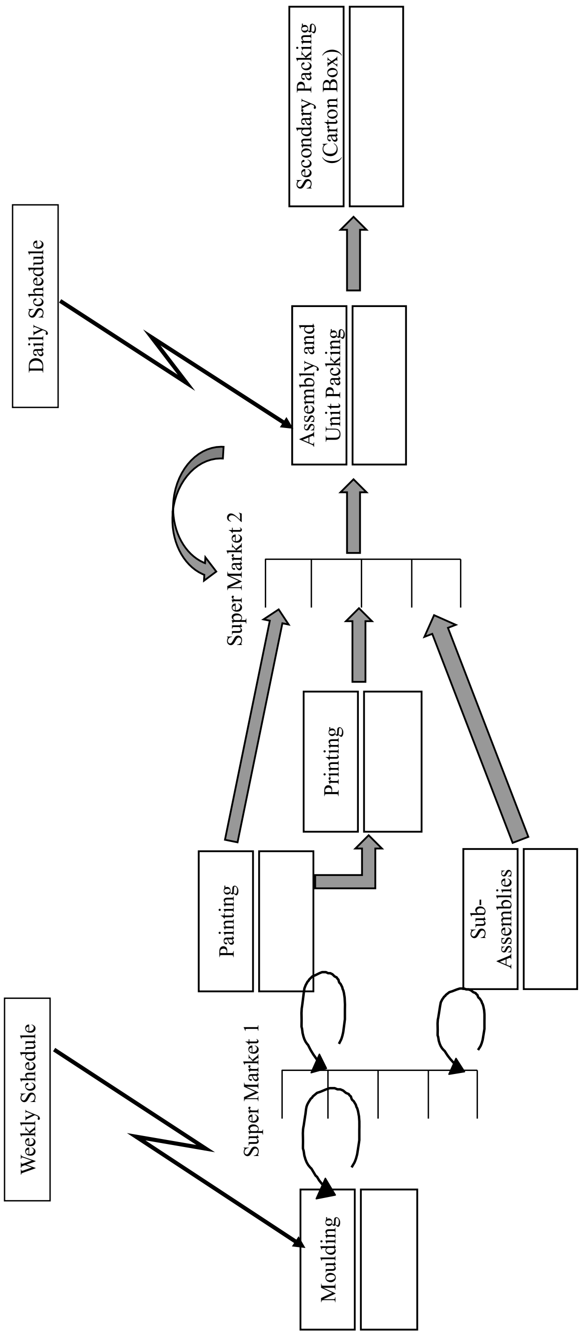

Fig. C4.2 Rough future state VSM

data was collected from them. The calculation for raw material stores and the Finished Goods warehouse involved computing maximum stock levels for all the major items and computing the space requirement considering effective use of vertical space. The rack space for the two WIP supermarkets was also factored in to the layout.

Finalize Layout Drawing

The design engineer who was part of the team was then tasked with preparing the first cut of the layout using AutoCAD software. He took into account the following inputs for this drawing:

1. Process flow design as per Step 1,
2. Physical shed measurements and details noted during site visit,
3. Special factors to be considered for adherence to factory laws and customer requirements.

Ultimately, the layout underwent multiple iterations as successive brainstorming sessions brought up alternate options that fine-tuned previously suggested layouts. After eight revisions, the final agreed layout was then taken up by the plant manager and project manager to plan the required civil works for the machines to be installed as and when they arrive. Some of the specific considerations that went into the layout finalization are:

- Dust and fume extractor set-up needed for painting booths—hence, the paint booths needed to be close to the building wall to connect to the extractor outside.
- One operator to manage two injection moulding machines influenced the parallel placement of these machines,
- Multiple assembly lines to assemble a mix of toy variants feeding a common secondary carton packing line,
- Cell grouping for the Tampo printing section.

The finalized layout with overall broad material flow is shown in Fig. C4.3.

Step 3: Physical Implementation of the Designed Process Flow and Layout

Physical Placement of Machines

As the machines arrived, they were put in position in accordance with the finalized layout drawing and all the required auxiliaries—electrical, pneumatic and hydraulic, water inlets and drains to enable operation of the same. The stores and warehouse areas were cordoned off with fences and storage racks were put in place. The assembly tables were also placed in the allocated location.

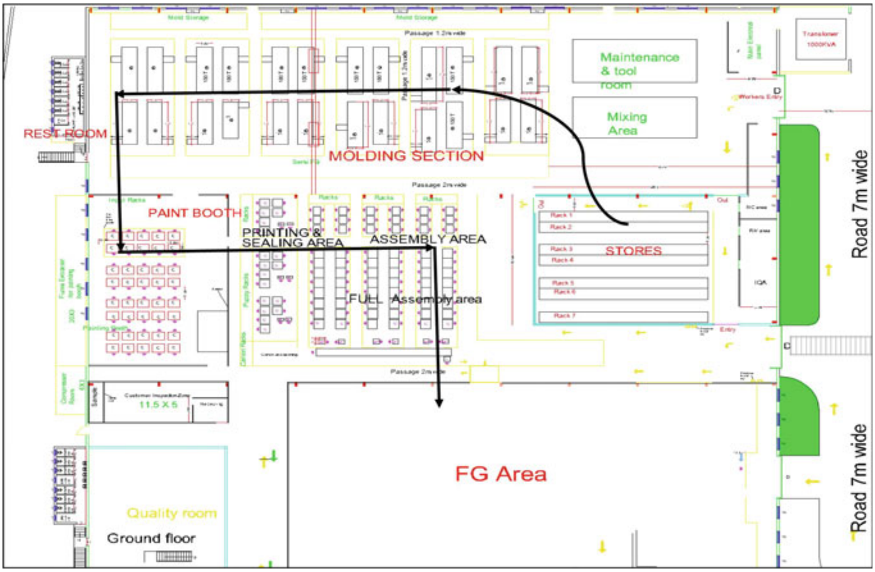

Fig. C4.3 Final layout

Pilot Production—Manufacturing Design

Initially, the customer had asked for a sample of about 50 numbers of each toy variant to be made, packed and sent to them for manufacturing approval. This was the first time the product was actually being made at FS and the team used this opportunity to observe and understand the *Muda*, *Muri*, and *Mura* in assembly and packing. As we saw earlier, the team had decided to finalize the assembly and packing process layout at this stage.

Operations such as stickering, wheel assembly, top assembly, and packing were observed in detail. Some operations such as wheel and hub cap fixing were converted into offline sub assembly operations which could feed all the assembly lines. Each assembly workstation was fixed including positioning of jig/fixture, component arrangement, tools, input and output placement and the operators were made to practice during the trial production stage.

The biggest constraint was in the blister packing of the toy—fitting the toy into the pack and tightening the "locks" was a strenuous job. Since the locks were located behind the pack, the fingers had to do this job by feel, resulting in high cycle times that varied from toy to toy.

As a remedy, a wooden fixture was developed where the pack is placed, toy fitted in position with the locks facing up to the operator giving her the visibility to complete the packing without any unwanted motion and strain. Cycle time could thereby be reduced to match the assembly time resulting in a balanced line.

The final assembly and unit packing line was a waist height work table with six workstations. The number of workstations in use depended on the toy variant;

some vehicles had more complexity and utilized all the stations while others could operate with three or four workstations. Each workstation was designed to accommodate all required components in plastic bins in front of the operator and the extra inventories stored below the table to be used for replenishment of the bins.

All the people working in this plant were newly recruited as this was the first such factory in the area. Women who comprised the majority of the workforce were from nearby villages and were working in a manufacturing industry for the first time. They all had to be trained on the operations such as painting, printing, and assembly from ground-up.

Ramp Up Stage

Within two months of pilot production, the plant had reached a production level of 6000 toys/day. The process and plant had been designed for 15,000 toys/day and the demand from the customer was picking up and there was an urgent need to ramp up and standardize the operations. By this time, the factory team including supervisors, engineers, planning, stores, and logistics executives was in place. They were to be responsible for the day-to-day operations of the factory.

At this stage, we conducted a Lean workshop for the newly assembled factory team, focusing on observing the running process to identify areas for improvement. Three-member cross-functional teams were formed for the moulding, painting, printing, and assembly processes. Key observations were shared as below:

- Process was designed with two days of supermarket inventories after moulding but more than a week's WIP was actually found in the racks spilling over onto the floor while some of the items in the running schedule were in shortage leading to incomplete assembly kits.
- The painting process was just about able to make parts for about 6000 toys per day and this was therefore identified as the bottleneck to achieve the ramp up target.
- WIP of parts seen in trays all over the printing area—while the scheduled production was running in a hand-to-mouth situation.

Based on these observations, improvement projects were identified in all the four major processes and were executed within the next couple of months.

Improvement Projects

Project 1: Line Flow in Painting Process

At the initial process design stage, the process route for each component had been defined in the P-P matrix based on available data from the other manufacturing location. But in the pilot production phase, several parts underwent process changes—for example, a part originally designed for printing was now undergoing painting. The team also observed multiple handling of painted components between one stage and the next as the allocation of paint booths as per process flow had not yet been finalized.

The team first established this line flow for all toy parts. For each part, there are multiple painting operations which were allotted to adjacent booths to support single-piece flow. All the operation cycle times were studied and booth allotment done based on line balancing principles so that the parts can flow through all the stages as shown in in Fig. C4.4.

The line flow was maintained for a month as per the booth allocation. However, the team recorded that even at the maximum cycle time of 15 s, instead of an output of 1680 parts, the actual output was only 1200–1300 parts per shift. Further observation showed that each booth would frequently stop painting operations for mask cleaning. The components were covered by masks so that only the surface area to be painted is exposed. After every few components, the masks need to be cleaned of the paint build-up to avoid quality issues. To minimize this loss, spare masks were purchased and a *mizusumashi* (material feeder) was allotted for material feeding and mask cleaning. Every 15 min, she exchanges all the used masks for cleaned masks, brings them to the cleaning station, and cleans them.

With these improvements and extending painting into a two-shift operation, the capacity went up to match the target requirements.

Project 2: Cell Formation—Printing and Sealing

The painting and printing sections were linked through a small rack containing painted components. Quality cleared painted components were placed in small trays and kept in this rack from where the concerned printing cell members pick it up for their work. However, several trays of partially processed parts were also observed on the floor which pointed to a lack of flow in the printing section. The rider toy parts needed multiple printing operations, 2 stages of sonic sealing

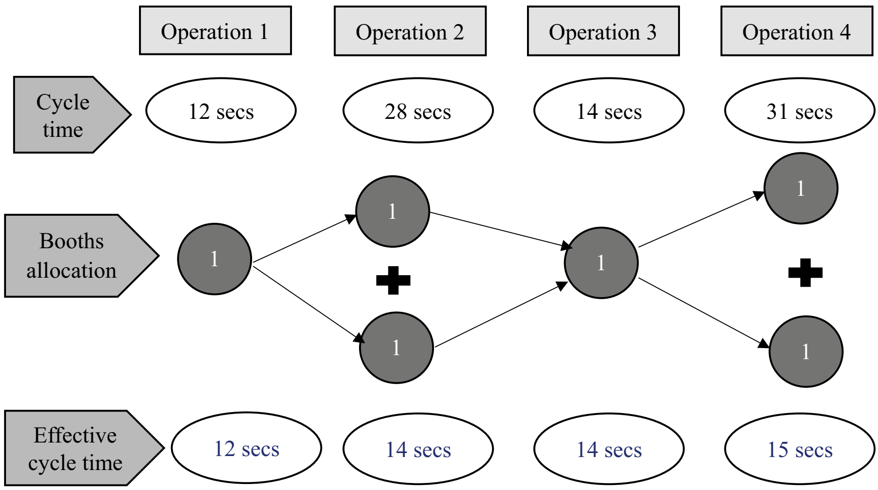

Fig. C4.4 Booth allocation and flow balancing in painting process and a glue-based head fixing operation before the rider is complete and ready for packing.

A product-process matrix was made for this section for the six toy variants and two identical cells were formed based on similarity and quantities required. Each cell comprised of Tampo printing, sonic sealing and glue fixing workstations. The cells were handling the rider part of the toy. Each rider consisted of two body parts (left hand side and right-hand side), two head parts (front and back) and a cap or hat. The cells were run in flow as follows.

Cell 1: Body parts LHS and RHS run in parallel and joined together in sonic sealing process.
Cell 2: Head front and back processed.

Head and body attached in second sonic sealing stage; the cap glued on in the final station.

Since each cell would handle multiple variants within a day, the schedules were made to ensure flow and completing the required quantities within the day. Fig. C4.5 shows the cell layout.

Project 3: Mixed-Model SKU Assembly and Packing
The original process design envisaged the final carton box pack to contain the toy variants in the approximate ratio of the monthly requirement. As per the original P–Q table, this ratio was blue and red 2 each, grey and yellow 1 each, green and orange 0.75 each. But as the plant operations gained momentum, it was realized that customer orders vary widely in terms of final pack size. Each order would have a different combination of the 6 toy variants to be packed into a single carton. The carton sizes also varied as can be seen from the order position for a particular week shown in Table C4.4.

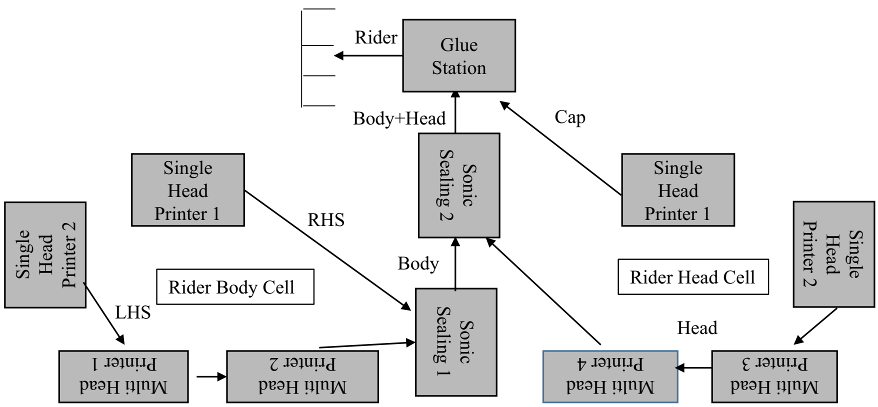

Fig. C4.5 Cellular layout at printing

Table C4.4 Customer orders in a typical week

PO No	Toys per carton	Pack ratio	Order size (cartons)	Line allotment (No. of Lines)	No. of days run
1	6	Blue—2, Red—2, Grey—1, Yellow—1	15,000	Blue -2, Red-2. Grey-1, Yellow -1	5
2	3	Green—3	3000	Green -1	6
3	4	Orange—2, Yellow—2	4500	Orange -1, Yellow -1	6

The assembly and unit packing lines were standardized for flow, and workstation arrangement and quality checks were such that a stable 1500 units were being produced per day per line. The layout was made to provide for 10 such lines—5 on each side of a motorized belt conveyor. These lines were flexible and any line could take up any toy within half a days' notice. To meet the demand as shown in Table C4.1, nine lines were allotted accordingly. Blue and red toys had a capacity of 3000 toys per line (twice as much as the other variants) as they had less operations. Hence as per the schedule above, all three POs would be running at the same time.

Each assembly line would deliver a blister packed toy onto the moving belt conveyor and these unit packs were being placed into the carton box by a packing team positioned at the end of the conveyor. However, while the assembly lines were well set, the team observed a lot of stress and strain for the carton box packing operators. They were placing the unit packs again on holding tables, where different variants were getting mixed up and the conveyor had to be stopped repeatedly to clear the backlog. Operators were moving around trying to grab the required toy unit pack to be put into the carton box as per the packing list.

A separator table was created—smooth laminated top on which the unit packs could be separated and placed without damage and this top was at an angle so that unit packs slid down to the end with a slight push. Fig. C4.6 shows this separator table.

Aeroplane wing layout was created at the carton packing zone at the end of the conveyor to ensure smooth packing operation with minimum operator strain due to movement, reduce number of touches of the unit packs and continuous flow of packing, final quality clearance and move to the FG warehouse. One operator stationed at the end of the conveyor picks up the unit pack and places it in the allotted row in the separator table. Packing operators stand along the table with the carton box positioned on a stand below the table; they pick up the required unit packs and place them in the carton boxes, seal the completed box and place it on the adjacent pallet. The modified assembly and packing layout is as shown in Fig. C4.7.

Fig. C4.6 Separator table at carton packing

Project 4: Standardization through Lean Scheduling Model

Once the complete physical material flow had been set in accordance with the process design, the team started working on finalizing the complete planning system. In designing the Lean information flows, pull-based scheduling were put in place. The scheduling philosophy was nicely captured in the slogan, "No Kit No Cut", meaning if the assembly kit is incomplete the assembly lines would not run putting pressure on the upstream processes such as moulding to make only what is needed, and in the quantity needed so as to fulfil the kits demand. The planning model is shown in Fig. C4.8.

The customer provides a three-month rolling demand forecast based on which a monthly plan is made for SKU-wise quantities for the next month. This activity is completed in the first week of the month and purchase orders/intimation placed to suppliers. While imported and smaller materials are procured by the 25th, packing materials which are bulky are procured in two lots—first by the 25th of the current month and second by the 10th of the next month.

The month's plan is converted to 4 weeks rolling production plan by the 25th, i.e. one week before and this incorporates any changes by customer or backlogs expected from current month. Every Wednesday, a firm production schedule for the next week is made for the pacemaker (the assembly process). Information on bought out parts, packing materials and raw materials is taken and only those pack combinations for which entire "kit" of materials is available are scheduled. A schedule given to assembly for D-date will translate to the painting schedule of D-1 date and the moulding schedule for D-3 date.

All finished goods (FG) are quality approved online and transferred to the FG warehouse and orders are dispatched from time to time as per customer schedule confirmations. To facilitate monitoring of operations and throw up deviations in the

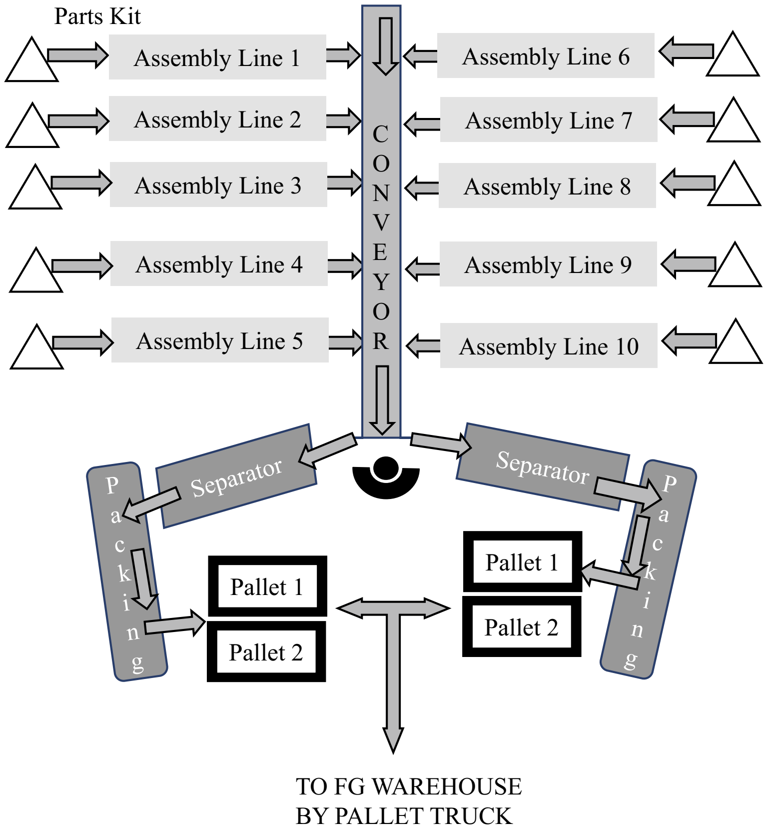

Fig. C4.7 Assembly and packing layout and material flow

process/plan for immediate action, several visual management tools were deployed both on the *Gemba* and electronically. These include an hourly production plan vs achieved board at each process, an assembly kit status board for each customer PO and an electronic raw materials kit status in a spreadsheet used by the planner.

Outcomes of the Project

FS had to design, execute, and run a completely new factory with a product variant that was completely new to them. This began with the initial process design and layout finalization in September of 2017. While this was taking place, the company was working on completing the site acquisition and legal registration process in parallel. Civil works began from end of 2017 and machines started arriving from the New Year. By April 2018, most of the machinery and facility was in place. The next six months were spent in implementing the layout and ensuring ramp up

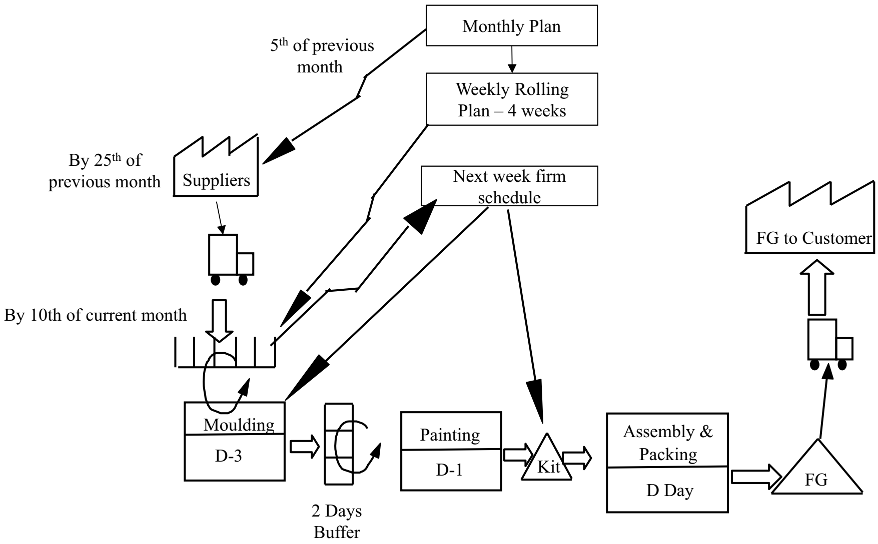

Fig. C4.8 Final planning model

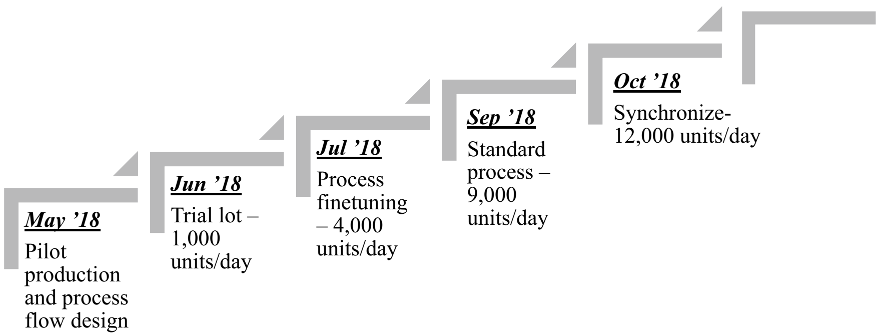

Fig. C4.9 Fast ramp up for from project execution to full production output

to the designed capability levels. Figure C4.9 shows the progression of this phase and the overall outcomes of this Lean design and implementation project.

Following are some of the highlights of this project.

- Consistent output of 10,000 + units per day is being achieved from November 2018 and comfortably meeting the customer peak season requirement.
- World class visually managed facility meeting global customer standards.
- Pull-based planning system enabled and line flow operations ensure that WIP is kept to a maximum of three days.

- Quick ramp up, streamlined operations, and quality standards being met have made the customer happy, and they have already given the go ahead for another set of new products requiring further expansion.

Case Study 5: Lean at Gubba Cold Storage

Background

Gubba, though an SME, happens to be India's largest cold storage company in terms of capacity. The company has multiple cold storage facilities (called plants) spread out cross the outskirts of Hyderabad, India. With seed cultivating regions and major pharmaceutical manufacturing in and around Hyderabad, the company's focus on seeds, pharmaceuticals, and food products seems to be well placed.

The earlier generation of Gubba family was involved in food products and traded tamarind. With the opening of their first cold storage facility in 2000, Gubba has been on a continuous growth trajectory led by the second-generation family members, brothers Kiran and Prashanth. Elder brother Kiran takes care of the finance, sales, HR and administrative functions and Prashanth handles the core operations, technology, and projects.

Gubba has always been on the forefront of technology, processes and systems. In their early years itself, they internally developed their own software application for managing the entire operations such as, truck loading/unloading, storage and invoicing. Having global agri-business giants including Bayer, Syngenta, and Pioneer Seeds as customers have driven Gubba to implement the best practices for safety, inventory management, pest control, and plant operations and maintenance.

By 2012, the company was a leader in the cold storage industry and Kiran and Prashanth were on the lookout for newer opportunities to grow. Is there anything more they could do to add value to their customers while improving business and profitability? It was at this point in time, that Prashanth had the occasion to meet one of his friends Ashish, who was working in his own family-owned enterprise, manufacturing deep freezers and bottle coolers. Ashish spoke to Prashanth about how his factory had been transformed through a Lean initiative leading to a huge increase in output, turnover, and profitability. This struck a chord with Prashanth, who took the initiative to contact the same Lean expert and invite him to Gubba for a discussion.

And soon after Gubba began its Lean journey under our guidance!

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G. Mahadevan and K. C. Chejarla, *Lean Management for Small and Medium Sized Enterprises*, Management for Professionals,
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Operations

The seed industry is a seasonal industry with a significant time-gap between seed production and sale to farmers who plant the seeds during specific times of the year. Seeds have a tendency to germinate in a warm and humid atmosphere; hence, the need to preserve these seeds in a low temperature, low humidity storage facility in the interim period. The seed companies therefore often use contracted cold storage facilities in order to store the seeds either closer to the markets or to production facilities. The logistics are handled by the seed companies themselves; after grading the seed in their plants, the seeds are packed in either jute bags (50 kg per bag) or large jumbo bags (1–1.5 metric tonnes per bag), loaded onto trucks and sent to Gubba. At Gubba, these bags are unloaded and stored in their cold storage plants. Whenever the demand for seeds picks up, the seed companies communicate the details of seed variety and quantity to Gubba and send their trucks to collect these. Thus, Gubba's services cover storage and preservation of the seeds.

Gubba operates three types of facilities—conventional storage, racked storage, and a standalone frozen foods storage plant. In conventional storage, the jute bags are manually unloaded, moved, and placed at the storage location within the warehouse using elevators (chain lifts) to access other floors. Jumbo bags are handled through forklifts. In racked storage, the bags are placed on pallets and the pallet put into a rack using a combination of forklifts, pallet trucks, and sleeves on rails. In recent years, the racked storage has been upgraded to handle pharmaceutical products which have more stringent storage and handling norms. The frozen food storage plant is a separate unit, and is not discussed in this case.

To avoid any discrepancy between what the customer has sent and what is received at Gubba and vice versa, an assistant supervisor is deployed during truck unloading and loading to count the bags and tick them off against the delivery *challan* (manifest or packing list). This cross-check is meant to verify the quantities of seed varieties based on the following three parameters.

1. *Seed Type:* For example, paddy (rice), cotton, wheat.
2. *Hybrid:* Within a type, say paddy, there are multiple hybrids, the hybrid is a specific variant developed by the company
3. *Lot Number:* The same hybrid can be produced at different locations/times and are defined by specific lot numbers.

Typical organization structure at each of the Gubba plants is shown in Fig. C5.1.

Contract labour gangs are employed to load and unload bags from the truck in the case of conventional cold storages while material handling equipment is deployed to handle palletized goods and jumbo bags.

Each plant can handle 2~3 trucks at a time and the assistant supervisors are deployed there for monitoring the loading, storage and unloading operations. The computer operator handles documentation and ERP entries from the office located at the entrance to the plant. The plant supervisor handles customer interactions with respect to material arrival, requirements and is responsible for overall upkeep of the plant and maintaining the storage conditions in conjunction with the

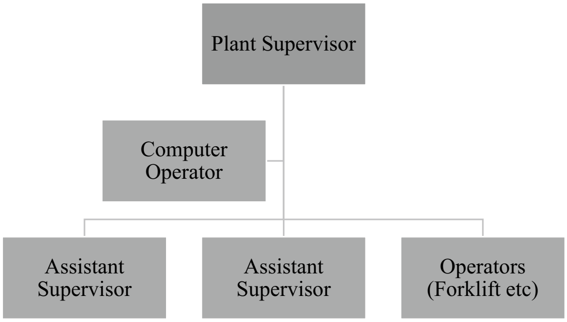

Fig. C5.1 Plant organization structure

refrigeration team. Each plant or group of plants have a refrigeration unit for maintaining plant temperature between 12 ~ 14 °C. The refrigeration unit is handled by a technician who reports to a Technical Head overseeing all the Gubba plants.

The Lean Journey

We know that Lean espouses maximizing value addition which is defined as the transformation of material into a product or information into a service. Hence, in manufacturing industries the stores and warehouse are considered as support functions and non-value adding as such. How then do you implement Lean in a cold storage facility which is essentially a warehouse for storing material? We do this by considering the core purpose of storage as value adding.

Lean philosophy talks about *"Doing more and more with less and less"*; more output with lesser use of resources. Applying this philosophy, Gubba's operational performance is measured in terms of storage capacity utilization and ability to handle customer receipts and dispatches in the shortest possible time. From the resource utilization angle, storage space, trucks and people were the main resources. Considering these factors, the team set the following goals for Lean:

1. *Maximum utilization of warehouse space*—This has a direct impact on the business profitability as the main cost of storage is refrigeration, which is directly proportional to the extent of space refrigerated.
2. *Minimum Truck Turnaround Time*—inward and outward—This enhances customer satisfaction as each truck is used for multiple trips on a given day.
3. *Maximize people productivity*—Personnel cost is a significant component for both Gubba and the customers who are charged for this.

Lean was initiated towards the end of 2013 with an initial four-month burst of improvement activities between December and March. Since seed arrivals and dispatches are at a peak from March–July, the Gubba team validated the results of the Lean initiatives taken during this peak time. Having done that, the stabilization phase kicked in and continued till the end of the year through development and implementation of standard operating practices (SOPs). In 2015, a core cross-functional team was formed to audit the adherence to these SOPs and highlight deviations. Repeated deviations were analysed and solutions implemented to improve these practices further. This was the path adopted to sustenance of Lean practices.

Another four years later, Gubba reconnected with us to look at taking Lean to the next level. In the interim period, a new customized ERP had been developed and put in use; this software incorporated critical points of the SOPs in an error-proofing mode which automatically ensured compliance. The booster Lean intervention of 2019 focused on the corporate functions including purchase, accounts, sales, HR, and administration while relooking at the information flow at the plants. More details on each phase of Lean are discussed in the following sections.

Initiating Lean Through Focused Improvement Workshops

The plant operations team was entirely composed of young males aged below 30 years, most of them were high school drop-outs and a very few were graduates. However, their first and only job till date was with Gubba and hence already were quite fixed in their outlook to work. For Lean to take hold it was therefore essential to break the team's complacency and charge them up. Initially, one plant of each type (conventional/racked storage) was selected and teams were formed to focus on the two primary goals—truck turnaround and space utilization. A series of three-day focused improvement workshops were conducted towards this objective. During the workshops, cross-functional teams were formed to take up specific improvement projects across the various plants. The team leader would be the supervisor of the plant, team members would include an assistant supervisor, computer operator from the same plant, third from another plant and a fourth member from the corporate team (safety office, quality, systems, etc.). These workshops are akin to Kaizen events; every morning we would conduct a training session; the teams would then work on the *gemba* the rest of the day and get together again at the end of the day to share their experiences. Prashanth involved himself fully for all the workshop days, sending a clear message to the employees on the seriousness with which Gubba is taking this Lean initiative.

On the **first day**, the Lean expert gave the teams a basic orientation on how to observe the process under Lean paradigms in order to identify *Muda* (waste or non-value added), *Muri* (strain), and *Mura* (inconsistencies/variations). The teams then spent the day observing the process and came out with a list of observations and opportunities for improvement therein. These were shared in the evening with the rest of the teams and Prashanth, and actionable points were decided.

Actions involving change in practices or methods of doing work, some modifications in equipment/tools to help workflow and reduce strain were implemented on the second day. A few strategic decisions were taken on how the process should be run and the new ways were tried out.

On the **third day**, the same process was observed to verify and validate the impact of changes made and results measured. A fortnightly action plan was prepared to complete the balance action items and these were monitored till completion on a daily basis at the plant level and a weekly basis at the management level.

We look at some of the key projects that were taken up.

Improve Space Utilization

For a cold storage facility, value addition comes through space while the biggest cost is also incurred in keeping that space at a specific temperature. At the outset, we drove one simple Lean paradigm repeatedly into the minds of the plant operations team "Cooling ***is meant for the seeds***". So, any space in the facility occupied by other things or lying empty is non-value adding from this perspective. It meant money is spent on refrigerating unwanted items or simply cooling empty space.

In the conventional (non-rack) storage, the seed containing jute bags are layered akin to bricks; each layer has bags oriented at right angles to the adjoining layers. If the first layer has bags placed length-wise, the next layer on top of it will have the bags width-wise and so on. Each such stack, called a *thappi* in the local language, is formed in a bay (a rectangular area marked by pillars and walls). Each storage bay is numbered in alpha-numeric term, and the material movement pathways are depicted with dotted arrows in the top view of a typical floor in Fig. C5.2. A typical conventional storage plant has about five such floors.

The first thing the team observed was the uneven heights of seed bag *thappis* in different storage bays, resulting in unutilized space above some of the *thappis*.

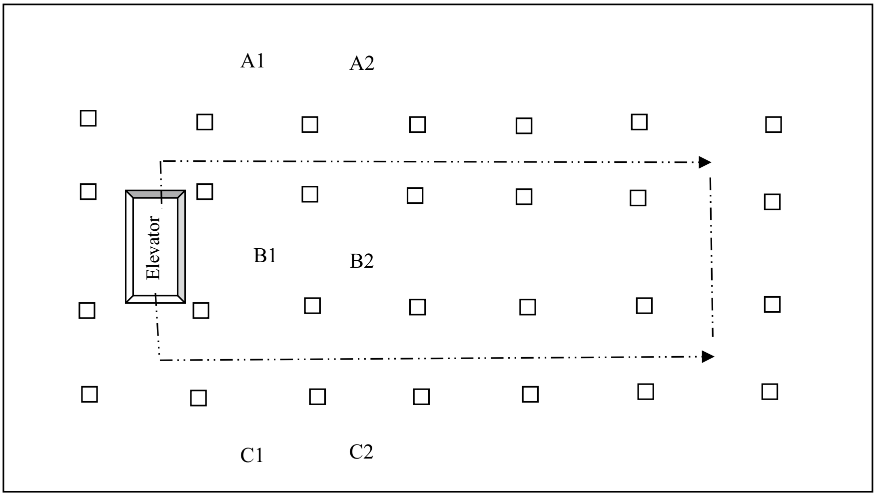

Fig. C5.2 Top view of storage layout in a typical floor

One reason for this was to keep different lots or hybrids in separate *thappis*. While this practice facilitated easy and direct access a given lot (during retrieval or stock checking), the loss of cold storage space had a much bigger cost implication. A decision was taken to store different lots or seed hybrids within a bay by separating the last layer of one lot from the first layer of the next lot with a coloured tarpaulin sheet. Each lot already had a stack card (similar to a store bin card) while the bags were also marked with the lot number. This arrangement necessitated extra internal shifting (discussed in the next section) which involved additional labour cost but this expense was far less than the refrigeration cost of unutilized space. Besides, the internal shifting work could be scheduled during idle times of *hamalis* (contract labour). *Thappis* could now be stacked to the maximum height and a level indicator was painted on each pillar serving as a guide to the *hamalis* who manually stacked the bags.

In the racked storage, the team counted a total of 4400 pallet slots available per cold storage plant. Additionally, the average weight of the loaded pallet was only 1.3 MT against the designed capacity of 1.5 MT implying 13% underutilization. The main reason for this was the difficulty in stacking the regular bags on the pallet for bulky (less dense) seeds like cotton. As the bags are not compact, the stacks reach the maximum height within the slot before the weight limit is reached. As the racked storage facility was dedicated to a few key large customers, Gubba was able to convince them to send the seed in jumbo bags of 1.5 MT capacity which could be easily accommodated in the racked slots. At the ground level of the rack, there was no such weight restriction. These slots were therefore allotted to pallets and bags weighing more than 1.5 MT.

Like the conventional storage, 20% of the racked slots were only partially filled, to keep customer orders separate. A similar policy of segregating customer lots with a separator and storing another lot in a different pallet on top of the existing pallet was implemented.

Within a couple of months of implementing these improvements, Gubba had increased the racked storage capacity from 1.3 to 1.5 MT/slot and overall space utilization in the storage facility by 7 ~ 10%. The resultant reduction of refrigeration cost per tonne directly boosted up the bottom line as customers pay for storage on a per tonne basis.

Reduce Truck Turnaround Time

Trucks meant to drop or to pick up seed are arranged by the customers whose plants are generally located within a two-hour radius of Gubba plants. The customers would like to utilize the trucks for multiple trips in a day to optimize costs. From this perspective, the sooner trucks are turned around at Gubba, the faster they can get back to the customer plant for another trip.

A cross-functional team was formed to observe the end-to-end process of "Gate-In" to "Gate-Out"; this process determines the overall time the truck is held up at Gubba. The essential activites in truck operations are physically placing the bags into the truck (if loading) or lifting bags out of the truck (if unloading). Every other activity can be categorized as unnecessary *Muda*, and contributes to truck waiting. Hence, the team's observed the entire process under the paradigm of **zero waiting time of truck.**

The team categorized their observations into three buckets and identified and implemented solutions in each bucket separately.

Gate-In to Docking

Trucks arrive at gate and wait. At Gubba's largest campus (Yellampet) consisting of six plants, the security at the main gate first checks which plant the arriving truck has to be sent to. At the docking point of the plant, if other trucks were already under process, then the newly arrived truck is sent to a parking area to wait its turn. Finally, when the truck is able to dock, the driver hand's over the delivery *challans* (manifest) to the assistant supervisor who then goes into the office and ask's the computer operator to check the location(s) of the seeds to be loaded (for dispatch) or empty location(s) where incoming seeds are to be unloaded. Through this period, the truck would be waiting. The computer operator then generates an inward or an outward memo sheet with the location(s) information and gives this along with a manual tally sheet (for cross-checking the bag count) to the assistant supervisor. The assistant supervisor proceeds to the docking point to commence the process. *Hamalis* (contract labour) are called and allotted positions to start the loading/unloading process. After observation and analysis, the team concluded that the major reason for truck waiting was that this entire preparation process prior to actual loading/unloading began after the truck has docked. And the root cause for this is the uninformedarrivals of trucks from customer locations.

After a brainstorming session focused at finding solutions to this problem, facilitated by Prashanth, the team decided to implement a system of "*Pre-Alerts*" where the plant supervisors would interact with their regular customers every evening to get information about the trucks expected on the next day. The supervisors were worried that implementing this radical new step would spoil their relationship with the customers. Over the years, customers were used to just sending the trucks and then pressurizing Gubba to quickly send them back. How would some of these global and local giants react to a small organization like Gubba asking them for prior information? To overcome this initial hesitancy, Prashanth and Kiran took the lead in communicating about the new "*Pre-Alerts*" to all the customers. The communication focused on how the customer would benefit through faster truck turnaround just by providing this basic information in advance. Already customers were sending a copy of their requirements by email. If truck arrival details are also known, the supervisor could plan labour, material handling equipment and advance internal shifting of seeds inside the plant.

Finally, a pre-alert form was introduced. The supervisor would speak to all major customers daily and fill up the details in this form. Based on the truck ETA, he would instruct assistant supervisors to prepare in advance. One of the activities of preparation is internal shifting. In many instances, different hybrids and lots are stored in the same bay, with bags stacked one above the other to maximize space utilization. Internal shifting involved removing the lots on top in order to access the required lots from below. In some cases, the *hamalis* would also remove and keep the required seed bags in the anteroom to facilitate loading. Similarly, if incoming material was expected the next day, internal shifting would clear suitable area for the bags of incoming seed to be stored.

In the first few weeks, less than 25% of the trucks were pre-alerted. The team patiently kept sensitizing the customers and some of the customers started noticing the improvement in their truck turnaround for pre-alerted trucks. As the season wore on, pre-alerts were up to 70% which meant at least 7 out of 10 arriving truck details were already known. In the last couple of years, the pre-alert sheet has been upgraded to a mobile application linked to the rest of the ERP. Plans are afoot to have these apps installed at the customer logistics team system so that information is fed once by the customers, and gets transmitted instantly to Gubba, without errors.

Actual Loading and Unloading Process

The team now moved on to observe the actual loading and loading process from the perspective of zero waiting. They recorded instances when no activity was happening while the truck was docked on the bay. Further analysis yielded the following major reasons for this waiting:

(1) Delay in either locating the material (for loading) or empty space (for storing) and the need for internal shifting to continue the job. The team could address this issue through pre-alerts as we saw in the previous section.
(2) Short stops of the elevator as the *hamalis* inside the store area are unable to offload the bags in-time during unloading.
(3) Gaps or empty platforms in the moving elevator when the *hamalis* are unable to place bags on each platform in time during loading.

To understand the short stops and gaps, we need to understand the layout of the warehouse. Each warehouse has five storeys including a basement level. The truck docks at ground floor. During unloading, the bags are lifted from the truck by *hamalis* and carried through an anteroom to the motorized chain-link elevator which operates at a fixed speed. Each bag is placed on a small platform attached to the chain as it is moving and the same bag is removed at the allotted floor (level) by another set of *hamalis*. Each *hamali* carries one bag at a time to the storage point, places it in neat stacks (*thappis*) and walks back to the elevator to pick up the another bag. The same process is done in reverse in the case of a truck being loaded. Figure C5.3 depicts the elevator layout in the plant.

While the distance from the truck to the elevator is fixed, the distance from the elevator to the storage location varies depending on the storage point (see Figs. C5.2 and C5.3). Therefore, the number of *hamalis* needed for continuous flow of material on the storage floor varies depending on the distance moved. The short stops were mainly cases where the flow rate was out of sync. The elevator moves at a fix speed and the seed bags placed on each elevator plate reaches the

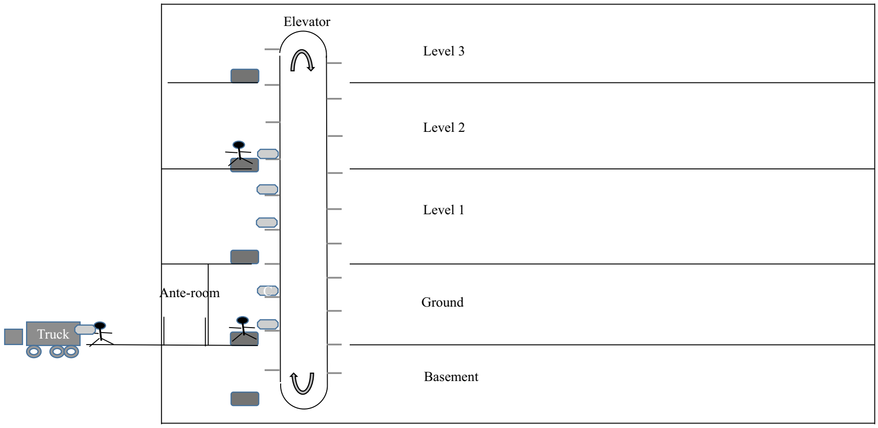

Fig. C5.3 Elevator layout

unloading floor platform within a few seconds. If a *hamali* is not available to take off the bag, the elevator is stopped by the unloader and restarted only when a *hamali* arrives to take off the bag.

A basic time study helped the team note the time taken to and from different points in the floor. Based on this, the number of *hamalis* required to synchronize with the elevator speed was calculated. This was verified by allotting the 'calculated' number of *hamalis* for a few trucks and observing again to see if there are short stoppages or empty plates (on the elevator). Once the team had verified the calculations, a standard was fixed for number of *hamalis* to be allotted for three different ranges of storage locations. This standard now serves as a guide to the assistant supervisors enabling them to efficiently allot *hamalis*.

Documentation and Dispatch of Truck

To ensure no discrepancy between customer and their own material count, Gubba had introduced tally sheets. The delivery *challan* (DC) brought by the truck driver has the details of seed lots. The assistant supervisor would copy the lot numbers on to the tally sheet and then maintain count against each lot received or dispatched on this tally sheet. These details would be then added up and sent to the computer operator who would then make an inward/outward memo which served as a gate pass for the truck to leave Gubba premises.

The team observed that anywhere from 10 to 20 min were lost in this documentation procedure. During this time, the truck continued to wait at the dock. The process flow chart in Fig. C5.4 a depicts the step-by-step existing procedure.

The team brainstormed and implemented a revised process that, with a slight modification in the software, made the computer operator's role redundant thus reducing document hand-offs (Fig. C5.4b).

Minimizing the documentation, need for multiple printouts and simplifying the inward memo and gate pass helped the team reduce the truck waiting time.

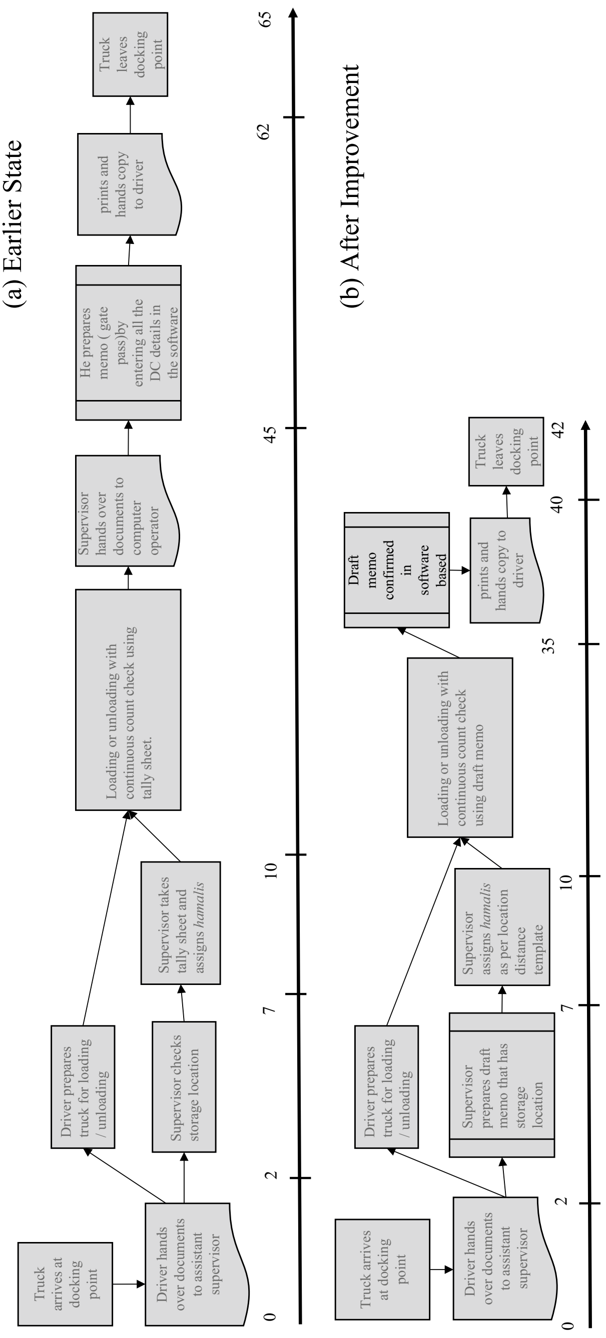

Fig. C5.4 Earlier and improved truck turnaround process

The Result
Through all these improvements, the average TAT for a 10-tonne truck was reduced from **70–75 min to 40–45 min**. The labour productivity went up as the idle time of *hamalis* reduced with them being involved continuously in the actual loading/unloading activity. Gubba was adding new facilities, and the "redundant" computer operators were retrained to do the work of assistant supervisors at these new warehouses. This helped Gubba reduce the cost of manning the plants by avoiding new hiring.

Standardization

The pre-alert form was updated with the actual truck arrival time and exit time from Gubba premises. With this information, the turnaround time of each truck could be tracked. As the ERP was upgraded and mobile applications developed it was even easier to capture this data without errors. At the gate the security officer now records the in and out time on the mobile app. Similarly, the assistant supervisor captures the dock in and out times. This data is presented in graphical format against the specified standard of 3 min per tonne for actual loading or unloading and five minutes per truck for documentation. Hence for a 10-tonne truck, the standard TAT is 35 min, and for a 15 tonner, it is 50 min.

Performance of various Gubba plants is compared and monitored on this parameter which has been incorporated as a KPI for the plant supervisors.

Stabilization Phase

In the peak season months following the initial round of improvements, the team was hard-pressed to maintain the improvements achieved. While, space utilization was ensured, these was still some firefighting to turnaround trucks within stipulated times, especially on the days with a peak load of over 50 trucks a day. Still the employees benefitted through a definite reduction in strain. While in previous years, they would stay till the night to complete the day’s loading and unloading; in this season, such occasions were few and far between. By end of the season, Prashanth estimated that Gubba had sustained about 60% of the original implemented improvements.

Post the peak season, the stabilization phase of Lean was launched through framing and implementation of standard operating procedures (SOPs) that would incorporate all the good practices implemented during the improvement phase. As a preursor, a TPM facilitator was invited to conduct a couple of training programs on autonomous maintenance for the refrigeration technicians and material handling equipment team. Abnormalities were identified and corrected, CLRI checklists developed and implemented and the existing Planned Maintenance sheets fine-tuned.

Standard operating procedures (SOPs) were then written for the entire gamut of operations at the plant including the interactions with corporate functions. Each SOP was written by the core team comprising of operations manager, group supervisor, quality manager under our guidance. This SOP would then be reviewed by Prashanth, discussed again with the concerned functions, revised as required and finally approved by Prashanth for roll out. The SOP incorporated all the improved practices and additional checks and verifications to ensure these would be followed. A sample SOP for material inward process is shown in Fig. C5.5.

The entire cycle of framing, reviewing, and freezing the SOPs took three months. By December, the team was ready to roll out and a launch event was organized. Prashanth and Kiran headlined this one-day event which began with Prashanth explaining to the plant teams, the relevance of SOPs. The structure of an SOP was then explained to the team. Two-member teams were then formed, with each team tasked to validate the current status of a couple of SOPs at the *gemba*. By lunch time, each team had identified the gaps in SOP adherence and the things to be done for ensuring compliance to the SOPs. These included floor marking, cleaning of cupboards, pallet segregation, visual markings on equipment, switches, etc., in other words basic 1S, 2S, and 3S activities needed to be done. Some quick fixes were taken up on the same day to demonstrate management intent and Kiran concluded the day with a stirring motivational address to the team. By the end of December, 5S was in full swing and Gubba plants were getting ready to adhere to the SOPs in the upcoming season.

In February, we along with the core team conducted the first SOP audit. Gubba team was familiar with customer audits and took them seriously. Hence, a typical 5S assessment wast weaked and re-branded as a SOP audit with the 5S scores being replaced by a count of the number of SOP deviations. This first audit also served to train the core team on the art of assessment as they were to take over the Lean initiative from us. A monthly audit schedule was fixed for the first three months coinciding with the 2015 peak season. A deviation register was created in Google sheets and shared across the plants and with Prashanth and Kiran. The deviations were captured with evidences such as a photo or video and the auditee (plant supervisor) was expected to take corrective action and record the evidence in the adjacent column of the sheet. At a glance, Prashanth was able to see plant-wise deviations and how many had been corrected, enabling him to intervene with the plant supervisors when needed.

A trend chart of deviations for each plant was also put in place for the monthly reviews. Once a month, all the plant supervisors met at the corporate office for a team lunch followed by a monthly plant performance review during which half an hour was kept aside to discuss the SOP adherence status. The core team also started looking at the data on repeat deviations within a plant or across plant locations. In line with a typical *Kaizen* approach, repeat deviations were analysed, root cause(s) identified and improvement actions implemented to prevent them from recurring.

Gubba also began implementing a reward and recognition scheme for employees wherein the best improvement ideas are appreciated in various forums like the newsletter, the notice boards, and in various internal forums.

Process Number	Process	Sub process Number	Sub Process
10	Receipts (Inward)	10.1a	Planning for racked storage
		10.1b	Planning for Conventional Storage
		10.2	Gate Entry - In
		10.3a	Unloading for racked storage
		10.3b	Unloading for conventional storage
		10.4	Gate Pass Generation & Gate Entry - Out
		10.5	Gate Entry - Out

Sub Process SOP

Sub Process Number: 10.1a

Sub Process: Planning for racked storage

Activity No.	Activity (Step)	Document Ref.No.	Responsibility
1	From the pre-alert sheet filled up the previous day, call transporter 1 hour before the truck ETA to reconfirm its arrival time	Pre-alert Sheet	Supervisor
2a	If the truck is delayed, reschedule the same in the pre-alert sheet and inform the client accordingly.		Supervisor
2b	If the truck is on time inform the Assistant Supervisor to prepare for unloading the same		
3	Keep ready the required *hamalis* if PP bags are expected, also alert the pallet truck operator to be ready for unloading.		Assistant Supervisor
4	From PACT system, check the availability of suitable slots for storing the expected material. Physically verify the condition of these slots as per *Racking SOP* and get the same cleaned and rectified if required.		Assistant Supervisor
5	In case truck gets further delayed, call up the client/transporter again and follow up.		Supervisor

Fig. C5.5 SOP of material inward process

Leveraging Technology to Sustain Lean

The practice of SOP audits, corrective actions, looking for repeat deviations, and trying to improve practices had become a routine in Gubba by 2016. In a couple years, it became evident that a few recurring deviations needed different solutions to permanently solve them. For example, the pre-alert sheet not being filled up or stack card updation not happening at the storage points were issues that cropped up in audit after audit across plants. Additionally, the existing mix of manual formats, updating the data again in Google sheets, and then compiling MIS from these sheets was proving to be cumbersome and error prone. In fact, a lot of time was going into these activities rather than the final analysis, decision-making, and execution of improvements.

Around this time, Prashanth started looking to improve or replace the existing software with a newer ERP. Technology especially with respect to smart phones, internet connectivity, and mobile applications had developed at an express pace in the last few years and Prashanth spotted an opportunity to leverage this. Through a referral, he got in touch with a local ERP developer who was using open-source technology to build custom ERP applications. Prashanth tied up with this firm and started work on a new ERP. Within a year, the basic version was up and running; Prashanth then recruited a bright young functional consultant into the corporate team to work on upgrading the basic version with add on functionalities. Most of the SOPs were integrated into the software so that the required MIS was generated automatically. More importantly, SOPs which were being repeatedly deviated from were integrated in an error proofed manner into the software.

We saw earlier that a pre-alert sheet would often remain unfilled and it was not clear whether supervisors were actually speaking to customers and taking pre-alerts. This pre-alert format was now in a mobile app installed on the supervisor's phone. Similarly, the earlier gate entry SOP had the security filling up manual registers for entry and exit of trucks. Now, they would fill it up in a mobile app while physically verifying the truck making it a lot easier to ensure. Since both the pre-alert and the actual truck arrival is on the ERP, trucks without pre-alert are automatically highlighted, and if more such deviations are observed, the concerned plant supervisor is counselled.

Another major deviation seen was the non-updating of stock location following internal shifting. In the existing process, assistant supervisors note the changed location on a scrap of paper when they are monitoring the shifting inside the plant. They are then expected to fill up these details in a separate "internal shifting register" kept at the plant office. The new locations were then to be updated in the ERP software. Not doing this resulted in delays in loading at a later date when the stock was not found at the location given in the software. The new mobile enabled ERP solved this problem as well. Assistant supervisors can now update the location at the time of shifting directly on their phones instead of using scraps of paper. The rest of the processes were rendered redundant since the ERP is automatically updated with the location details.

From these two examples, it is clear that most SOP deviations occur when the SOP is cumbersome or hard to follow consistently. Using technology to simplify and make it easy to follow ensures adherence in the long run while also alerting immediately of any deviations, without the need for special audits. In fact, by 2019, Gubba had reduced the frequency of SOP audits and the type and content of each audit was also restricted to the essentials.

Lean in the Latter Years

Over the years, Gubba had some success in Lean. Improvements made in the initial intervention have got institutionalized through the SOPs. Some processes have been improved further under Lean paradigms of eliminating or minimizing *Muda*. Error proofing and improved standards have been incorporated through technology. But what Gubba had not been able to achieve as yet was the spirit of continual improvement. Lean thinking had not become a way of life for the employees and initiatives to keep improving processes and standards was not a part of the company's DNA.

This reality struck home when in late 2019, Prashanth and Kiran decided to relook at the processes and activities that had become a routine over the past five years. Another round of focused improvement workshops was planned. But the objective this time was more towards expense reduction through optimization of people. Gubba was under some financial pressure due to market conditions and felt that by reapplying Lean principles and reducing non-value-added activities, there would be a reduced need for the people who perform these activities. We were roped in once again to guide the teams in this renewal of the Lean program.

Rationalization of people has never been an objective of Lean and no wonder then that enthusiasm of both the consultants and the team was markedly less than in previous years. Relooking at plant operations now using the new ERP software threw up a large number of non-value-adding duplications and clearly showed a reduced need for supervisory attention. The earlier structure of one plant supervisor with two assistant supervisors was continuing and it was now seen that a plant could easily be managed with one assistant supervisor. Another reason for this rationalization is the off-season period of more than six months during which the incoming and outgoing transactions are only a fraction of that in the season. The supervisory staff are on the company rolls and therefore a fixed cost which yield no real benefit for this off-season period.

Another solution which came up for discussion involved having a common team of supervisory staff at the cluster locations like Yellampet (with six plants) and Medchal (with four plants). On a given day, the assistant supervisors could get assigned to the trucks as they come in irrespective of the specific plant where they have to load or unload. This idea though sound in principle did not find traction with the plant teams who gave all sort of reasons for not attempting it. In earlier years, the operations manager, a management graduate brought in from outside, had embraced and driven Lean activities. After his departure, one of the brighter supervisors was elevated to this position. During this intervention, he was also unable to convince his colleagues and supervisors about the need for improvement. It was clear that the employees, the same ones who embraced Lean with gusto in 2013–14 had become too well entrenched and complacent in the system.

A similar intervention targeting corporate office functions went somewhat better as the new ERP had clearly thrown up the need to eliminate a lot of non-value-adding paperwork and duplicating activities being done on Google sheets. In fact, the new ERP itself was called into question on a few processes. For example, the purchase process involved multiple approvals leading to an increased time between indent and actual purchase. A why-why analysis threw up the reasons and almost half the approvals were found to add no value and were done away with. Customizing the technology to suit the operating procedures of the company, rather than other way round, is very important for lean to sustain, as can be seen in the case of Gubba.

The action points that emerged from these workshops between December 2019 and February 2020 were in progress when COVID broke out, throwing the whole team off gear and Gubba has had to redefine the way of working over the last one year to adapt to the "new normal".

Conclusion

When Kiran and Prashanth went ahead with engaging us in 2013, Kiran was still sceptical on whether Lean would really make any difference to their business. In his words "We had already put in place the best systems and processes and felt we were operating at the maximum possible level in terms of capacity". He was therefore pleasantly surprised by the response of his employees and the outcomes of the initial Lean improvements.

The focused improvement workshops brought together diverse employees, promoted teamwork and a sense of achievement which left everyone on a high. A 10% increase in storage capacity utilization is a huge gain for a cold storage facility. The ability to turnaround trucks at an industry leading benchmark of 3 min per tonne sets the standard for others to try and emulate. Coupled with the productivity increase in supervisory staff and overall look and feel of a world class plant through SOPs and visual management have definitely given Gubba a positive Lean experience. In the words of Prashanth "*Before Lean we thought we were already the best and there is nothing left to improve. But Lean opened up a different paradigm and this in turn gave rise to a whole new set of improvement opportunities and ways of thinking*".

Prashanth, a system-driven and tech savvy person, had always been implementing innovative practices and systems. With his growing belief in Lean, he was the key driver in developing several permanent solutions to simplify SOPs and ensure adherence through the ERP software during subsequent years.

On the flipside, the inability to maintain the momentum given by the first couple of years of Lean and allowing complacency to set in among the employees has meant that Gubba has still not realized the true and full potential of Lean. The years ahead will tell us whether they can reignite the passion for improvement and bring in a lasting cultural change or remain content with past achievements.

Case Study 6: Applying Lean to Problem Solving in the Pharmaceutical Sector

Background

A decade ago, the Indian pharmaceutical industry had just begun its growth trajectory with the opening up of the global market. Large Indian pharmaceutical companies were contracted to supply to global majors which in turn drove the expansion of the local supply chain as they developed vendors to supply the various bulk drugs and intermediates required by them. These vendors were mostly SMEs. As the demand rose, these SMEs often struggled to meet the customer delivery time expectations. For most part, the SME bulk drug units stayed with the tried and tested formula; make one or two products for one of the large pharma companies with a fixed set-up employing the minimum people needed to run the operations. Once the product was trialled and approved, there were no further changes. The process was standardized and continued that way as long as the concerned product was in demand. Margins and earnings were fixed and a few, if any, thought of growth or dynamic expansion.

At this time, GTZ, a not-for-profit organization of the German government, was working on a scheme to help SMEs improve their long-term sustainability and growth prospects. Mr Chandrashekhar Reddy, who led GTZ in India, was open to new ideas related to process improvements and technology that could help SMEs work towards the twin objectives of sustainability and growth. A referral led to a meeting with Ganesh Mahadevan at the GTZ office, where the idea of a targeted Lean intervention at select SMEs was born. GTZ invited SME owners to a seminar titled "*Performance Improvement through Lean*" which was attended by more than thirty entrepreneurs.

Two of these entrepreneurs came forward and expressed interest in applying Lean to improve their operations. Over the next couple of months, they managed to rope in a third SME and formed a mini-cluster to implement Lean at their units. All three were young second generation entrepreneurs who had finished their studies in the USA, worked briefly at other large organizations there and returned to India to join their respective family businesses. The stint abroad had

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G. Mahadevan and K. C. Chejarla, *Lean Management for Small and Medium Sized Enterprises*, Management for Professionals,
https://doi.org/10.1007/978-981-19-4340-9

Table C6.1 Key differences between discrete and process manufacturing

Parameter	Discrete Manufacturing	Process Manufacturing
Product	Unique, easily identifiable	Undifferentiated, often not visible during the process
Measurement	Discrete, one unit of product remains through-out the process	Weight/volume can change from one process step to the next
Operations	Not continuous, each can operate independently at its own rate	Continuous, all the steps are generally linked
Key components	Assembly of parts, Bill of Materials	Mixing of ingredients, recipes/formulations
Outcome	Reversible, parts can be reworked as change is only physical	Irreversible, often chemical change

given them a basic awareness of Lean as well as the openness to try something new which had not been attempted in bulk drugs sector before.

The manufacture of bulk drugs typically involves material synthesis in reactors, separation of the liquids in centrifuges and drying of the wet product mass in dryers before the final dry product is packed. The liquid by products from the centrifuges/filters may undergo distillation for solvent recovery. The remnant liquid is finally sent for effluent treatment. The effluent may be either completely treated and discharged from the factory itself or partially treated and sent to common treatment facilities.

At that time, there were very few documented cases of Lean implementation in this industry. So, with a sense of adventure the bulk drug SME mini-cluster kicked off a six-month long pilot Lean initiative exploring the use of Lean concepts, tools, and techniques in resolving their constraints, getting better in operations, and enabling them to grow.

Applicability of Lean in Bulk Drugs

With its origins in TPS, most of the Lean tools and techniques like SMED, workstation design, line balancing, and error proofing were initially developed to improve flow of material in the machining centres, press shops and assembly lines. However, a process industry such as bulk drugs is quite different in several key parameters as we see in Table C6.1.

Most importantly, material flow is by design an integral part of process manufacturing. All the steps are already linked (usually) and material flows from one step to another; in this sense, the bulk drug manufacturing process can be called Lean by nature. So, was there any scope for applying Lean here to obtain significant gains? We will now see how Lean was deployed to improve processes here through a few specific. examples from all the three SMEs.

Setting Up the Cluster

Two factors were key to this cluster.

- The industry owners knew each other. Two of them, Vamsi and Chaitanya, were cousins while the third member Srinivasan was a friend
- Each of their factories was making a unique and different product for a different customer, so there was no competition.

We planned to have focused improvement workshops at each of the three factories wherein team members from the other factories would also join the cross-functional teams to learn and apply Lean concepts and tools. They were expected to then use the learnings to improve their own processes. We would review the progress in all three factories post each workshop. This cross-factory team formation and learning was quite unique considering it was cross- organization as well and actually contributed to the success of the implementation in two specific ways.

1. Process observations by the "outsiders" were rational, as there was no emotional or intellectual bias towards the process
2. Solutions for improvement were enriched by the different set of experiences and practices being followed in their respective factories.

The initiative began with the usual current state assessment and drawing up of a unit-specific Lean roadmap. This exercise was conducted independently at each of the three factories involving the key functional in-charges of that factory. The concerned owners were was also involved in all the workshops and reviews in their factories.

Current State Assessment

The first step in a typical Lean implementation is to assess the current state with respect to the business goals and opportunities and identify the constraints. An improvement roadmap of series of projects is then framed for logical and sequential elimination of these constraints. The example of Porus Drugs (SME #1) shows how such a roadmap is made for this industry.

Porus was producing and delivering about 28 TPM (tonnes per month) of Product X for a European customer until now. For the coming year, the customer signalled an intent to increase the purchased volume to 40 TPM. This served as the primary target for the Lean intervention at Porus with the management goal being to increase output quickly without having to necessarily invest in new infrastructure. A value stream map (VSM) was developed to assess the current state for product X which is manufactured through a series of processes.

In a discrete environment, VSM is made using data from practical observation. Cycle times and changeover times are recorded by observing the process when it is on. Most of the cycle times are in seconds or minutes and thus observation, measurement, and recording is practically feasible. In the pharmaceutical industry, the reaction cycle times are often of the order of several hours and the process is not visible. However, it is mandatory to maintain a detailed batch record and in this case the process data from the records of recently completed batches was compiled to prepare the VSM. The steps for making current state VSM are described below.

Step 1: Set target output based on projected customer requirement. For Porus, this was 40 TPM of finished product X.
Step 2: Convert target to *takt* time. Calculation for product X is shown below.
Available time: 30 days x 24 hrs = 720 hours per month
Customer demand: 40 TPM ÷ 500 kgs per batch = 80 batches per month
Takt time = Available time ÷ customer demand = 720 ÷ 80 = 9 hours per batch
Hence, the plant is expected to deliver **one batch of finished product every 9 hours** and every process in the value stream has to produce at this or a faster rate.
Step 3: Compute batch equivalent so as to have a common output measure for all the processes. This is again a unique feature of chemical industry. Unlike discrete manufacturing, the output to input ratio varies from process to process depending on the chemical reaction. For Product X, final product batch size was 500 kgs of finished product, but batch equivalent varied for each process.
Step 4: Compile process-wise data from the batch records and input the same into VSM format. To identify any *Mura* (process inconsistencies), not just the average cycle time but the minimum and maximum cycle times and the standard deviation were all computed and incorporated into the VSM.
Step 5: Identify constraint or bottleneck(s) processes which need to be improved. Basically, any process whose cycle time is more than the *takt* time is a bottleneck. However, processes with too much variation can also impact the lead time, and therefore should be targets for improvement.

The VSM data for Product X was captured by using these five steps as shown in Table C6.2.

The bottleneck processes are those with average cycle times more than target *takt* time of 9 hours and it can be seen that there is also a large variation from batch to batch. The core Lean concept of value-add and waste was incorporated in this VSM as well. Activities within the process where a change in material property or characteristic takes place are value-adding and the times taken for these activities were summed up as the value-adding time for the process.

The process value-adding ratio is the value adding time divided by the total cycle time, and gave an indication of the scope for improvement within the process. Looking at the bottleneck processes, the team saw that reaction already had a high VA ratio of 85% but with significant cycle time variations. Drying on the other hand had a VA ratio of <40%. This helped the team decide on the appropriate Lean tool to be used for process improvement in each specific case.

Table C6.2 VSM data for Product X

		Current	Target
Customer requirement	(Tons/month)	28	40
Batch size	kgs	500	500
Demand rate	Batches per day	1.9	2.7
Takt time	hours per batch	*13*	*9.0*

Process	Available equipment			Cycle time	Value Added Time	Change Over time	Effective Cycle Time	VA ratio (%)
	Numbers	Batch equivalent					(hours per batch)	
Reaction	5	5	Average	67	57	4	*13.4*	85
			Min	*57*	*46*	0		
			Max	*87*	*73*	10		
Neutch filter	1	1	Average	11	4		*10.6*	*33*
			Min	*6*	*1*	0		
			Max	*18*	*6*	0		
Dissolution	1	1	Average	6	2		5.8	33
			Min	4	1	0		
			Max	12	3	0		
Carbon	3	1.5	Average	18	12		*11.7*	69
			Min	*12*	*8*	0		
			Max	*27*	*20*	0		
Acidification	3	3	Average	16	6		5.3	37
			Min	10	4	0		
			Max	26	11	0		
drying (Part-II) (350 kgs per drier)	4	2	Average	20	8		*10.0*	39
			Min	*16*	*4*	0		
			Max	*41*	*21*	0		
Methanol purification	1	1	Average	11.8	3.8		12	32
			Min	7.5	3	0		
			Max	34.75	6	0		
Filtration	3	3	Average	21	12		7.0	55
			Min	11	4	0		
			Max	34	21	0		
drying part—III (350 kgs per drier)	3	2.07	Average	21.4	8.44		*10.3*	39
			Min	*10.5*	*2*	0		
			Max	*30*	*9*	0		

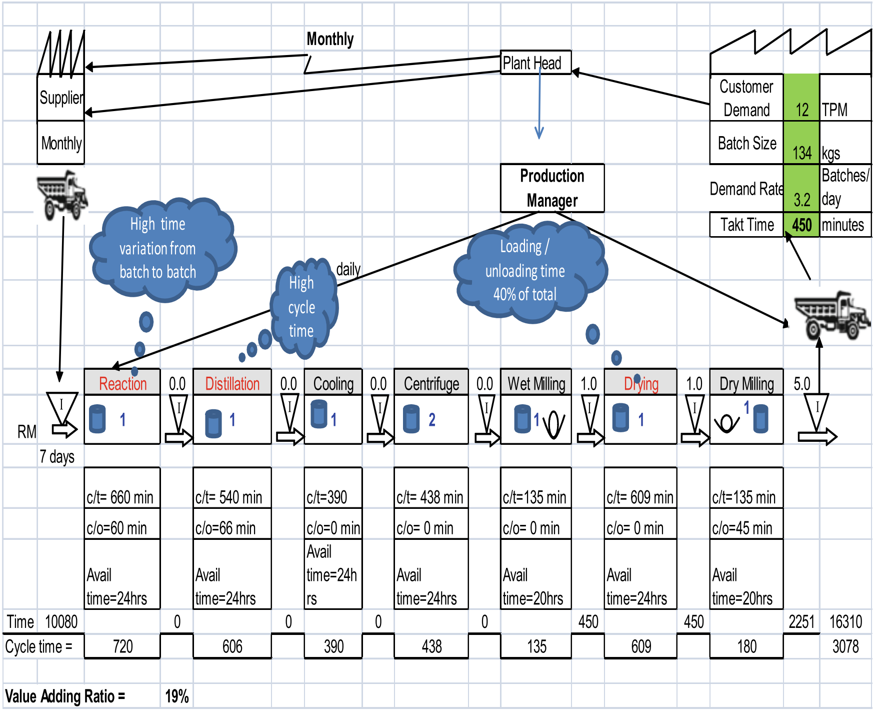

Fig. C6.1 Current state VSM for product Pavest

A similar VSM (this time pictorial) made for KRR Drugs (SME#2) for its main product, Pavest as shown in Fig. C6.1. Here, we see that reaction, distillation, and drying are bottlenecks to achieving the *takt* time of 450 min per batch.

Once the VSM was done, the team did a detailed walk-through of the shop floor to identify improvement opportunities with respect to the working conditions, safety and environment as well as upkeep of the plant and machinery. A Lean roadmap was then made listing out the performance goals and the improvement projects to be taken up for achieving these.

Implementation

There were two main phases of this pilot Lean initiative as shown in Fig. C6.2.

A cross section of the key improvement projects done across the three factories are explained in further detail below.

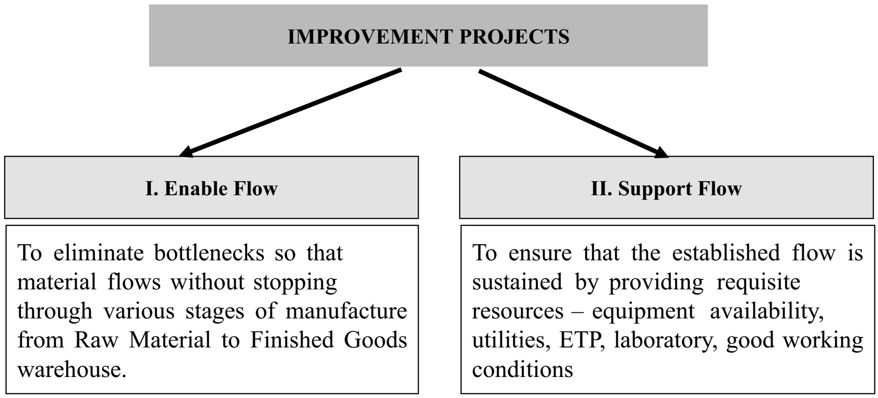

Fig. C6.2 Phases of improvement projects

Phase 1—Enable Flow

In this phase, each SME worked on all the bottleneck processes identified in the VSM. The focus was firmly on *Muda, Muri* and *Mura* reduction through adoption of Lean tools such as VA and NVA analysis, line balancing, problem solving, and improving work methods. An example of each type of project is explained in the following sections to give the reader an overall perspective of Lean implementation in this industry.

Reducing Muda of Batch Wait Time

Problem Definition
To understand the concept of *Muda* as it applies to a process plant, we shall take the case of product Pavest. The VSM shows a constraint of high cycle time in the distillation stage of the process; the cycle time is 585 min per batch as against *takt* time of 450 min per batch. A cross-functional team was formed to work on reducing the cycle time to below 450 min which would enable the plant to meet demand of 3.2 batches per day.

Observation and Analysis
The product is processed through three stages, each stage being carried out successively in Reactor No's 114, 115 and 116 with the key distillation process taking place in stage 2. The current sub-process with the activity-wise cycle time break up is shown in Fig. C6.3.

Reaction takes place in Stage I under brine-based cooling condition after which the separated organic layer is first transferred to Reactor 115. The aqueous layer is then extracted with solvent and also transferred next to Reactor 115. Only after both the layers are transferred, the next process, high temperature distillation begins.

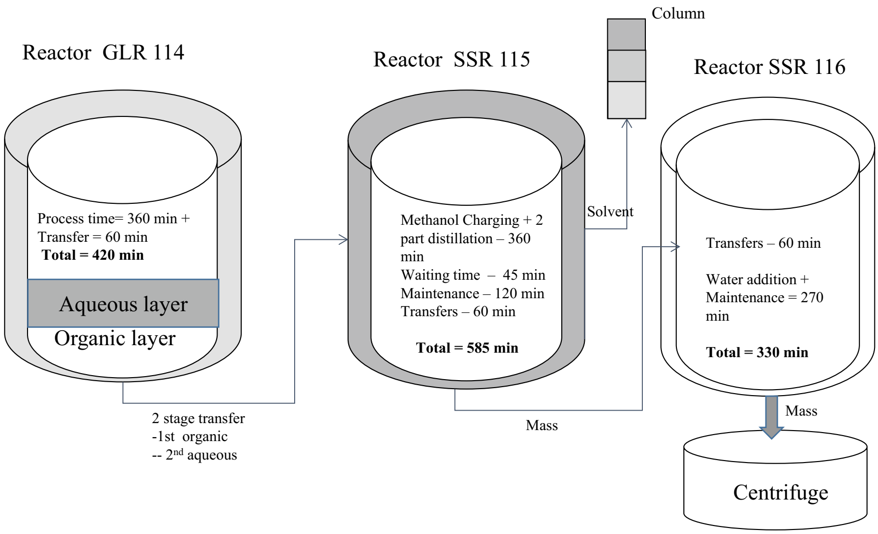

Fig. C6.3 Process stages of Pavest

Detailed process observation was carried out for the distillation process wherein four consecutive batches data was taken over two days. For each batch, hourly distillation quantities were monitored along with the relevant process parameters (see Table C6.3).

The activity-wise cycle time break-up and the why-why analysis of distillation batch data presented the following insights:

- Excess water found in organic layer transferred from previous stage in batches 1 and 4
- Steam pressure fluctuation leading to slower distillation rate in batch 3

Table C6.3 Distillation monitoring data

Distillation monitoring board								
Batch No.	1st hour	2nd hour	3rd hour	4th hour	5th hour	6th hour	Total time (min)	Total quantity (l)
Target	**350**	**225**	**225**	**150**	**100**	**0**	**300**	**1050**
1	*480**	220	225	*127*	93		315	*1145*
2	345	235	234	*122*	90	21	310	1047
3	345	215	*200*	135	*80*	*90*	*410*	1065
4	340	221	225	150	*120*	*153*	*400*	*1209*

**Values deviating significantly from Target are marked in italics, and analyzed further*

- The cycle time of next process in Reactor 116 was only 330 min which meant a 120-min cushion against the takt time of 450 min.

Countermeasures Implemented

Eliminate, Combine, Simplify and Rearrange (ECSR) principles were used to improve the process. The key solutions implemented were:

- The reactor level indicator was made visible to the operator and water flow control valve shifted next to the level indicator to **simplify** and enable filling of correct quantity of water in Stage 1 thus avoid excess water in the organic layer
- The waiting time between transfer of organic and aqueous layers was **eliminated** by starting the distillation immediately after getting first Layer from previous stage
- A ***Kaizen*** was done to reduce distillation time by preheating of Reactor 115 by hot water. Hot water already available from another process was routed through an existing overhead tank to Reactor 115 before each transfer. This small modification using existing resources was implemented within two days and resulted in significant reduction and consistency in distillation time.
- The last process step in Reactor 115 involves maintaining the still mass for 120 min post distillation. Since the next stage in Reactor 116 had a lower cycle time, this step was **rearranged** such that half the maintenance activity could be done in Reactor 116 by transferring the mass one hour after distillation.

Result

The highest cycle time was brought down to 420 min and the three stages were well balanced as can be seen from Fig. C6.4. As a result, an average of 3.3 batches could be produced per day which is 30% higher than earlier and enough to meet customer requirements for Pavest.

Reducing *Muri* (Eliminating Dust in the Milling Room at KRR Drugs)

Problem Definition

The dry milling process inludes grinding, weighing and packing the bulk drug. As per the VSM, the time taken for dry milling of Pavest was well within the *takt* time. However, during the shop-floor walkthrough at the time of current state assessment, it was observed that the operation was generating of a lot of fine dust and powder. This was not only leading to material loss at the final stage of processing but also affecting the working environment and health of the operators in the room. The operator would be fully covered with product dust by the end of his shift; in fact, there was so much dust that the camera lens itself was fogged while attempting to take a photograph of the current state. Please see Fig. C6.5.

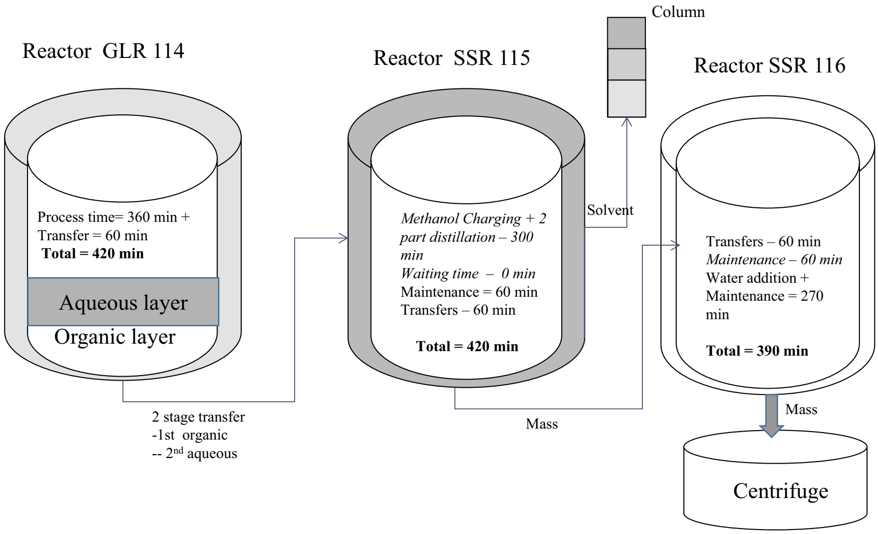

Fig. C6.4 Three stages after improvement

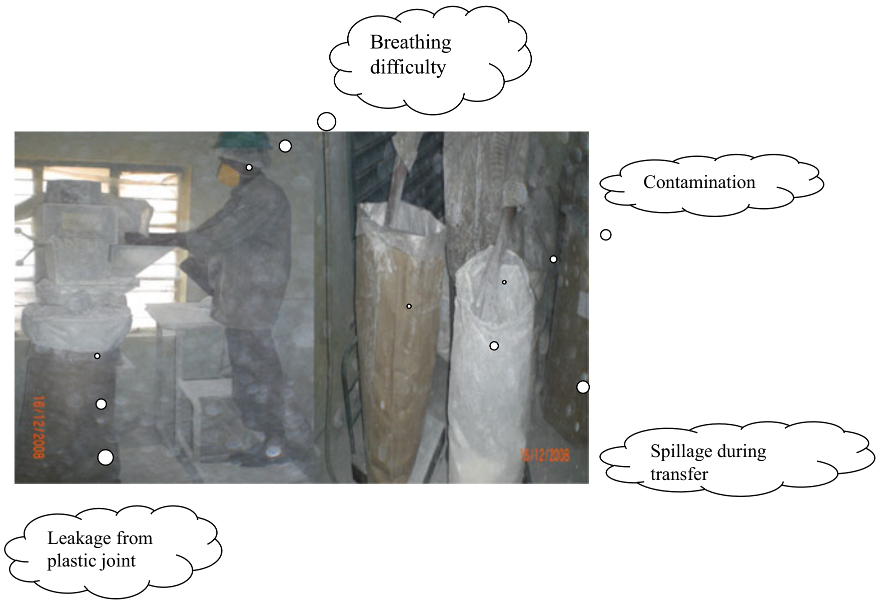

Fig. C6.5 Grinding and weighing—current state

Table C6.4 Root causes and solutions to reduce dust spillage

Observation	Solution implemented
Weighing and packing was done manually in the next step and involved manual transfer of finished product from one bag to another. Material spillage as well as generation of fine dust observed during the transfer	By providing the weighing scale directly underneath the miller, manual weighing activity and transfer of fine powder from one bag to another was eliminated
Material spillage observed while feeding the miller, leakage of fine dust during operation from sides of the dome, and while collecting the material into the bags	All valve leakages and generation of fine dust during milling was eliminated by sealing the miller and providing venting arrangement for releasing trapped air
Physical strain of the operators and helpers while lifting the bags weighing 25 kgs each to charge into the hopper	To reduce the strain and make the feeding hopper easily accessible the milling stand height was increased

An improvement project was therefore taken up with a goal to ensure "*zero powder loss*" by eliminating all leaks and spills of material at this stage.

Observation and Analysis

The operation was observed in detail (see Fig. C6.5) and a why-why analysis done to identify root causes of spillage and leakage. Key observations and implemented solutions are summarized in Table C6.4.

Result

Zero dust working environment created where the operator could work comfortably without even feeling the need to wear a protective mask. Product loss due to spillage and leakage was eliminated. The following Fig. C6.6 shows the condition of dry milling area after the above-mentioned improvements were implemented.

Reducing *Mura* (Smoothening Inconsistency in Reaction Time at Porus)

Problem Definition

The VSM for Product X (Table C6.2) shows reaction to be the bottleneck processes that constrains the manufacturing unit's capability to meet customer demand. Five reactors were available for carrying out this single stage reaction process and all of them were utilized fully. Analysis of batch data from the VSM showed that the average cycle time was 57 h which translated to an Effective Cycle Time of 13.4 h per batch and this was well above the *takt* time of 9 h per batch. A cross-functional team was formed to work on this problem and bring down the reaction time to below 45 h per batch in order to match *takt* time.

Observation and Analysis

Data showed that there was a wide fluctuation in cycle times from batch to batch with the actual value-adding (reaction) time ranging from 46 to 73 h. Since five

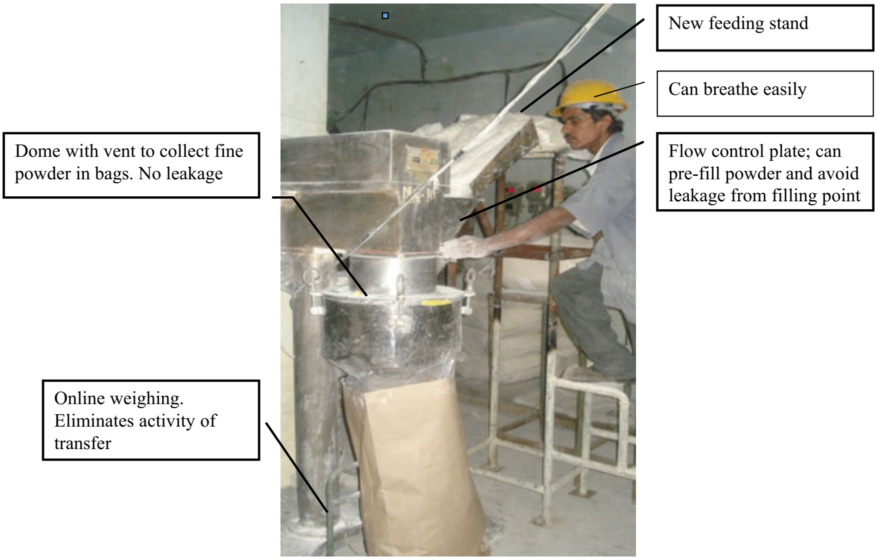

Fig. C6.6 Improved condition in dry milling

reactors were used for carrying out the same reaction, the ***differential diagnosis*** technique was used to analyse the problem and arrive at the root cause(s) of this variation. ***Differential diagnosis*** is a backward or deductive approach for solving chronic problems. This method involves a combination of direct process observations and data collection to answer a series of questions under the following categories:

1. What is the problem,
2. Where or in which place does it occur,
3. When does it occur, and
4. How much (quantity or frequency).

In each question, both the presence and absence of the condition is noted. Through this, the causes of the problem are narrowed down and what remains at the end will yield the root cause through a why-why examination.

In this case, the data showed that all five reactors exhibited significant variation in reaction times which meant that there was a common cause for the inconsistency. Each reactor had in some batches, been able to complete the reaction in a time below 50 h. By comparing these low reaction times to the higher times, the root cause could be identified. Whenever the reaction temperature of 145–147 °C was consistently maintained, cycle time was between 46–50 h irrespective of which reactor was doing the process. In cases when cycle time rose to much higher levels, it was observed that the temperature dropped below 145 C due to fluctuation in the pressure of the steam used for heating. It normally took at least

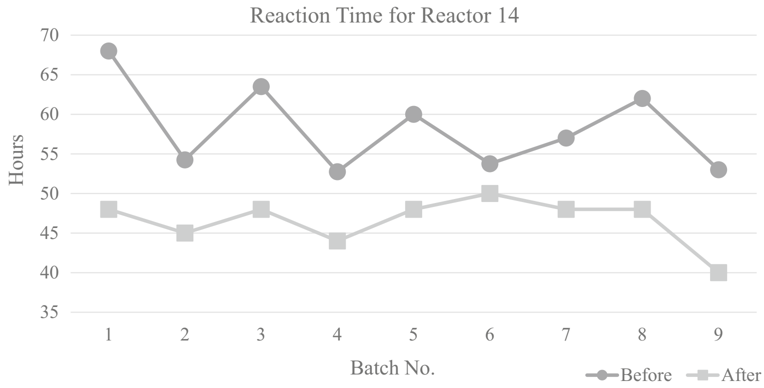

Fig. C6.7 Reactor time variation

two hours for the temperature to come back to the required range in such instances. Since there was no alert mechanism, any such drop in temperature would be noted during the operator's routine half hourly observation round. Whenever this happened, the operator would manually adjust the valve and try to get more steam to the reactor to raise the temperature. This adjustment time also varied due to trial and error and operator experience.

Countermeasures Implemented
An improved method of steam control was put in place which included valve position marking and an alert mechanism for pressure deviation. A process chart was prepared and visual management system for monitoring of parameters put in place. To ensure that there was no other possibility of variation, recalibration of all temperature sensors and display units and cleaning of thermo-wells that house the sensors was carried out.

Result
Variation in time fell by 50% across all the reactors (Please see Fig. C6.7) and average reaction time came down to 44 h from earlier level of 57 h. As a result of this improvement in conjunction with reduction of other bottleneck process cycle times, the output of the product increased from 28 to 33 TPM.

Phase II—Stabilization

The improvement workshops targeting the 3 M's helped the teams from all three factories to apply the **core Lean concepts of flow and waste elimination** and improve their critical processes. It also highlighted the importance of the support processes such as quality laboratory, utilities maintenance, and stores, etc. It was time to move to the second phase of the Lean journey, stabilizing the gains made through streamlining of the support processes.

Reducing Laboratory Testing Time

One of the observations at AR Life Sciences (SME#3), pertained to the completion of reaction stage. Their major product Q underwent eight reaction stages and at each stage the completion of the reaction was known only through lab analysis and verification of a sample drawn from the reactor. When the material had spent the expected amount of time in the reactor, a sample was drawn and taken to the laboratory for analysis. The lab chemist would confirm the completion of the reaction and inform the production shift supervisor who would then transfer the reacted mass to the next stage. This process (take sample - >go to QA - > test - > confirm results - > start transfer) took 30–35 min on an average. So, we asked the team a fundamental question "What happens in the reactor during this time?". Since the test result essentially gives the status of reaction half an hour ago, it meant that reaction was already complete at that time. So, the material was actually waiting for the result which was a *Muda*.

It took some persuasion of the team to come around to this Lean perspective but once they got it, they quickly got onto the target of reducing the time for result. Of the cycle, about 20 min was spent in the lab and the balance for collecting the sample and bringing it in. At the sampling end, the spoon design was changed to make it easy to pick up the sample in one shot thereby halving the time required. At the testing stage, the team observed and shot a video of the entire activity from the time the sample is brought in till the result is communicated to the production floor. The major observations were:

- Actual test time only about 50% of total time spent,
- Chemist has to make multiple movements inside the lab during testing process—the testing had multiple steps which needed various equipment including an oven, titrator, wash basin for rinsing and a spot test set-up,
- Searching for glassware and chemicals during testing took some effort and time,
- Physical strain—bending for taking out certain reagents and glasswares, and
- Unused items were found occupying space in the shelves.

The observations highlighted the need to implement the core 5S principles in the lab. Within the next couple of days, the team worked on the following;

1. Segregated unwanted items and disposed off to appropriate locations thereby freeing up 50% of the shelf space,
2. The team made a simple product-process matrix for the lab tests after categorizing the tests as runners (frequently done), repeaters, and strangers. For example, reaction tests that happen daily are runners while tests on certain imported incoming raw materials happening once in three months would be strangers.

Cells were formed with test equipment, reagents, glassware, and test formats for the runners arranged in one place as compared to the earlier item-type-wise arrangement. All the items and locations were then marked by labelling and indexing.

The change in orientation from item-type-wise to test specific arrangements brought down the movements for the chemist. This coupled with search free arrangement resulted in the testing time dropping to 12 min from 20 min. Overall, the material waiting time in the reactor was reduced by 40% while the lab chemists enjoyed strain free working conditions.

A 5S checklist was instituted which included the following.

- Red tag area defined and unwanted items to be shifted there periodically.
- Daily lab cleaning SOP framed and implemented.
- Disposal protocols including timelines and methods for rinsed solvents, broken glassware, and old records were defined.
- Reordering of solvents, reagents, and other chemicals based on visual stock level checks.

Autonomous Maintenance for Utilities

The value-adding processes in any chemical plant are dependent on the consistent availability of quality utilities such as steam, chilled, or compressed air or vacuum. To ensure the process delivers consistent value and throughput, we have to make sure there are no disruptions in the quality and quantity of these utilities.

In the stabilization phase of three months, the teams engaged in the initial basic steps of autonomous maintenance focusing on the utilities. And these are extensively driven through a network of pumps and motors and pipelines carrying them to the customer processes. AR Life Sciences, like most other SME units, had a basic maintenance team consisting of one mechanical fitter and an electrician who both reported directly to the production manager. Utility operators were few and were mainly for the boiler and chilling plants.

A maintenance expert consultant was therefore deployed to guide the plant teams in abnormality identification, rectification, and certain good practices that can prevent abnormalities. Cleaning, Oiling, Tightening, and Inspection (COTI) sheets were developed for the all the critical equipment. Visual markings were done on pipelines, pumps, and motors to facilitate quick and simple adherence to the COTI routines.

Reorganizing the Stores

If autonomous maintenance was expected to keep the equipment up and running, there was an equal need to ensure availability of the required spare parts for routine time-based and condition-based replacements. Also, in the case of an unexpected breakdown, having the spare in hand made all the difference between a quick repair and restart versus hours or even days of downtime. One look at the stores at Porus Drugs highlighted why the maintenance personnel spent significant time searching for the required part and sometimes end up not finding what they need.

The team's observations pointed to the need to implement 5S in the store. The store was full of materials with no aisles to move inside. Material was found lying in mixed-up conditions in most of the racks and on the floor; in some cases, unusable items were also mixed up with the good ones. The stores assistant found it difficult to reach items on the top most shelf of the racks for which he needed to use ladder. All this meant that it took a lot of time to search for and get required items.

The team initiated 5S on a war footing. Within the week, they had segregated all scrap and expired items, and kept them separately to be disposed off. This enabled them to discard two damaged racks and change the rack arrangement to create aisle space and accessibility. They then rearranged all useful items neatly on the shelves and racks as per type (e.g. bearings, motors, switches, etc.) and area of use. Item address locators were pasted on each rack to create a search free store as shown in Fig. C6.8.

Now, any item could be located in a minute without searching for it. Almost 20% of stores area was freed up and ease of access to all items provided. The visibility provided for a better control on inventory and ensuring reordering of items as and when required.

Sustaining Lean

They say that success is the biggest motivator; if that be, all the three SMEs ended up with very good reasons to sustain the Lean path. Table C6.5 is the summary of the outcomes reached at the three factories by the end of the pilot intervention.

Fig. C6.8 5S—Before and after in stores

Table C6.5 Summary of improvements achieved by the bulk drug pharma SME cluster

SME#	Parameter	Before	After	Improvement
1	Production volume (MT)	28	35	25% gain
	Throughput time (days)	10.4	4.5	57% reduction in WIP
	Yield (kgs)	510	540	6% savings in material loss
2	Throughput time (days)	32	20	38% reduction
	Production volume (MT)	300	480	Potential of 60% increase
3	Production volume (MT)	8	12	Potential of 50% increase

A quick look at where these organizations are a decade later gives some pointer on how early stage Lean intervention has shaped their thinking and growth. Porus has grown tenfold in turnover with large new facilities set-up at different cities. In fact, Porus is no longer an SME. AR Life Sciences was at a pilot phase of developing a niche low volume but high value product (refer Table C6.5 for the quantities) at the time of Lean intervention. They have up scaled to two midsized manufacturing units one of which is US FDA approved and a third facility is under construction. KRR Drugs did not really focus on their pharmaceutical business in later years. Instead, they have grown their fabrication unit which now supplies equipment to pharmaceutical factories in India and abroad. Vamsi, the owner, took an additional step of implementing Lean in his foundry unit and ensuring his fabrication unit team also follow core Lean concepts.

Conclusions

This experience with bulk drug manufacturing clarifies some important differences in terms of how Lean is to be applied in a process industry as compared to a discrete manufacturing unit.

- *Muda* is observed by understanding the change that has happened to the material in terms of its chemistry and this change is often not visible or obvious visually. A discrete process lends to physical observation of the seven wastes which is easy,
- Reducing *Mura* leads to significant benefits in these industries as the processes are reaction based and depend on multiple process parameters and raw material variations. For this, the collection of accurate data is very important. In discrete manufacturing, process variations are in manual operations can be observed visually and acted upon
- In process manufacturing, effective value addition depends on utilities like boilers, chillers and compressors being able to help maintain the required conditions. The focus is therefore on ensuring these utilities perform to their optimum. Whereas in discrete manufacturing, the focus is operator's work methods in conjunction with machine.

In conclusion, it may be said that the core philosophy and paradigm of Lean remains equally relevant to a process industry as it is to the discrete manufacturing. The concepts need to be applied keeping in mind the inherent nature of process manufacturing by slightly tweaking the methods of observation and increased focus on data collection. The benefits of implementing Lean are equally significant as could be seen from the three case examples described in this case study.

Case Study 7: GSV Industries—A Case study on Lean Implementation

Background and Context

GSV industries (GSV), located at Coimbatore, India, primarily manufactures two types of products—stator and rotor stampings and motor guards. They cater to the needs of the pump industry with their customers including industry leaders such as Aqua pumps, CRI pumps, PSG Industrial Institute, Texmo Industries, etc.

Each year, the pump manufacturers have been constantly putting pressure on their vendors to cut costs resulting in margin pressures for companies such as GSV. The managing partner of GSV therefore felt the need to enhance the operational efficiencies of the unit. As a member of one of India's biggest industry associations for small scale industries, Coimbatore District Small Scale Industries Association (CODISSIA), he attended an association seminar on the benefits of Lean manufacturing where other members who had earlier implemented Lean shared their experiences. This was a precursor to a Lean cluster implementation program promoted by the Government of India (GoI) to help SMEs on the path to sustainable growth. GSV joined the cluster to implement Lean manufacturing under the guidance of the selected (by GoI) Lean Management Consultant. The program was envisaged to be an 18-month long journey in implementing key concepts of Lean.

Projects Identification and Selection

The journey commenced with a diagnostic exercise during which the processes at GSV were observed and studied under Lean paradigms of **zero waste** and **zero defects**. The factory consisted of two sheds, one for manufacture of motor guards and the other for stampings. The core team consisted of the two section-in-charges and the managing partner all of whom joined the Lean consultant during this diagnostic exercise. Key observations from this exercise and the improvement areas identified are discussed further in this section.

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G. Mahadevan and K. C. Chejarla, *Lean Management for Small and Medium Sized Enterprises*, Management for Professionals,
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Stamping

Significant investment had been made in two large stamping presses which are used for pump stator and rotor parts. The stamped pieces produced by the machine are then assembled manually in the form of stacks. The Overall Equipment Effectiveness (OEE) was computed to be around 45% only with the factory working for 12 h (including overtime) to complete the daily production target. The equipment availability was the major loss contributing to lower OEE and the following observations were made in respect to these losses.

Changeover Time

There were two types of changeovers (viz., batch and product) observed in the press. The raw material is in the form of steel strip coils. As one coil gets consumed, the end bit is cut off and the next coil loaded and strip fed into the die. This batch changeover from completion of one coil to the starting of the next took 5 to 10 minutes and was done several times in a day. Technically, this loading and unloading is a part of the coil processing cycle time; however, it was deliberately categorized as a changeover to have the team focus on it.

Further, the stamping die itself needs to be changed to run another product variant, and this took about 90–120 min. There was no proper marked location for dies and tools resulting in long searches for them at the time of changeovers.

Breakdowns

Frequent breakdowns were stopping the presses, the mean-time-to-repair was more than two days as an external service technician had to be called to solve the problems.

Stamping Projects

While the customer demand was expected to remain the same, the management was focused on minimizing the overtime expense which was eating into the already low margins. Increasing OEE would lead to a direct and proportionate increase in output and the following improvement projects were identified to work on this.

- **Reduction in changeover time:** With at least six coil changeovers per day and three die changeovers per week in stamping, the press availability eroded by more than 30%.
- **Reduction in breakdowns by establishment of system of autonomous maintenance** (AM): With a large amount of time in stamping lost due to breakdowns, establishment of an AM system is expected to enhance the OEE of the stamping lines.

Motor Guard Section Observations

The motor guard manufacturing process has multiple steps involving man and machine and *gemba* walk was done to observe *Muda* (waste) and *Muri* (strain). The observations are listed here.

Inventory

Batch production system was being followed in motor guard section. Each process was planned independently and there was significant overproduction leading to piling of inventory between various processes. WIP inventories of various sizes of motor guards had been kept deliberately before the *jhali* (grill punching) stage (please see Fig. C7.1 for value stream map of motor guard production process) in order to expedite delivery as and when order schedule was received.

Material Transportation and Handling

The team observed multiple handling of components between each process leading to increased strain (*Muri*) to the workers. The component generally drops to the floor after the process is completed and has to be picked again and placed in baskets/bins before being moved to the inventory area or next process resulting in significant operator strain and material handling.

Following the gemba *walk*, the overall process flow in motor guard manufacturing was mapped through a value stream map (VSM) as shown in Fig. C7.1.

As can be seen the value adding ratio (VAR) is only 0.01% mainly due to the high WIP between processes leading to a high throughput time.

Motor Guard Section Projects

Given the low VAR, establishing flow was considered important in the implementation phase. There was a large WIP build-up between various motor guard production processes because of independent batch processing by different workstations. With cycle time of the various processes being extremely low (usually in seconds) and the lead time for delivery being at least a week, establishing flow in motor guard line was expected to enhance the throughput of the line and improve On Time In F startull (OTIF) delivery substantially.

Roadmap Creation

A core team was formed to work on the identified improvement projects, and a stage-wise project roadmap was created. The projects were implemented in Stages II, III, and IV of the implementation journey and the improved processes were standardized in the last Stage V.

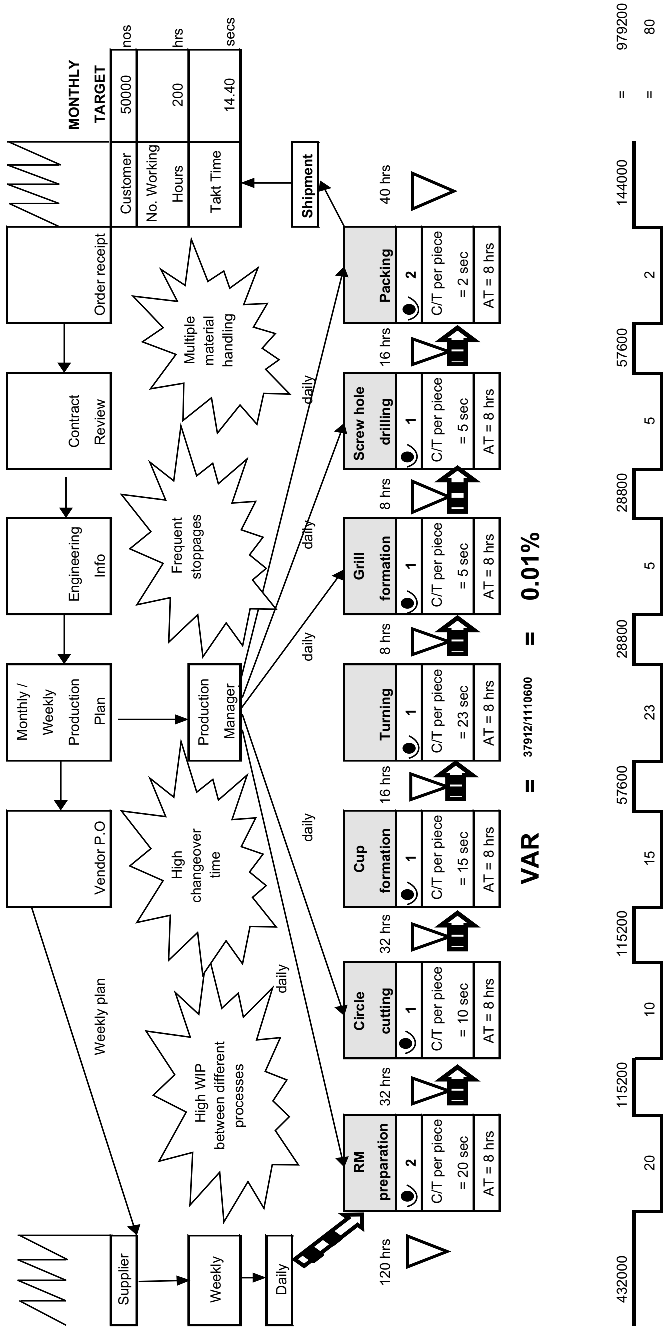

Fig. C7.1 Value stream map of motor guard line

Table C7.1 Phase-wise implementation roadmap

Improvement project	Activity	Phase I	Phase II	Phase III	Phase IV	Phase V
	Milestone completion date	Mar-16	Jul-16	Oct-16	Feb-17	Jul-17
I. Motor guard line: improve flow to increase throughput and reduce lead time	Set up one flow line with balanced cycle times and run in single piece flow		2400 nos	3200 nos		
	Reduction in WIP from 2–7 days thereby reducing strain		1.5 days	1 day		
II. Reduce material handling and transportation through flow layout	Change the entire plant layout as per the line concept validated for one flow line					
	Define standard WIP where needed and mark space only for the fixed quantity					
	Implement 1S, 2S and 3S at every work station and throughout the factory					
III. Stamping line: improve stamping machine OEE	Reduce die changeover time for stamping from 120 min to <60 min		30–45 min			
	Improve the OEE of stamping from current levels of less than 45%			60%	70%	
	Implement basic Autonomous and Planned Maintenance practices to minimize breakdowns					
IV. Synchronization and sustenance of Lean	5S audits and self-sustenance model		32%	40%	68%	80%
	Visual management systems					
	Training on Kaizen					
	Reporting system for Kaizen					
	Indicative target for no. of Kaizens					
	Structure and action plan for handover to unit and long term sustenance					

Project Team

The core project team comprised of:

- Mr. Vijayarangharajan—Managing Partner
- Mrs. Beoula—Stamping section in-charge
- Mr. Das—Motor guard section in-charge

Project Schedule

The phase wise road map with targets for each project was finalized in conjunction with the managing partner and is shown in Table C7.1.

Implementation

Increasing the Stamping Press OEE

Die Changeover Time

As we saw earlier, there is a coil changeover several times a day and a die changeover almost every alternate day. The team first focused on die changeover time reduction.

A die changeover normally happens every alternate day on each press. A cross-functional team was formed to observe the die changeover from product PE80 (single chute) to PE63 (double chute). The stamped parts are automatically discharged into chutes where they get auto stacked continuously. Small stacks are removed at the exit of the chute by an operator, and kept aside for weighment and manual assembly process. The chute size is specific to the product and each die cavity is linked to one chute. The total changeover time recorded for this particular changeover was 102 minutes and involved two operators. The team first noted that many of the changeover activities were being carried out after the press was stopped (internal) even though they could be done while it was running (external). These included:

(a) Movement of the crane from its existing location to the machine,
(b) Searching for the tools needed for changeover,
(c) Bringing the chutes needed for next product near the machine,
(d) Moving the removed chutes to its designated location,
(e) Bringing the new set of dies from its existing location,
(f) Moving the removed die to its designated location.

They then analyzed the observations on the activities that are done post machine stoppage (internal changeover):

30 mins were spent in removing the output (stators and rotors) of the production run from the chute. Only after this, could the chutes be replaced with the set of chutes for the next product.

Gear changing and setting adjustments were also found necessary in some of the changeovers.

In order to locate the chute plate, a steel ruler was used to measure the distance from the left-side of the bed. It was observed that the operator made a mistake in noting the reading which resulted in redoing the chute plate fixing.

Taking cues from the SMED concept, the team worked out an improvement action plan and implemented the following:

- All the *internal* activities (a to f) listed above were converted to *external* and carried out before (a, b, c, and e) the press is stopped for changeover or after (d, and f) the press is restarted.
- Tie rods were used to remove the rotor material from the chutes instead of by hand. Distance piece was used to correctly align the chute plate for every die changeover instead of using the steel ruler for measuring the distance from the left-side of the bed. The product number is inscribed in the distance piece itself to avoid using of wrong distance piece. Pneumatic gun used for loosening and tightening of bolts.
- Internal activities were done in parallel by different operators as per the responsibilities assigned. All the available operators were utilized during the course of the changeover as shown in the activity allocation Table C7.2.

The above improvements resulted in reduction in die changeover time from an average 90 min to 45 min. This meant that press availability increased by 4% resulting in an equivalent increase in output.

Table C7.2 Changeover activity allocation

S.No.	Activity	Dependent activity	Manpower	Time (min)
1	Die bolt removal	–	4 persons	1
2	Die removal	1	2 persons	2
3	Material removal from chute (stator + rotor)	1	4 persons	2
4	Chute removal (4 bolts per stator + 3 bolts per rotor)	3	4 persons	4
5	Gear changing	1	1 person	12
6	Chute fixing	4	4 persons	7
7	Die positioning	6	2 persons	7
8	Die bolt fixing	5, 7	4 persons	1
9	Coil feeding and setting	8	2 persons	1

Time in min→	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Worker 1	1*	2		4				6							7							8	9
Worker 2	1	2		4				6							7							8	9
Worker 3	1	5																				8	
Worker 4	1	3		4				6														8	
Worker 5		3		4				6															
Lady Worker 1		3																					
Lady Worker 2		3																					

Improve the Availability of Stamping Press Through Autonomous Maintenance

During the diagnostic stage, the team found that there was no recorded data on the machine breakdowns and initiated data collection of machine breakdowns and short stops. The data showed that:

i. Regular breakdowns were occurring in the press and the mean-time-to-repair was high because of need to call in external service technician.
ii. On an average three to four short stoppages per hour were observed on the stamping machine.

The Lean consulting team brought in their TPM specialist to conduct a workshop on initial cleaning and abnormality identification. The operator was then given the responsibility to regularly identify all abnormalities in his machine, correct those which he could immediately do so and escalate the rest to the supervisor. After this initial restoration of the stamping press, the next two steps of AM were put in place.

i. Cleaning of machines was introduced as a regular daily activity. The operator was provided 15 min at the end of the shift for machine cleaning.
ii. A CLRI (Clean, Lubricate, Re-tighten, and Inspect) checklist was developed and implemented for the press and was regularly followed by the operators.

Operators started recording the abnormalities in a register kept in the supervisor's office and depending on the need, the external technician would be called in to correct the identified issues before an actual breakdown occurs.

The effect of the above countermeasures was an improvement in the OEE of stamping press seen in Fig. C7.2.

The actual production trend is shown in Table C7.3; the output is now completed in regular shift timings of 8 working hours instead of overtime in 12 h per day, taken earlier.

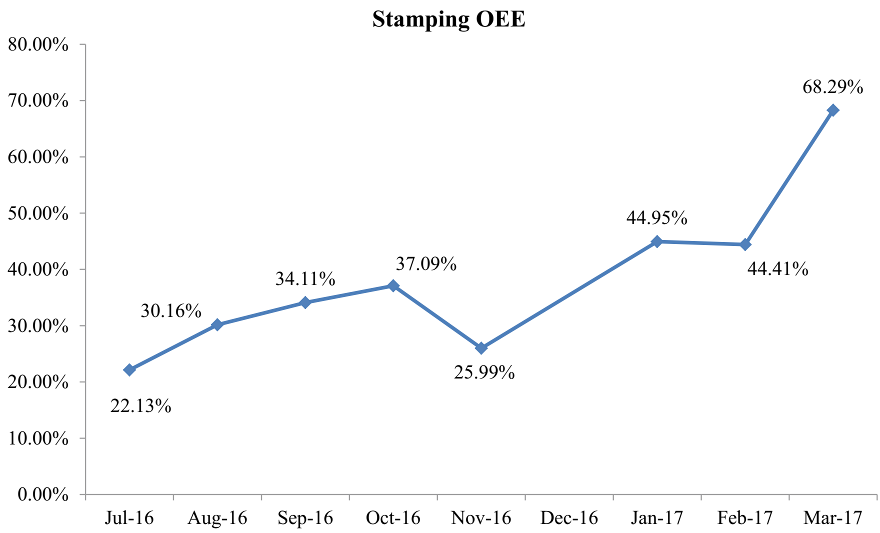

Fig. C7.2 Improvement in stamping OEE

Table C7.3 Stamping production—output trend

Before implementation		During implementation		Standardization	
Period	Tons	Period	Tons	Period	Tons
Feb, 2016	74	Oct, 2016	89	Apr, 2017	107
Mar, 2016	76	Nov, 2016	120	May, 2017	127
Apr, 2016	92	Dec, 2016	131		

Improvement in Throughput of Motor Guard Line

The second shed at GSV factory houses the motor guard manufacturing line. With an increasing demand from the pump OEMs, there was pressure on GSV to adhere to the stringent and ever-tightening delivery schedules. The current throughput time for a batch of motor guards varied anywhere from 2 to 30 days, most often resulting in delivery delays. Thus, the team decided to focus on improving the throughput at this line.

The process flow for motor guard manufacture is shown in Fig. C7.3:

The team identified the existing layout as the prime cause for the shop floor being filled up with stacks of WIP, leading to multiple material handling and transport. They also observed that the operators themselves were moving the materials intermittently keeping their machines idle.

The original machine layout was designed on conventional batch production concepts. Machines were laid out functionally and no two machines were linked together leading to WIP build-up between processes. Each machine operated independently of the others and it's was collected in large cages as seen in Fig. C7.4.

Cages of such components were then moved to the centre of the working area from where the next process would again draw the material as and when needed. When the cages became full the material was placed in heaps on the floor as

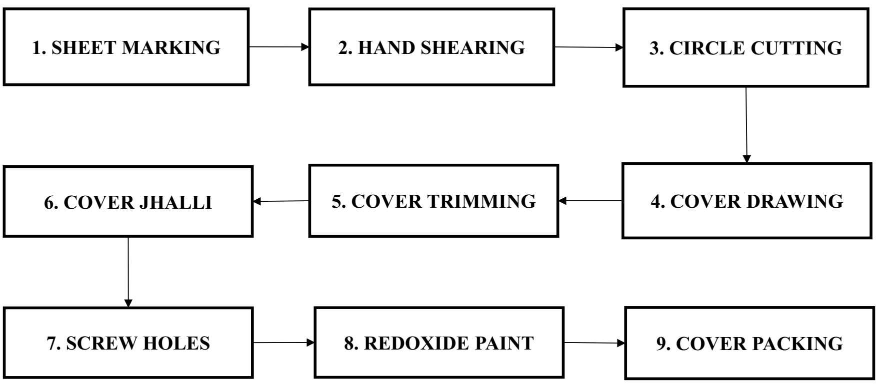

Fig. C7.3 Motor guard manufacturing process

Fig. C7.4 Material handling in cages

well. Inspite of all the WIP, some machines were still found waiting for input materials. The team walked through the value stream (See Fig. C7.1) and measured the material movement between operations as shown in Table C7.4.

There was no clear tagging of WIP, or identifying the next process it is supposed to undergo. While a weekly production plan was made, it was not strictly adhered to. Components taken up for production were often left incomplete and a new order would be taken up succumbing to customer's pressure of immediate deliveries.

As the team walked through, there was also a realization on the extent of criss-cross material movement between operations and this came out clearly in their material flow ("*sphagetti*") diagram depicted below (Fig. C7.5).

With this visualization, it was evident that the current layout and batch production method was hampering the smooth flow of motor guards through the value stream thereby increasing WIP and the throughput time.

Table C7.4 Material movement between processes

Process Step	Distance Travelled (m)
Cutting to Circling	4.8
Circling to Hydraulic	15
Hydraulic to Lathe(Trimming)	4
Lathe to Jhalli	5.2
Jhalli to Screw Hole	1.5
Screw Hole To Painting	17
Total	47.5 meters

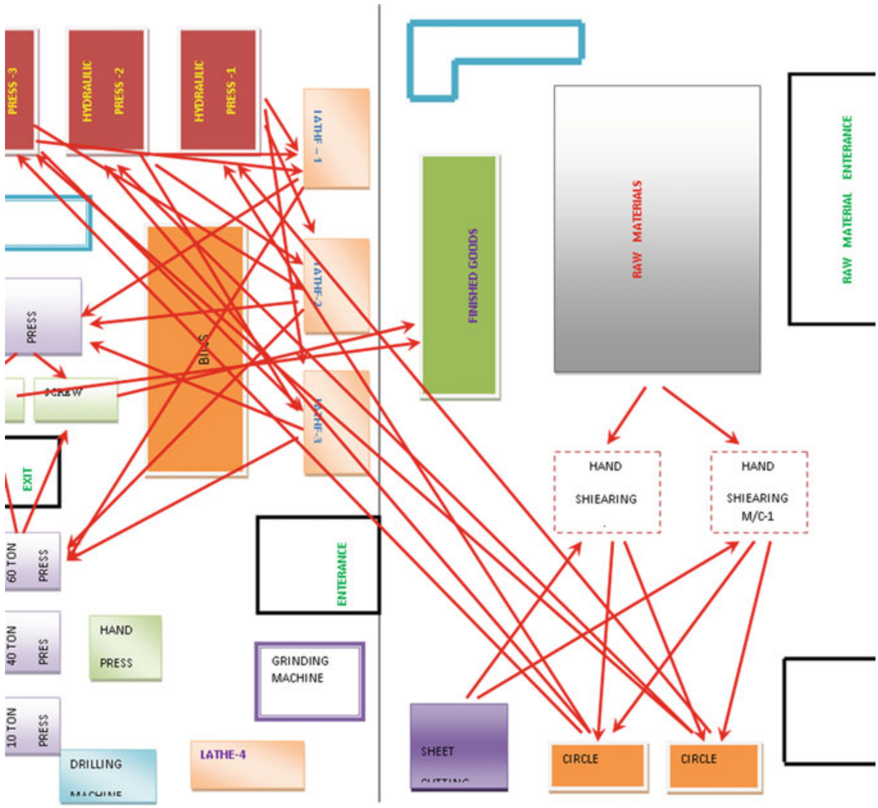

Fig. C7.5 Material flow in motor guard manufacturing

Improvement Plan

The machines were reorganized based on sequence of operations for different components to form a cell. Two such cells were formed as shown in the layout drawing (Fig. C7.6). The dotted lines indicate the two cells while the solid line traces the material flow in the new layout. The cells were designed based on the motor guard size as larger motor guards needed to be made on the higher capacity hydraulic presses.

In the new layout, the machines were spaced so as to facilitate an operator to directly pick up the component from the outbox of the preceding process. Wherever the machines could not be brought close enough, a simple inclined chute was fabricated to enable the components to flow from one workstation to another. The WIP between the workstations is controlled by length of this chute; if the chute becomes full, the supplier process stops. Figure C7.7 shows one such chute.

Since the sheet marking (1) and circle cutting (3) operations were much faster, they were delinked from the rest of the processes and a fixed standard inventory of

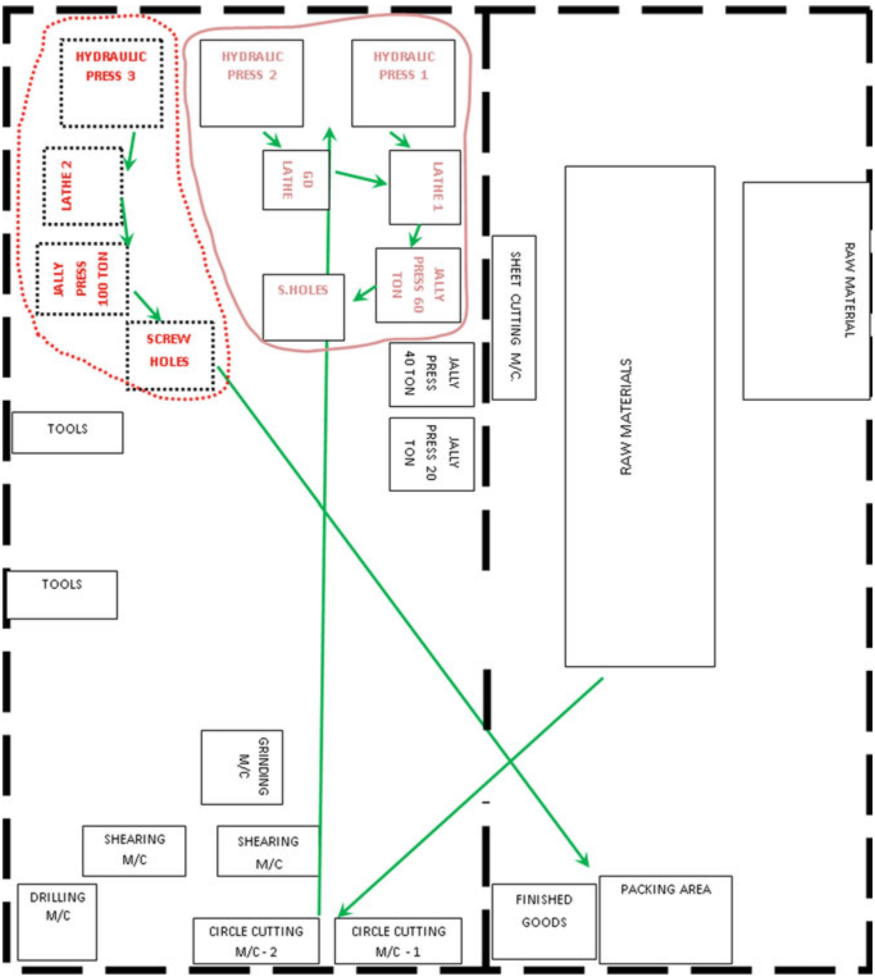

Fig. C7.6 Cellular layout for two products

cut sheet circles maintained for use by all the cells. The weekly customer requirement was the basis for fixing the standard inventory levels. Two-day requirement of cut circles of the sizes planned were maintained and replenished on a daily basis. The production of these upstream processes was now driven by a pull-based model where the replenishment of cut sheet circles was based on withdrawals by the cells.

Based on the cycle time, some of the components on the *jhalli* formation (6) and screw hole drilling (7) was done by a single operator in order to balance the line. The machines were aligned to facilitate multi machine operation by a single operator as shown in Fig. C7.8.

Fig. C7.7 Chute controlling the WIP between processes

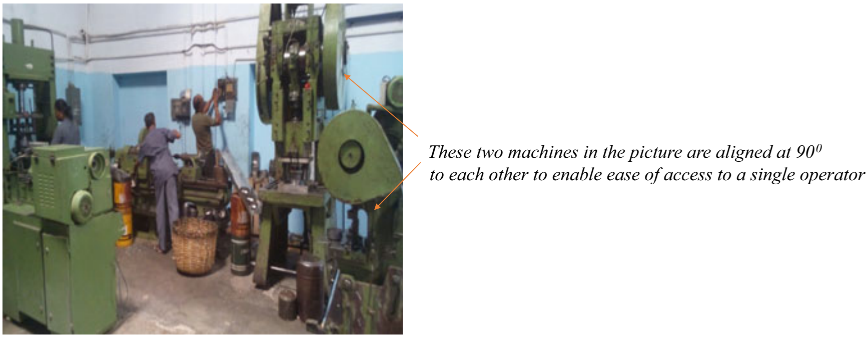

Fig. C7.8 Machine alignment to enable single worker operation

Another observation by the team working on this project was the multiple handling of scrap being done by the machine operators. At each machine, the punched or milled scrap was falling onto the floor behind the machine. Operators would spend time before close of work in collecting this scrap and putting it into bins in the designated area outside the shop floor. With the new chute system in place and flow replacing the earlier batch manufacturing, most of the cages became redundant. Some of these cages were now placed to directly collect the scrap falling from the machine and moved out by a pallet truck when they became full.

Table C7.5 Motor guard production trend

Before implementation		After implementation	
Period	Quantity	Period	Quantity
Jan, 2016	39,768	Mar, 2017	45,530
Feb, 2016	40,955	Apr, 2017	49,776
Total	80,723		95,306

Outcomes

With the establishment of flow in motor guard line, the Lean team could demonstrate an increase in the output from about 900 per shift to 1800–2000 units per shift with the same number of operators and machines. On an overall basis, allowing for other factors such as actual customer orders, material availability and schedules, the year-on-year comparison of output during the peak season shows an actual 18% gain as seen in Table C7.5. At the same time, the new layout uses only 50% of the space used by the earlier layout.

Standardization and Sustenance Plan

Following the improvement phase of the Lean journey, the last six months of the roadmap schedule were devoted to ensuring standardization of processes and building a structure for long-term sustenance of Lean.

Standardization Through 5S

This began with an awareness workshop for all the supervisors of the plant highlighting the importance of 5S and how it facilitates the sustenance of improvements made under Lean implementation. The unit was divided into various zones and each zone was assigned to a zone leader responsible for all Lean activities within their span of control. To start off, a red tag area was identified in the plant in order to accommodate all unwanted/unused tools, etc. The unit head was assigned the responsibility for periodically reviewing the items of the red tag area and take appropriate decisions for disposal or reuse.

2S activities were planned and carried out by each zone so as to have a systematic arrangement facilitating their process flow. The machine cleaning introduced under AM was now merged into the *shine* activity with a fixed daily schedule to carry out cleaning activities in their respective areas.

Two months into 5S, the Lean consultant carried out the first 5S audit to measure of the level of implementation of 5S in the plant and to create zone wise competition as a motivating factor. By the end of the six months, the 5S score of the plant had improved from **30%** in Feb 2017 to **52%** in July 2017.

Table C7.6 Lean organization

S. No	Particular	Responsibility	Role	Frequency
1	5S Audit (cross audit)	Ms. Beoula/Mr. Das	Auditor	Monthly
2	Lean implementation	Ms. Beoula/Mr. Das	Lean coordinator	Weekly
3	Lean review	Mr. Vijayarangarajan	Proprietor	Monthly

Organization Structure for Sustenance

In order the carry forward the improvements made under the various projects so far, a responsibility matrix was created assigning responsibilities to the Lean champions of the unit. The matrix contained the name, role, and the frequency of review. GSV being a small-sized organization had a very limited managerial bandwidth. The people available to take the onus for continuity of Lean and 5S were few. This limited the scope for assigning too many responsibilities and a basic structure was created within the limitations as shown in Table C7.6.

Conclusion

Even a unit as small as GSV could gain significantly from the implementation and sustenance of core Lean concepts. The output of the stamping section rose by 30 MT per month over the previous season as a result of an increase from 75,000 to 85,000 strokes per day in each stamping press. This resulted in an increase in saleable output to the tune of **Rs. 21.9 million** with the same resources. An increase of 5000 motor guards per month was also seen which translated to a revenue growth of about Rs.3.6 million per year. All this was achieved with the existing resources of people, machinery, and facilities and this resulted in a significant contribution to the profitability of the unit.

In the 18 months, the team had worked hands-on and understood how each of the Lean tools could be customized for their operations. This enhanced the confidence of the members of the team to bring in necessary changes to stay competitive in the market.