Chapter

Application of Lean in a Small and Medium Enterprise

Venkataramanaiah Saddikuti, Saketh Saddikuti Venkat and Ganesh Babu Shanmugam

Abstract

Application of lean principles in manufacturing as well as services has been revolutionizing the operations for more than five decades. Many large as well as small enterprises have implemented lean and reported benefits in both direct and indirect activities of business. Due to advent of digital technologies and better understanding of process improvement approaches made lean much more effective across many sectors. In this chapter, we highlight various elements of lean and its application to a small enterprise in food processing sector in India. We draw some useful insights based on the implementation of lean and challenges faced by SMEs.

Keywords: lean, Toyota Production System, customer value, value chain, food processing, SMEs, Total Quality Management

1. Introduction

> *"One of the most noteworthy accomplishments in keeping the price of Ford products low is the gradual shortening of the production cycle. The longer an article is in the process of manufacture and the more it is moved about, the greater is its ultimate cost" [1].*
>
> *Henry Ford 1926*

Lean was identified at Toyota Production System (TPS) to eliminate or reduce waste or non-value added activities in the manufacturing system. It is also believed that application of Lean was implemented by Henry Ford at Ford Motors in 1920s. Lean is defined as by the National Institute of Standards and Technology Manufacturing (NISTM) Extension Partnership's Lean Network [1]: "A systematic approach to identifying and eliminating waste through continuous improvement, flowing the product at the pull of the customer in pursuit of perfection." It is a systematic approach for reducing different types of wastes which are constituting around 95% of the total waste. Important elements of TPS is given in **Figure 1**. TPS/Lean system was built on two major aspects (i) Elimination of Waste and (ii) Respect for people. TPS has three pillars (JIT, Continuous improvement and Jidoka) with fundamental blocks of standardized and stable process and level production. Some of the wastes in manufacturing environment are given in **Figure 2**. **Table 1** gives the brief description of eight wastes in TPS [2, 3].

The main objective of this chapter is to highlight various elements TPS and wastes in a typical manufacturing organisation and demonstration of application of

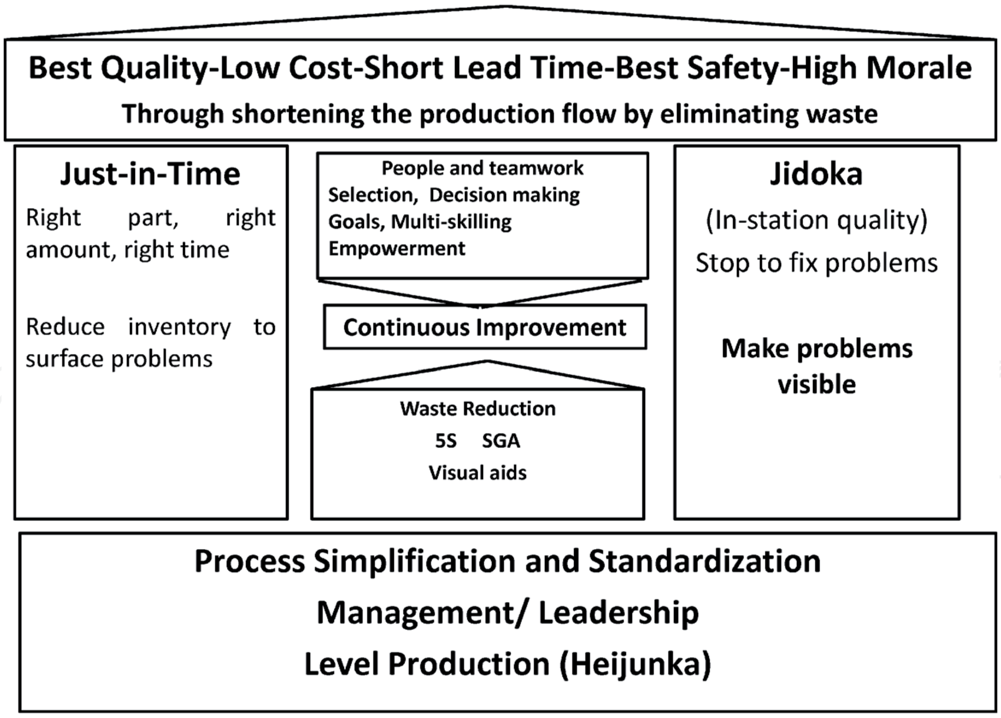

Figure 1.
Elements of Toyota Production System.

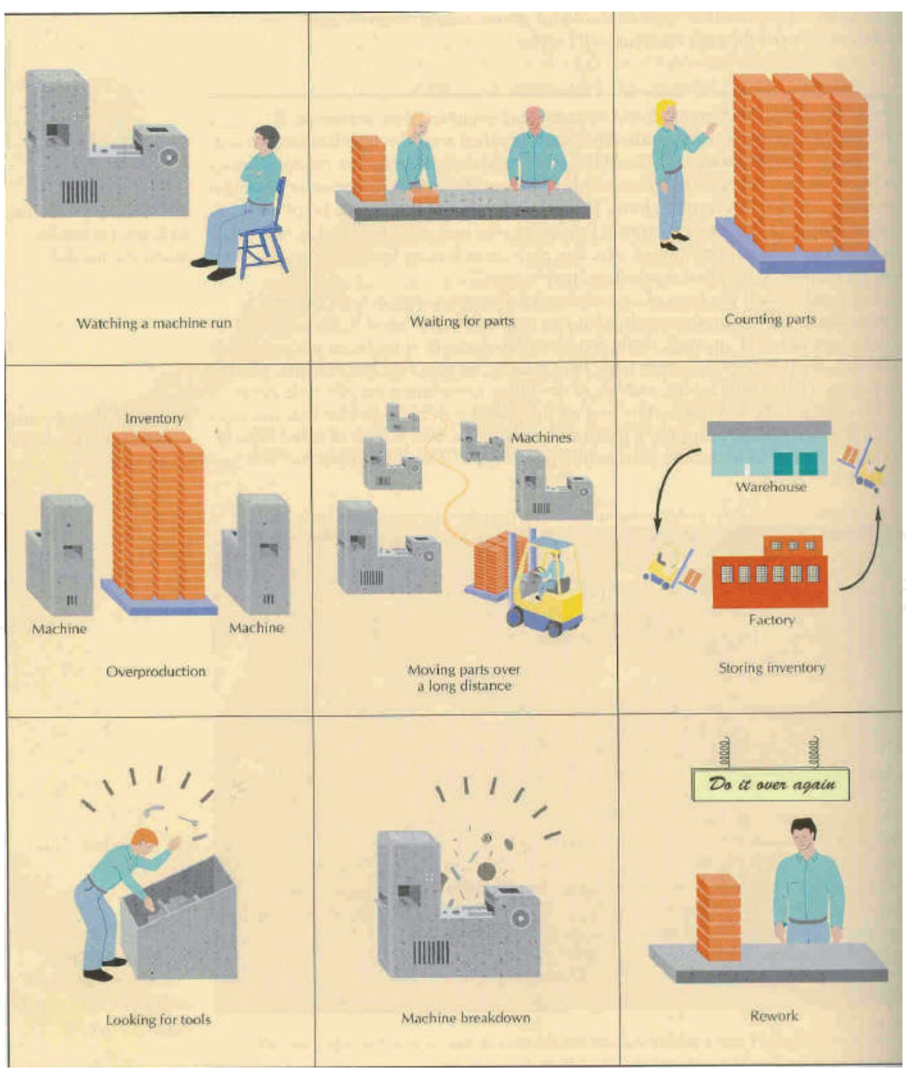

Figure 2.
Different types of wastes in manufacturing.

Sl No	Waste Type	Brief description and Examples
1	Overproduction	Producing more than required. It includes safety stocks, work-in-process, Finished goods etc
2	Waiting	Waiting for authorization, information, tools and equipment or operator. Example, waiting for machine, operator or handling equipment before or after completion of an operation at particular stage of the process.
3	Transportation	Distance travelled by various resources including parts, operators, handling equipment from point of availability to point of use. Example, an item travelling from storage to assembly or from vendor to manufacturer.
4	Over Processing	Processing more than required. Example, finishing more than specifications
5	Inventory	Any resource kept in reserve for future use due to uncertainties. This would include raw materials, WIP or finished goods.
6	Defects/Errors	Not meeting the customer specifications. Under size or over size dimensions of an item.
7	Excess Motion	Unnecessary motion or movement of products/resources due to poor layout or lack of coordination.
8	Underutilized People	Underutilization of highly skilled manpower. Example, high skilled person doing low skill job.

Table 1.
Different types of wastes in manufacturing.

lean at a small food processing enterprise. This chapter is organised in five sections. Section two highlights the methodology adopted in the chapter, section three describes building blocks and benefits of lean, section four application of lean at a small food processing organisation and finally conclusions in section five.

2. Methodology

In this study, we have adopted a generic method for literature search and industry practices in the area of lean manufacturing. Literature search has been carried out using key words like Lean, SMEs, Food processing, Toyota Production System, customer value, TQM from the databases like ABI, EBSCO, Google Scholar, etc. The search does not include other databases. Apart from these we have also used the case of an SME in food processing sector. The author's own research and consulting experience in the area of lean and transformation of SMEs in manufacturing and services.

3. Building blocks and benefits of lean

Lean/TPS uses various tools or building blocks which are proven and easy to implement in practice for minimizing or elimination of waste. Major building blocks of Lean include the following:

- Pull System
- Kanban

- Work Cells
- Total Quality Management
- Total Productive Maintenance
- Point-Of-Use-Storage
- Quick Changeover/SMED
- Batch Size Reduction
- 5S
- Visual Controls
- Concurrent Engineering

These are not only used in manufacturing organizations but also apply equally to service organisations. Summary of these are given in **Table 2**.

Many organisations around the world from manufacturing and service organisations have reported both operational and administrative benefits of successful implementation of Lean principles. According to NISM survey of firms implemented lean have reported operational and administrative benefits and are given below.

Operational benefits:

- 90% reduction in Lead Time (Cycle Time)
- 80% reduction in Work-In-Process Inventory
- 80% improvement in quality
- 75% improvement in space utilization
- 50% increase in productivity

Administrative Improvements includes the following:

- Reduction in order processing errors
- Streamlining of customer service functions
- Reduction of paperwork
- Reduction in staff required
- Improvement due to outsourcing of non-critical functions
- Reduction employee attrition
- Improved job standards

Sl No	Name	Brief Description
1	Pull System	Manufacturing based on customer demand/order, Make-to-order (MTO), in terms of exact requirement and time. This is against Push system. Capacity driven or Make-to-Stock (MTO).
2	Kanban	Producing based on accurate and timely information given in the form of a card where material is moved based on the timely information between stages. It can use single card Kanban or dual card Kanban system. Size and number of Kanbans are decided based on the volume of demand and production economics.
3	Work Cells	Lean or TPS focus on improved flow of material, manpower and other resources. The resources are organised around the requirements of the job done. Generally U-shaped layouts are more productive. It also helps better coordination and communication
4	Total Quality Management	Lean is built based on TQM fundamentals where every aspect of the organisation is very important. It recognizes the strength of the human resource and team work.
5	Total Productive Maintenance	It is based on proactive or preventive maintenance approach using knowledge and cooperation of people, vendors and other resources. It tries to identify and eliminate the breakdowns and improve the reliability of the system for improved throughput.
6	Point-Of-Use-Storage	This aspect of lean focus on keeping the required resources near the place of use. For example, the tools and equipment required at work center kept at the work center itself. Dedication of resources.
7	Quick Changeover/ SMED	It focuses on reduction of long changeovers which will be costly in terms of time and cost. It allows more frequent changes and smaller lot sizes.
8	Batch Size Reduction	Traditionally, manufacturing organisations used to manufacture to reduce the cost of set-up. In pull system, small batch size is more appropriate which will result in low WIP, low quality cost etc. Small batch size increased inventory turnover and better visibility, improved cash flow.
9	5S	5S is a systematic way of organizing the workplace.
10	Visual Controls	TPS heavily uses visual controls in almost every aspect of the business since it enhances the productivity, visibility and easy to understand at the executional level.
11	Concurrent Engineering	This approach helps in reducing the lead time drastically and utilizes cross-functional teams. This aspect particular helpful in reducing the time-to-market of new products/services. Some of the empirical results shows that around 50% decrease in the time-to-market.

Table 2.
Building blocks of Lean/TPS.

4. Application of lean at a small food processing organisation

This section highlights the implementation of Lean at a small food processing organisation in Southern part of India. The organisation was established in the year 2002 and gained a significant market share. The founder of the organisation is a first generation entrepreneur with high levels of enthusiasm and energy along with dedicated team of around 50 members including 10 members representing planning and execution [4].

4.1 The context

The organisation is a leading manufacturer and exporter of high-quality aquarium and pet food.

The organization was unable to increase the sales turnover and also struggling to maintain healthy profit margin despite that the organization catered to both Indian and export market. The founder of the organisation sought the help of one of the authors of this chapter for improving the market share and revenue. A five-member team consisting of internal members and external Lean transformation expert identified the following challenges.

- Sales Turnover is stagnant for the last three years
- Declining profitability
- Manufacturing cost is on an increasing trend
- No clarity on the losses in both manufacturing and sales function
- No management reviews and lack of data transparency among the team members
- No proper coordination among Team on deliverables
- Founder get involved in all day to day decision making

4.2 Solution methodology adopted

Internal team along with external Lean transformation expert identified various areas for improvement using brainstorming sessions and listed the following areas for improvement.

- Training of the core team on Quality Management and Lean project
- Awareness workshop for the senior executives
- Development of overall system with suitable metrics and fixing of responsibilities for each functional area of the business.
- Identified the waste in plant utilization,
- Efficiency, and quality issues
- Implemented Quick changeover techniques to reduce changeover losses between food products
- Identified the constraints that affecting the equipment efficiency
- Set the key performance metrics (KPI's) for customer deliveries, cost, and quality and reviewed every month along with Business Head
- Implemented sales and operational key performance reporting on a daily, weekly basis to avoid communication problems
- Analysed and implemented right inventory norms for raw material and finished goods to improve stock availability and reduce inventory

- Identified and implemented cost-saving projects in plant and administrative areas
- Identified the staffing levels and gaps and recruited suitable skilled personnel in the areas of shortage
- Improved the communication process among operations, sales, and finance team to take decisions on time
- Identified the utilization of floorspace in the plant and movement of the products inside and outside the organisation

4.3 Application of lean tools & process

The team has adopted and designed transformation process using well proven lean management tools and processes including the following:

- Performance Measurement and Management at business and operation level
- Application of Lean tools and techniques
- Designed suitable inventory management systems for raw material and finished goods
- System for Performance reporting on daily, weekly and monthly basis
- System for communication at all levels of the organisation
- Metrics for supply chain management at internal and external to the organisation.

4.4 Business result achieved

- 40% reduction in changeover times
- 40% reduction in inventory value without affecting deliveries
- 33% Reduction in number of shifts (from 3 shifts to 2 shifts)
- 30% Improvement in plant capacity utilization;
- 30% increase in production tonnage with reduced working hours
- 15% increase in sales turnover and increase in delivery performance by around 10%
- 15% (appr) increase in operating profit (from negative to positive)
- 5% reduction in overall manufacturing cost

4.5 Recommendation for sustainability and future growth

Based on the detailed study and implementation, the team has suggested the following for future growth.

- Training and development of workforce in all functional areas with right caliber of professionals
- Monitoring and evaluation system for financial performance and cash flows
- Expanding into new markets
- Structured review mechanism on business and functional performance on regular basis
- Accountability improvement through organizational structure/role clarity and management practices
- Streamlining New Product development process w.r.t new markets and sales plan

5. Insights and conclusions

Implementation of Lean has benefited both small and large business organisations in manufacturing and services. Lean systems/practices are built on the strong empirical evidence of both operational and administrative benefits. Lean focuses on elimination of waste by utilizing the dynamics of team work and strength of people and processes. Implementation of lean has proved in improving quality of products and services across all industries and organizational boundaries and revolutionizing the operations [5]. There are many other studies like [6–10] focused on various aspects of lean implementation. However, the implementation of lean requires certain level of certainty/stability in the system, discipline and culture at inter and intra organizational level. Further, studies can focus on the impact of socio, economic and technological determinants of lean in different sectors of business.

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Chapter

Lean and Kaizen: The Past and the Future of the Methodologies

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Abstract

Lean and Kaizen improvement methodologies have been in the entrepreneurship spotlight for a long time. They can be adopted by any kind of enterprise, and they succeed in producing better long-term results, improving their performance, but most important, influencing the philosophy of the organizations implemented. In this research, many case studies and success stories of companies implementing Kaizen or/and Lean methodologies, or even the new Lean Kaizen methodology, will be introduced. We attempt to evaluate the performance of Lean and Kaizen implemented companies and distinguish the elements that made the difference. Maybe, it is some specific tool, or an aspect in the culture that was enhanced, since the implementation of these business process improvement methodologies. Finally, thoughts and estimations will be presented, regarding the future of these methodologies, in the unstable and rapidly changing economic environment.

Keywords: Lean, Kaizen, Lean Kaizen, performance, process improvement

1. Introduction

This chapter presents the methodologies of Lean and Kaizen, their contribution in the enterprises' field and their future potential contribution to the field of management.

1.1 Lean (production, manufacturing or management)

First of all, lean manufacturing, will be referred, as it seems to be a methodology, that was keenly embraced and wields a great acceptance in the management (theoretical and practical) world. It started with the efforts of Toyota automobile company, while some believe that Ford motor company, was also a great influence in creating its concept.

Its main scope and its achievement is the elimination of waste and this can lead in an increase in productivity.

There are many proven cases of continuous improvement with the implementation of lean thinking methods and tools. However, it is not a concept that impose specific rules or tools to be implemented, but rather it is a philosophy that encourages efforts in order to achieve its main goal, which is to eliminate waste.

1.2 Kaizen

Kaizen is more of a philosophy than specific technique or methodology, yet it has also affected and changed seriously the minds of the managers. It utilizes many analytical techniques to succeed in its mission, as value-stream mapping and the5 why's.

It has been introduced that these two methodologies have provided valuable assets in the field of management. It is notable that in the last years, Lean is also referred as Lean Management, representing the value that the methodology has produced in the management field. Moreover, and even though these two above methodologies, were introduced in the manufacturing field, they have managed to expand in all business industries and it seems that have achieved much in improving organizational performance. They are highly appreciated in the theoretical and practical field of management. They are considered (many times along with Six Sigma), as business process improvement methodologies, since they aim at improving all the processes in an organization. They perform activities in order to gather data, to track and evaluate all the functioning processes, and of course, they apply a continuous improvement effort.

However, in the last years, many other aspects have emerged in the economic status, like the constant economic uncertainty, which seems to be critical and threatens even the existence of many companies. Hence, the answer to be answered is if and with which manner could these methodologies keep up their efforts and produce sustainable solutions for the enterprises.

To answer these questions many writings from experts in the field were looked into the literature and their views were registered. In the conclusion, the future aspects of these methodologies will also be presented.

2. Introduction to Kaizen and Lean

2.1 Lean

Lean is called by many names as lean manufacturing, lean production, or lean thinking. New terms are the lean management and lean industry.

The main focus of the Lean methodology, is to eliminate waste in order to obtain more resources dedicated in finding ways to satisfy the customers. It intends to intervene to the value stream of the organization, in order to improve or eliminate every unneeded process that waste resources. It is also said that lean production was founded on the idea of Kaizen.

It has a great history and it is always linked to automotive industry. Many ideas that form the lean philosophy, were created by car companies like Ford and Toyota. Sometimes lean thinking is referred as a synonymous to Toyota or Toyota production system.

Author [1] has presented the Toyota Production System, which has been defined as a method which focuses on defining and eliminating non-value added activities or waste in all systems and processes [2]. One of its approaches was the Just-in-time (JIT) methodology, which acquired the necessary resources when they were exactly needed and helped in solving many material flow problems.

Authors [3], in their book 'Lean thinking: Banish waste and create wealth in your corporation', that introduced lean to a broader audience, have managed to extend the concept in a general perspective. The same authors, define lean as: "a way to specify value, line up value creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively".

Lean is a multi-faceted concept which was identified and coined to explain the success of the "Japanese Way of Working" that enhanced their increased competitiveness at the time [4].

Components of the "Lean Idea" include:

- operations concepts, such as zero inventories [5], Just-in-Time (JIT) [6] and small lot sizes [7];
- the underpinning of robust quality procedures exemplified by Total Quality Management (TQM) and Total Productive Maintenance (TPM); and,
- a method of working that encourages empowered employee participation which challenges the over-bureaucratic top-down, function orientated organizational structures that had traditionally dominated many "Western" organizations [8].

This view of Lean was endorsed [9], categorizing the components of Lean into four "bundles":

- JIT bundle
- TQM bundle
- TPM bundle and
- Human Resource Management (HRM) bundle.

To be successful in implementing all these Lean facets in a coordinated, coherent manner, strong leadership and a clear alignment with organizational strategy over many years is required.

The 4P's model of lean are:

In the book of [10], the 14 principles for continuous improvement are categorized in four pillars (P's):

- Philosophy
- Process
- People
- Problem solving.

The above framework is created and implemented in Toyota company.

2.1.1 Customer value

Lean emphasizes in the provision of value to the customer and there are three types of value:

- Values added: contribute directly to the needs of customer.
- Non-value add: no contribution to the needs of customer.
- Non-value add: (but necessary or essential non-value add)

2.1.2 The eight wastes

According to lean philosophy, the non-needed (not-adding value) activities are considered a waste. These are the following:

- Defects
- Overproduction
- Transport (moving of products)
- Waiting
- Excessive Inventory
- Motion (moving of people)
- Processing (unwanted process steps)
- Skills (lacking)

The main wastes were seven. Skills is an new addition.

Lean is much depended on the tools and methodologies that it utilizes. Some lean strategies that seem more successive for the concept and can be implemented in many different ways (e.g. merged), are [11]:

- 5S
- Automation
- Continuous flow
- Continuous improvement
- Kan-Ban
- Kaizen
- Six Sigma
- Total Quality Management (TQM)
- Value stream mapping (VSM)
- Work standardization
- Zero defects concepts
- Lean thinking
- Work in progress
- Flexible manufacturing system

2.1.3 Benefits from lean adoption

The benefits from the implementation of lean can include many aspects, like the minimization or even elimination of waste, less work load, qualified and skilled workers, zero delays, saving time, reduction of costs, etc. [12].

Lean manufacturing changed the way that industry worked in the era of mass production and it presents many differences from the traditional manufacturing way. The major differences include [11]:

Higher flexibility, higher customer satisfaction, higher empowerment, shorter lead time, the inspection is performed in a 100% level and by workers, the inventories are produced per demand, the batch size is small and continuous, pull scheduling is implemented.

However, lean has not only domained the manufacturing field; it has also managed to enter in many more sectors, like service, trade etc. It has been also accepted as a new management system and a new term 'lean management', was created [13]. Hence, lean seems that can play a vital role in the management theory and practice, in order to produce a sustainable future for the enterprises.

2.1.4 Barriers and disadvantages from lean

Lean implementation or the attempts to implement it, presents some drawbacks like the below:

- Every new concept and change in the workplace it is not easy to be accepted by the human workforce.
- Lean is not considered easy to be implemented in practice [14].
- The main scope of lean is to maintain industry stable without any disorders, but this is difficult to be applicable.
- The barriers created from the new concept, prevent the workers to perform their duties normally. However, lean thinking can contribute in overcoming those barriers, by creating a cooperative environment [14].
- Not every industry seems ready to accept the drastic changes of lean in production and quality [15].

2.2 Kaizen

Kaizen is a Japan-oriented strategy (also referred as culture, philosophy, approach, or methodology), which literally means continuous improvement (CI). It manages to involve all the workforce of an organization in its activities (e.g. Kaizen events, suggestion system) and it also highlights the importance of the workplace as the center of all actions, activities and processes. One of its main advantages is that it does not induce financial burdens to the organizations.

Its main philosophy is to produce small changes, which when taken together they can have a large impact. It utilizes the continuous improvement approach in every aspect of the organization.

It aims to involve workers from multiple functions and levels in the organization in working together to address a problem or improve a process. It requires skilled and well trained workers to achieve its scope.

It was first captured and implemented in big manufacturing sites, like the Toyota motor company. However, its philosophy was suggested that it can be implemented in every human life activity [16, 17]. Anywise, its main idea is that everyone and everything can change to the better, doing small steps.

It promotes process-oriented thinking [18] and continuous improvement of the standard way of work [19]. It is an endless effort for improvement, involving everyone in the organization [20]. The actions of mobilizing staff and encourage them to participate, could make them also responsible and able to contribute to the company's development [21].

Sometimes it is identified as a management approach (like TQM, Lean manufacturing, or company wide quality control), while other scholars considered it as a group of techniques and tools for cutting waste and finally others, appraised highly its success to intensify staff participation through its suggestion schemes [22].

The scholar that managed to introduce it in a formal aspect, was Imai, with his two books [16, 23], although the method still lacks a detailed explanation that would clarify better its theoretical context [22, 23]. Kaizen forms an umbrella that covers many techniques including Kanban, Total productive maintenance (TPM), Six Sigma, Just-in-time (JIT), suggestion system etc. [16]. According to [16], Kaizen is a continuous improvement process involving everyone. Broadly defined, Kaizen is a strategy to include concepts, systems, and tools within the bigger picture of leadership involving and people culture, all driven by customer [23]. Its success in uncovering a problem, making it visible, looking for its root causes and then eliminating them, was of extreme importance in the development of the manufacturing sector in countries such as Japan and Korea [24].

2.2.1 Kaizen actions

One of the actions that Kaizen implements is the Kaizen event, which is a five-day (or six) team workshop defining specific goals for an area that requires improvement. A team leader will lead this event and will include training, data collection, brainstorming, and implementation. At the end of the event, the team leader will create a follow-up plan and a report to be submitted to management.

A typical Kaizen event may include the following

- Define goals and provide the necessary information
- Evaluate the current status and create a plan for improvements
- Implement planned improvements
- Review and fix what does not function
- Report results and determine any follow-up items.

The above cycle is also referred as PDCA (Plan, Do, Check and Act). This cycle is a vital part of the Kaizen philosophy.

2.2.2 The Key Players of the Kaizen Team

Kaizen requires the support of an appropriate team with the right Team Roles. There are the following team roles.

- Champion: The champion is the person driving the train. It is normally a senior manager or executive who can defy barriers and inspires.

- Facilitator: Part coach, part trainer, and part leader, this person is typically well-versed in Lean and brings substantial experience to the table. At any given time, a facilitator may be overseeing several kaizen events in different stages.

- Team Leader: The team leader is in charge of the event and does most of the planning and preparation under the supervision of the facilitator. The team leader is often the manager, supervisor, or engineer in charge of the process being improved.

- Team Members: Team members are picked from the work area, from the stakeholders, or from the company at large. The best teams combine a variety of experience and skills. Teams typically range from 5–10 people depending on the size of the project.

- Stakeholders: Kaizen events influence a lot of people. Those people are known as stakeholders and should be included in decisions about the project.

- Support Team: Kaizen events often require support that goes beyond what team members can perform. This often falls on the facilities team and on IT.

2.2.3 Kaizen umbrella (tools and techniques)

Kaizen philosophy needs assistance to achieve its scope and therefore it includes many weapons (they called the Kaizen umbrella), such as the following:

- Total quality control

- QC circles

- Suggestion system

- Automation

- Kanban

- Just-in-time

- Zero defects

- New product development

- Quality improvement

- Total productive maintenance

- Small-group activities

Of course many of the above Kaizen activities, could also be part of the lean methodology, which sometimes includes a Kaizen project.

2.3 Lean-Kaizen

Lean-Kaizen is a new suggested approach of quality improvement in the literature that combines the two methodologies, which as already has been refereed, many times are implemented together and it is not such a surprise to see them combined together. However, it is also introduced as a new approach and will be presented as such, in this chapter.

The Lean-Kaizen technique, as a novel one, is composed of two basic words i.e. Lean and Kaizen which implies continuous elimination of waste through small-small improvements [25]. It is adopted for waste identification and elimination; it helps industry to be lean [26, 27]. It is a systematic way that focuses on continuous improvement of the process, productivity, and quality of the product by suggesting effective and efficient Kaizen events [10]. Leanness can also be defined in terms of efficiency and effectiveness of the manufacturing system [28].

The adoption of the Lean-Kaizen approach improves the organization output by solving problems through identifying and implementing small improvements in process, product, and system [29, 30]. So, the Lean-Kaizen approach is required to be implemented in order to produce quality products by eliminating waste Muda) in the entire system of the organization [31].

Quality is understood as a measure of excellence or a synonym of zero defects, zero deficiencies or absence of variations in the product by many industries. In order to achieve the desired product quality, the quality system performance is continuously monitored and evaluated for the sake of constant improvements of customer satisfaction, morale and reliability [32].

3. The contribution of the methodologies

3.1 Lean

3.1.1 In which industries

Lean and its strategies can eliminate all types of industrial waste [33]. Lean manufacturing has as a goal to eliminate waste and it succeeds in it without having to define additional requirements of resources [34, 35]. However, it seems that except the manufacturing sector, which gave birth to the concept of lean, many more industries have been profited from its power.

3.1.2 In which fields

Lean manufacturing contributed in improving manufacturing operations, protecting the industrial jobs and lift customer satisfaction [36].

The appropriate implementation of lean, improves the quality and the productivity and reduces the amount of inventory and work processes [37].

Except the improvement in productivity, lean manages to level up customer and employers satisfaction [36, 38].

The study of [39], presented the implementation of lean in various types of industries and it managed to achieve various types of waste reduction, manufacturing system design parameters and business value achievements.

In their study [40] concluded that despite the resistance to change in public organizations, the implementation of lean succeeded in the optimization of resources and the simplification of processes.

In a study in health care services, [41], noticed that waste was eliminated and quality was maximized, benefiting the customers.

Public sector seemed to be a nice field to implement the thinking of lean, as there is many waste and the needs for better quality are more than before.

Therefore, continuous improvement approaches have been formally applied in the public sector all over the world, in an attempt to improve service quality and streamline processes, often in response to cuts in public expenditure budgets imposed by governments.

New Public Management (NPM), a new theory, emerged as the supporting doctrine to this policy, that advocated the imposition in the public sector of management techniques and practices drawn mainly from the private sector, as according to NPM greater market orientation would lead to better cost-efficiency, with public servants becoming responsive to customers, rather than clients and constituents, with the mechanisms for achieving policy objectives being market driven.

A new effort that contributes in examining lean in the public sector is the "Lean in public sector" project (http://leaninpublicsector.org/). Launched in 2007, the aim of LIPS was to extend lean project management to public sector construction projects. Its scope is to include the application of lean thinking to government operations generally so that new facilities support, new and more effective ways of delivering government services.

Some of the successes of this project, include:

- Introducing the lean management philosophy and methods to Australia's project alliancing.

- Following the pioneering work of the Finland's Transportation Agency, a range of Finnish government organizations has successfully applied lean and Integrated Project Delivery (IPD) principles to over 35 projects since 2009 with more on the way.

- At the 2013 conference it was announced that the European Commission ruled against a challenge to the contract award of one of those Finnish projects, thus providing proof that integrated project delivery is legal under EU construction procurement regulations.

- In the US, the University of California, San Francisco (UCSF) has led in the development and testing of alternative contract structures and methods of aligning commercial interests, and this without multi-party contracts, which are not currently allowed for the university system.

- The California state university system and many community college systems are also successfully applying lean concepts and methods within the limits of current regulations.

3.2 Kaizen

Some examples of Kaizen implementation and success are presented in the **Table 1**.

It can be concluded that Kaizen has also been implemented in organizations of all business industries and provided valuable solutions.

Authors	Industry	Tools, actions	Results
[42]	Manufacturing foods product	5s Technique, team training	Decrease in quality rejections, reduction in change over times and increase in manufacturing activities.
[43]	Industrian technology	Kaizen approach and lean thinking	Reduction in space used, material handling costs, lower scrap rates.
[44]	Manufacturing industry	Six sigma, JIT	Eliminate waste, increased sales.
[45]	Manufacturing	Kaizen event, inventory management Kaizen,	Reduced process time
[46]	Public agricultural organization	Kaizen project, 5S,	Process improvement, shorten work processes, decrease n financial expenses
[47]	Semiconductor industry	Kaizen technique	Cost reduction,
[48]	Automobile assembly production line	Set-by-step kaizen procedure	Elimination of major functional problem, reduction in quality rejections, elimination of rework processes.

Table 1.
Kaizen implementation examples and results.

4. Conclusion

Having realized the potential of Kaizen and Lean, even big consulting organizations have dedicated many writing in presenting and exploring the methodologies. Consulting companies are organizations that provide professional services in other companies in the fields of marketing, financing, ICT, logistics, business plans etc. Some of the biggest consulting companies worldwide are: Deloitte, McKinsey, EY, Boston consulting company.

For example Deloitte has attempted to connect Lean with Industry 4.0* and has presented many other cases of lean implementation in several fields. Some links of relevant articles follow:

https://www2.deloitte.com/us/en/insights/focus/industry-4-0/digital-lean-manufacturing.html

https://www2.deloitte.com/us/en/blog/human-capital-blog/2020/lean-strategic-planning-design-thinking-agile-what-does-it-all-mean-in-becoming-exponential-hr.html

https://www2.deloitte.com/content/dam/Deloitte/ca/Documents/life-sciences-health-care/ca-en-life-sciences-health-care-lean-in-health-care.pdf.

https://www2.deloitte.com/us/en/insights/focus/industry-4-0/digital-lean-manufacturing.html.

* Industry 4.0 is the concept of creating a digital enterprise by establishing digital technologies and integrates them with advanced production and operation techniques.

McKinsey, also a big consulting organization, has presented some analytical guides and presentation of the methodologies. Many of them are evident in financial institutions and the links of some follow:

https://www.mckinsey.com/business-functions/operations/our-insights/the-work-of-leaders-in-a-lean-management-enterprise 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

https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/financial%20services/latest%20thinking/reports/lean_management_new_frontiers_for_financial_institutions.pdf

https://www.mckinsey.com/business-functions/operations/our-insights/next-frontiers-for-lean

Digital lean

Digital lean is an example of the integration of digital technologies and lean principles It utilizes lean theory to decrease the waste in digital technology actions and processes.

Digital lean uses Industry 4.0 and other digital tools to create the appropriate information for all operations and processes. As data come in a high frequency way, it can be managed and directed in the appropriate resources.

Digital lean can be a valuable asset and some of its achievements are: reduced costs, improved quality and higher return on investment, compared with any other methodology that is implemented individually.

Lean Industry 4.0

A new concept deriving from the combination of lean and Industry 4.0 is presented.

The main scope of lean is to reduce waste in the value chain, focusing on client's value and strengthening the role of the employees in all this process [3].

On the other hand, the basis of Industry 4.0 is the ability to quickly collect, process, analyze and exchange large data sets between machines. Thanks to modern technologies such as: Cyber-Physical Systems (CPS) or Internet of Things (IoT), it is possible to react faster and more flexibly to existing problems, but also to more efficient value creation processes, while reducing costs [49].

A suggested solution is the combination of the above concepts, in order to solve the problems that modern production faces. Despite, the significant differences, between the two concepts, they seem to have the same goal, to increase added value [50].

4.1 The present and future of the methodologies

Lean can provide solution in many fields and it is evident that even service companies embrace and appreciate it [51]. Lean reached functions that previously seemed quite difficult to transform. (management principles once known as lean manufacturing [52].

The new concept of lean management, which introduces the values of lean in the modern management, has been adopted by many organizations. It provides a roadmap that holds the organization (and the workflow) stable and able to solve all of the derived problems. The primary winner of these efforts is the customer and then consequently the organization.

Lean seems not to be a static methodology. It is still developing and could be a valuable solution for many enterprises [53]. Lean can be fitted in the rapid changing world, which seems to be even more intense after the COVID-19 crisis. The Toyota lean business system has managed to deliver: better quality, productivity, customer focus, innovation, employee engagement, profitability and even environmental sustainability [54]. Organizations should concentrate on involving all employees in the continuous improvement organizing appropriately the value stream and offer the ideal products and services for the customers. Money and profit should not be their main incentives, as customers have improved demands and there is intense competition.

Questions that challenge current entrepreneurship could be, how well large, modern organizations work as almost as old as management [52]. Problems that could affect organizations are: slower growth, debt burdens, aging workforces, mismatches between worker skills and available jobs.

There are successful organizations that attain a state of continuous improvement. Their performance is consistent in the short and long run. However, it is not always effective for every organization to imitate best practices.

Hence, lean management system [13] could be in the forefront of the management field, in order to provide valuable solutions. Its main aspect, which is to improve material flows, could be a valuable asset.

Lean can contribute in the appropriate integration of the technology field in the organizations, as it can provide valuable information with the customers' feedback [54].

The lean system could assist information management system to solve their information flow problems. If the information provided is the essential and appropriate, the information system could be benefited and improve its performance.

The information gathered with many ways and directed appropriately, could be an instrument to link this information with direct customer needs and inform the relevant departments in an organization.

From all the cases and the thoughts about Lean reported in this study, it is evident, that it is a philosophy that can be an asset in the management field and the question is if the organizations could make the right choices and be benefit from its positive aspects.

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Chapter

Introduction to Lean Waste and Lean Tools

Shyam Sunder Sharma and Rahul Khatri

Abstract

In the turbulent and complex business environments, many Indian SMEs are facing stiff competition in the domestic as well as in the global market from their multinational counterpart. The concept of lean has gained prominence due to the fact that the resource based competitive advantages are no longer sufficient in this economy. Hence, lean is no longer merely an option but rather a core necessity for engineering industries situated in any part of the globe, if they have to compete successfully. Lean Manufacturing (LM) which provides new opportunities to create and retain greater value from the employee of the industry based on their core business competencies. The challenge of capturing, organizing, and disseminating throughout the aggregate business unit is a huge responsibility of the top management. The success of any industry depends on how well it can manage its resources and translate in to action. The adoption of lean manufacturing through effective lean practices depends on interpretations of past experiences and present information resides in the industry. Generally, in an industry, some tangible and intangible factors exist in the form of non-value adding activities which hinder the smooth lean implementation are known as lean manufacturing barriers (LMBs).

Keywords: Lean, waste, kaizen, manufacturing

1. Introduction

In the present worldwide situation, manufacturing industries are primarily handling difficulties from two directions. First, cutting edge manufacturing ways of thinking are arising, while the current techniques are getting outdated. Second, consumers demand is changing in very short of time. The clients have become more demanding for inventive product in short timeframe and at less cost. Basically, to adapt up to such difficulties, the idea behind manufacturing industries' these days is to capture the customer demand while limiting waste [1]. Subsequently, manufacturing firms working in such quick changing in customer demand in competitive market. In last thirty years, manufacturing industries are introducing lean thinking. The lean manufacturing word means to minimize the industrial waste or to eliminate the waste and improve the benefits of manufacturing industries by smooth production flow [2]. Without lean practices any industry cannot be successful in the present-day situation due to globalize competition in market with low cost, high quality, and shorter delivery time. It is very difficult for engineering industries to shift from traditional system to lean system. a troublesome undertaking to move from a conventional assembling framework to a lean assembling one. This change makes attention both employee and method.

Lean manufacturing is a management strategy that tries to make industries more competitive, minimize the manufacturing cost by eliminating the industrial waste and increase the productivity of an organization [3].

1.1 Research background of lean

Afterward World War II Japanese industries were confronted with the difficulty of immense deficiencies of skilled manpower, money, and material. These difficulties that industries of japan were challenged with compared from those of their Western partners. This introduces "lean" thinking in manufacturing industries. Toyota Motor Company runs by Toyoda identified that American manufacturers were manufacturing better than Japanese manufacturing industries; during the 1940's American industries were beating Japanese manufacturing industries. To take an action for progress timely Japanese pioneers like Shigeo Shingo, Toyoda Kiichiro, and Taiichi Ohno, they are receiving the challenge to improve the production system by eliminating the industrial waste, they have developed a new manufacturing strategy that is called "Toyota Production System," or "Lean Manufacturing." Taiichi Ohno, accept the responsibility to improve efficiency at Toyota is the primary force to develop Toyota production system. Ohno drew upon certain thoughts from the Western countries, and especially from Henry Ford's book "Today and Tomorrow." Ford's stirring production lines for continuous material flow developed the basics for TPS. After research, the TPS was refined somewhere in 40's and 70's, is still emerging today all over the world. The crucial thought of this system is to maximize the resource utilization and minimize the inputs that cannot be enhanced any value to a product that is a waste.

To contend in the present furiously competitive market, United States manufacturing industries has understand that the mass production idea must be modified to the lean manufacturing. An assessment that was done by MIT of transformation from mass production toward lean manufacturing, as explained in the book "The Machine That Changed the World" [4] arise the US companies from their nap. The assessment highlighted the extraordinary achievement of Toyota and pulled out the enormous gap that developed between the Japanese and Western engineering firms. The thoughts came in the mind of US industrialists on the ground that the Japanese industries developed, manufactured, and delivered items within less manpower, less investment, less floor utilization, less time, instruments, raw material, and overall investment cost [5].

1.2 What is lean?

The fresh transformation in engineering products and service division has made extraordinary difficulties for US firms. The consumer focused and exceptionally aggressive market has delivered old-fashioned of management that was not enough to overcome these complexities. These factors present a key test to industries to seek for new methods to survive in competitive global market. While a few industries keep on developing based on financial steadiness, different firms fight because of their absence of understanding of the change in consumer mentalities and cost practices. To avoid the present situation and to turn out to be more valuable, many industries implemented lean principles in their organization and perform well in global market [6].

Waste exclusion, cost drop, and employee encouragement are the basic ideas behind the lean manufacturing system, which has been implemented in Japanese companies for many years. The Japanese thinking of making business is completely distinct from the thinking that has been dominant in United States for a long time.

The typical western belief was that the just way to get turn a profit to apply it to the cost of production to reach the preferred sales price. The Japanese method, on the contrary assumes that the generator of the sale price is client. The more consistency you build into the manufactured goods higher the cost that consumers pay. The distinction among the price of the goods and this price is what decides the profit [7, 8]. To minimize cost, raise investment, get in more revenues, and remain competitive in a rising international market, the lean manufacturing discipline is to function in all parts of the value stream by reducing waste. The value stream is explained as the specialized activities needed to plan, order and supply a specific product or value within a supply chain [9, 10]. As of Womack describe it the term "lean" indicates a system that utilizes less with respect to output, to produce the equivalent outputs as those generated be a conventional mass manufacturing system, which adding more varieties to the final consumer [11]. This theory of business goes by various names. Agile production, just-in-time-production, synchronous production, world-class production, and continuous flow are all concepts that are used in contrast with lean production. The resounding theory of lean manufacturing, therefore, is to minimize costs by continuous improvement, which would ultimately reduce the cost of services and goods, thereby increasing profits.

"Lean" focuses on the removal or reduction of waste ("muda", the Japanese word for waste) [12, 13] and on optimizing or allowing maximum use of activities that add value from the perspective of the consumer. Quality is equal to something that the consumer is willing to pay for in a product or service that follows, from the viewpoint of the customer. The reduction of waste is also the central concept of lean manufacturing.

1.2.1 The 8 wastes of lean

The aim of lean is to abolish the waste from the production process. It is very important to identify the eight waste before digging it. Waste is in the least action or activity that will not enhance any cost to the product, or we can say, waste is any unwanted process that will reduce the value of the product and customer do not want to pay for that. Taiichi Ohno identified the initial seven types of waste that was called Muda in japan [12]. Transportation, inventory, movement, waiting, overproduction, overprocessing and defects are seven types of waste identified by Taiichi Ohno. The acronym 'TIMWOOD' also applies to them. The eighth waste was invented by western industries in 1990s, and that was unused of workers talent or 'Skill' of workers was later added. Therefore,' TIMWOODS' [14] is generally referred to as the 8 wastes [15].

1. **Transport:** Unwanted movement of the product during manufacturing. It is caused due to unplanned layout and product are unnecessary move from one workstation to other. In addition, excessive movement causes fatigue, wear and tear of product and equipment's [16–18].

2. **Inventory:** Over production or semi-finished product to convert into finished product. Sometime customer is not receiving the order or customer is canceled the order. So, this type of products is store and called waste. The advantage of inventory is that some time vendor will offer discount on large amount of purchasing. For maintain large inventory manpower and store cost is also involved and there is chance of product damage. Over procurement, work in progress (WIP) or the production of excessive goods than the customer demands may trigger surplus inventory. Certain inventory countermeasures take in procuring raw materials only when appropriate amount needed, reducing buffers between production stages, and establishing a queue system to avoid overproduction [15, 17, 18].

3. **Motion:** Workers are moving from one workstation to the other workstation without necessity and the manufacturing lead time is increase. This type of unwanted motion is considered as waste. Any excessive movement of workers, vehicles, or machinery requires waste in motion. Running, raising, reaching, bending, stretching, and shifting are part of this. To improve the working conditions for workers and improve health and safety standards, repetitive motion activities should be eliminated. Some motion countermeasures consist to make sure that the tools material is place near machinery in well organized manner [19].

4. **Waiting:** These are time delay and idle times during which value is not added to the product. If the machines, men, and material wait it is waste of these resources and it demoralizes the employees. The waste of waiting includes: 1) Operator is waiting for his turn and not receive material on time. 2) Machines are idle due to line unbalance [19, 20].

5. **Overproduction:** Excess of production over consumption. In market demand is less compare to the consumption, but industries are manufacture more to reduce the manufacturing cost. In this case inventory cost is increase and money is also block. So, it is considered as a waste. Overproduction means manufacturing additional goods via a 'push production mechanism'. Three countermeasures to develop overproduction. Firstly, by use of 'Takt Time' confirms that the production rate among workstations is continue. Secondly, reducing idle time like loading and unloading, setup times. Thirdly, reduce the WIP by using a pull or 'Kanban' system [19, 21, 22].

6. **Over-processing:** Over-processing will increase machining time, material handling time and add more process steps. Due to over processing the cost of the product is increased that will pay by the customer. For reducing over processing on products, consider standard job specifications for manufacturing. Prior to starting work, always think to the customer and produce product quantity as per the requirements of the customers and try to reduce the unnecessary operations and manufactured quantities where it is required [19, 22].

7. **Defects:** The product is not manufactured as per the specifications and tolerances given by the customer. Those products are rejected in quality inspection and consider as waste. Product/material will reject when the product/material is not suitable for use. Due to defective product/material it will loss of money and defective piece will not be reused [23–25].

8. Skills - The 8th Waste: This waste was not developed by Toyota, this 8th waste - the waste of human skills - is well known to many individuals. Also explain as no utilization of manpower skills, creativity, efforts consider in the 8th waste. This waste is developed when management not identify the skills of his workers in the organization. Employees is just following the boss order and do work as per the boss instructions. It is very difficult to optimize the process without taking help of frontline workers. This is because the worker who perform the job on shop floor is recognize the problems first and he has the solutions for that problem [14].

1.2.2 Identifying and eliminating the 8 wastes

Perceiving that they exist and giving a proficient system to characterizing them is the initial step to slashing waste. Value Stream Mapping (VSM) is a tool of Lean Management to assess the current state and to design a likely state. This outlines the progression of information and substance as they emerge. VSM is an effective strategy to plan the process involved, outwardly show the connection manufacturing process and to recognize nonvalue added and value-added activities. Utilize the VSM to characterize waste and proceed in view of the end client. Work in reverse to the beginning of the production process from the end client. Record cases of the eight waste in the process and construct a methodology to eliminate or limit them. Keep on provoking the staff to discover more waste and reliably build up their strategies. Draw in with and bring out their thoughts for change from the forefront staff. They will grow more trust in their critical thinking abilities as the group keeps on limiting efficiencies and waste decrease turns out to be important for their regular everyday practice after some time.

1.3 The 9 principles of lean manufacturing

Assembly work is categorized by short development cycles and batch sizes continuously decrease, Although the number of categories of goods and the models are still growing. Constant pressure to cut manufacturing lead times precedes to these needs and really makes the mix difficult, also for the highly imaginative producers. The capability to react quickly needs evolving buyer requirements usage of production systems that it is possible to re-configure and extend the fly that can fit, and advances in methods for assembly without having any initial output obsolete investment [26].

Lean production, An Approach That depends heavily on versatility and flexibility. Organization of the office is an exceptional Starting point for businesses who want to take a new look at their present Methods for production. Lean approaches are also worthy of study, since big capital is removed by them dedicated equipment outlays until automation becomes completely, needed. The idea of lean manufacturing, indeed, represents a big departure from such a famous automated factory the past few years. The "less is better" Manufacturing policy leads to a widely condensed, strikingly uncluttered, environment which is carefully calibrated to the environment manufacturer's specifications. Goods are generated in response, one at a time, to the specifications of the customer rather than of the batch produced for inventory. The target is to only generate the amount used and no more [27].

The number of parts is produced, it can change procedures, it is appropriate to handle various components and allow full utilization of workers, services, and floor area. The intrinsic versatility in manual assembly therefore, cells are superior to automated ones. This maximum requirement flexibility makes distinctive requirement on the lean work cell and the elements compose a lean work cell. Admittedly, the lean solution is not the only the solution to all production issues. But it does deliver a versatility that is special solution for more complex assembly commodities. This guide explains 9 essential descriptions Lean principles of development that should be assist you in evaluating lean manufacturing solutions for your own.

1. Continuous Flow:

The lean work cell's chosen to form U-shaped workcell. In order of method, each subprocess is linked to the next. And an employee within the U, minimum movement to move is needed the workpiece or one-piece assembly toward the next workstation. Ultimately, one of the targets of the slim workcell is to remove all movement with non-value-added; hence its U-shape. Where, when the procedure has been completed by the employee, he it just turns around and is back on the move. The workpiece may be carried from one piece to another. Operation with value applied to the next one. There are times, however when the workpiece or the fixture which holds the workpiece is too heavy and between workstations must be manually moved [28]. While it is possible to transport very heavy components on belt conveyors, manual push conveyors of gravity or gravity are suitable for moving the components between workstations. Theirs' The minimal complexity makes it easy for them to support and reduces time. Moreover, they are easy to attach to end-to-end, making it quick to switch inside a workcell workstations. The bent U-shaped "corners" a working cell can pose a problem. As they may serve as a possible dead space, they may act as a mini storage room, thereby facilitating a storage area going back to batch manufacturing. Alternatively, the use of a ball roller transfer should encourage the movement of parts through the corners and the U-shape [29, 30].

2. Lean Machines/Simplicity:

One-at-a-time from continuous-flow another aim of lean manufacturing is it is necessary to produce each one, the workstation is designed to match a nominal covering. The Minimum the envelope guarantees the removal of excess of flat space at the workstation or workstation that machine [28]. This is done to prevent the risk of components or subassemblies being stored from the computer. Components stock increases "work in method and outcomes in " batch processing, which then defeats the goal of lean. In addition, smaller workplaces and devices of minimal size remove unnecessary steps taken by the worker between Via subprocesses [31].

Ultimately, valuable floor space can be saved by sizing workstations correctly machines and the implementation of uniform machine bases or workstations for all processes should be avoided, while tempting for the sake of conformity and standardization. Every base machine to optimize assembly subprocesses, which in most cases may differ from workstation to workstation, the workstation or workstation should be built. For virtually every structural material, this customisation can be accomplished. However, to save on costs and to minimize the environmental issues associated with the disposal of inflexible welded steel structures, material that is reconfigurable and reusable should be given priority. The modular characteristics of extruded aluminum and bolt-together systems make them suitable for lean manufacturing principles to be applied. In addition, constant enhancement as a method, all workstations and work cells need to be simple to alter [32].

3. Workplace Organization:

The desired outcome of a smooth, uninterrupted flow of finished workpieces is a lean workcell, correctly planned. Nothing here this flow can be slowed or stopped quicker than the tool failure or misplacement. Thus, all, applications used on a workplace must have a holder on their own. Exactly, there are as many tool holders as there are tools, so that the deficiency of a tool is quick observed [33]. Using an integrated tool holder device for each instrument with a particular holder that is ideal. If it is possible to add holders quickly, to a workstation or taken away from it, this it adds to the workstation's versatility and enhances its usefulness in a lean production technique. Backup tools, to reduce downtime, at any automated workstations, they should also be available. These instruments should be equipped to being out of the way of the worker before a failure this happens at an automated workstation. In the maximum advantage is tool holding frameworks that allow instruments to swing or slide [30].

4. Parts Presentation:

Naturally, the workcell will require additional components during the average work shift. In a lean workcell, traditional techniques of resupplying workstations are not useful. With the minimum number of interruptions, each worker can go about his job. Each part should also be delivered from outside the work cell to each workstation. The use of gravity feed conveyers or bins suits the lean work-cell's streamlined nature. Parts bins should be filled from at the back (outside the work area of the work cell) so that production can be continued without interruption by the worker. Gravity transports the components to the area of reach of the worker. Bins can be reconfigurable as well. The containers using a key stud in the picture to secure them in place [30]. When reconfiguring the workspace, bins are conveniently stackable and provide the ultimate in flexibility.

While bins are suitable for small parts, larger parts are needed for many assemblies. In bins or boxes, these can be shipped. Again, without entering the workspace, the components should be sent to the workcell. This function is served well by gravity feed conveyors. An additional gravity feed conveyor can be placed in the reverse direction if scrap, or containers must be removed from the cell. Lift assist devices are recommended in instances where pieces are very large. With mechanical, pneumatic, or hydraulic control, heavy parts or boxes of parts can be loaded onto a case lifter and lifted to the correct working height.

5. Reconfigurability:

A lean workcell that is properly built must be easy to reconfigure. In fact, it is a must to be able to adjust the process and go from good piece to good piece as fast as possible. Faster the changeover, less time is lost in production. Switching can be done in a matter of seconds with a strong quick-change fixture. As the situation requires, a variety of different fixtures may be kept at the workstation and swapped. At times, a lean cell must be rapidly attributed to process shifts or other variables to accommodate assembly of a new product, reconfigured or even relocated. In the ability to transfer each part of the work cell rapidly becomes extremely essential if a computer or workstation needs to be changed. The versatility required for rapid and efficient changeover is given by lockable casters on machines or workstations [28, 34].

6. Quality:

A reduction in quality concerns is one of the consequences of one-at-a-time production. Visual inspection by the worker will check that it is correctly assembled when each component is made. They should be installed on the computer or workstation if verification is necessary via gages. And they can be replaced quickly. Fast release of fixtures is a must using star knobs or locking levers. There will be a time when it is not easy to address a quality issue. A defective method or a malfunctioning computer could be the root of the problems with consistency. In the case of a defective process, the structural framing scheme allows for improvements in a minimum amount of time, no matter how big. Once again, in limited time, bolt-together construction addresses a big issue [34]. A malfunctioning machine can also be easily replaced, particularly if it is fast. When the lean cell is constructed, disconnections for all pneumatic or electric lines are given. Furthermore, in the lean cell, there should be no pneumatic or electrical contacts between machines. These would slow the machines inside the cell from changing. If the system has been removed from all power sources, if installed on lockable casters, it can be transported easily. Ease of reconfiguration and swapping eliminate any inability on the part of the employee or management to attempt to "Make do" with "almost" accurate devices or processes. This adjustment in Attitude can contribute greatly to the development of true quality [35].

7. Maintainability:

A further requirement of a lean cell is ease of operation. In a pull-through system, long down periods cannot be tolerated. The product must be generated while consumer demand exists. The ultimate in keepability is given by a modular structural framework. Components may be removed in a matter of seconds [34]. The design of bolt together ensures that computer stands, part presentation equipment or workplaces can be repaired in seconds. In a limited amount of time, even whole computer bases can be restored. Also, the systemic framing scheme provides for all machine bases, guards, a source for common components, workstations and with standardized elements, maintaining a structure requires a minimum number of resources. Three or four basic hand tools are necessary to construct or restore any structure with a structural framing system [36].

8. Ease of Access:

All required work elements can be installed in easily available locations using an aluminum mounting system as the basis for a lean cell, since each side is a possible mounting side. For productive work, parts bins, instruments, shelves, and fixtures may all be placed in the ideal spot. The T-slot on the surface of the framing device often enables if clearance space is critical, swift repositioning of pneumatic or hydraulic parts. Components can be rapidly attached to any workstation and quickly repositioned to ensure each worker's usability [34]. Additionally, with simple hand tools, whole guards or individual panels can be removed easily, allowing service technicians to conduct maintenance in a matter of minutes [37].

9. Ergonomics:

The worker must, eventually, be shielded from ergonomic issues. Each lean work cell properly designed must be ergonomically designed. It is always necessary to maintain work at the ergonomically correct height in the work cell. While it is sometimes not considered, a design for the average height of the worker is also a requirement. Since average heights vary from country to country, it is important to easily change the height of a computer or workstation if there is a risk of a it is possible to ship workstations from country to country [34, 38].

1.4 Lean tools and techniques

Several industries introduce Lean by seeing Lean as a series of 'tool'. For a while, this could be helpful, but in the long run, it will not be enough. Behavior is developed by defining values like as dragging the Andon chord when a difficulty arises, but it continuously does this, always expects it, and always supports it [39]. Lean techniques are the base of lean thinking and the most common applied techniques are listed below:

1. 5S

It is the most common methods used in lean management. Starting the Lean journey with 5S, however, might not be a good idea. Although 5S is simple to incorporate, it has improve the efficiency and quality, it can also be a distraction from real goals or simply clean-up [39]. A 5S program's real goals should be:

- To lower waste
- To enhance variant
- To increase productivity

It is necessary for senior management to be supportive before introducing the 5S Lean technique.

Since 5S may be ideal model for many organizations, even if they understand the concept of it. Using the model methodology is one way of helping workers grasp 5S. It targets small section of the shop floor and implements 5S there. Before any consideration is given to moving to another location, the 5S should be identify every detail. The primary reason for doing this is to inspire employees to look and assess the outcomes of 5S with their previous way of working. Since 5S would be the better option compare to the older ways, the workers would be ready and able to proceed to other regions and eventually the whole business with it.

i. **Sort:** Everything sorted in the work area. First, they categorized what is required for manufacturing and what are not required. Those that are not needed in the work area or serve no purpose must be discarded immediately. The company can choose to red tag products when in doubt. Red tag is a sticker indicate the date of object and then it is discarded if the object is not used up to the date [17].

   The products are sorted accordance with the use. High use equipment's are kept close (perhaps daily) as possible to staff so that they do not waste time reaching them. Those that are used less often are positioned slightly further (perhaps once a week) so it is easily reachable to the workers, but not very near as to compete with the use of regularly used objects. Lastly, those that are seldom used are kept furthest away (per-haps once a month).

   The sorting should be carried out regularly, maybe single time in a month but it is habit [18, 40].

ii. **Set in order:** The set deals with each item's location. Each item should be place in the manner that it can be easily available for everyone and everyone knows that where it is placed. Two methods used to identify the product for all employees where color coding and labeling on the product. Whenever there are some products, parts or instruments shift, this stage should be repeated [17, 18, 40].

iii. **Shine:** Everyday, the work area should be kept physically clean, workers also checked the working area that everything is placed in proper manner and if it is outplaced then it can be fix instantly. One technique is used to clean shop floor in every five-minute routine basis on each day (this process should be standardized for getting best results). The cleaning and tidying equipment's are properly arranged and regularly maintained. 'Cleaning is testing' implies the incorporation of both. You are not just washing up, you are looking for any abnormality's and their root causes [17, 18, 40].

iv. **Standardized:** For the first 3Ss, expectations must be established to confirm that the employees do what the business requires from them. "Standard work aims to create repeatable, reliable and capable processes and procedures". The greatest norm is one that employees consider to be so strong and consistent that the workers are followed the given process plan and they do not divert in some other way (or do the process in some other way) [17, 18, 40]. For the introduction of the 5S to be a success, these standards need to be well managed.

v. **Sustain:** All staff should make a habit of the first four Ss and must also continually strive to use and improve them. Audits are supported and enhance the values of 5S to uplift [17, 18, 40].

2. Just-in-Time (JIT)

JIT is a lean technique based on waste reduction and productivity growth. Waste can be defined as any action which does not add any value to the manufactured goods. Excess lead times, overproduction, and scrap are common examples of waste [17]. Instead of moving goods based on expected demand, JIT can be considered as a 'pull' operation based on client demand [40]. JIT's primary aim is to "produce and transport what is needed, when it is needed, amount needed, in the shortest possible lead time" [41]. "In summary, JIT is based on the concept of supplying raw materials just when required and producing products just when required".

3. Kaizen

The most well-known Lean approach is Kaizen. The combination of kai and zen, meaning "change" and "good" is Kaizen. This is what we have simply translated as "continuous improvement". For Kaizen implementation no initial cost is required or with in very less money it can be give big profits. Neither it cannot change the floor layout, nor it is need any advanced technology [17, 18, 40, 42].

4. Kanban

Kanban the Japanese word means "sign" or "card" This is the main technique used for continuous work flow between the work stations. It is used to identify the condition of product and what operations are carried out on the products and who is the operator. Kanban will maintain the flow of product from start to the end [40, 43].

5. Poka-yoke

"Poka-Yoke is fool-proofing technique for error prevention and elimination". This approach is not restricted to being used only in production but can also be used in office activities (such as post office, clinics etc.). Poka-yoke helps an industry to avoid the occurrence of a problem or flaw, or to interrupt a procedure immediately when a probation occurs. The clutch in a car is a normal and daily instance. The vehicle will not start until the clutch is pressed [44].

6. 5 whys

Sakichi Toyoda would have designed the Lean system of the "five whys". It is one of the significant approaches that Toyota uses to solve problems. The theory is to evaluate the problem before the root cause or causes are found, not to stop at the first cause of a problem (the first why). In fact, it is more of a theory than a cause analysis tool since it is not sufficiently organized nor 'accurate' (why 5 and not 4, 6? In the 2nd, the root cause can be quite well discovered) [44].

7. Andon:

The Japanese origin term is the mixture of the two symbols 行(go) and 灯(light) that can be translated as "going where the light is". The andon is a luminous show activated in its technical application when a problem is found on a workstation to fix it as quickly as possible [45]. It can be caused by an operator or by the equipment where the problem happens automatically. To perform suitable activities, color codes may specify the form or degree of urgency of the anomaly. Initially, it was planned for large production workshops that are very important for visibility. It does, however, refer to other cases, such as call centres, and in its computerized form, in which warning lights can be displayed on the PCs (or mobile devices) of the persons concerned [46].

8. Autonomation or Jidoka:

Jidoka (働化) is an automated shutdown of a machine in the event of detection of a defect. It is a word coined by Sakichi Toyoda in 1896 when he invented the first weaving machine that stops automatically when the yarn breaks; it means “automation with human touch” and has been translated by autonomy (contraction of automation and autonomous) into English; it eliminates the human interference from the machine because if it stops itself, it not required to watch continuously [46].
It has two important concepts in the original TPS:

- One operator can handle many machines at same time, it will improve the human efficiency and save manpower cost.
- To fix them efficiently, the “built-in Quality” identifies quality issues as soon as possible; the full definition also consists of determining the root causes to definitively correct them.

9. Continuous flow:

Unlike batch processing, which consists of producing many products at a time, continuous flow production consists of producing only one product at a time at every stage of the process. It minimizes inventory levels of work in progress and decreases production cycle time, because before going on to the next production stage, each product does not have to wait for others [46].

10. Gemba:

This is undoubtedly one of Lean’s most iconic strategies. Gemba, is a Japanese term that means “crime scene” literally. Toyota, which originally used this term, replaced it with the term “Genchi genbutsu” which has a more positive connotation and means “going where the problem is encountered” In fact, the word most widely used today in the industry is the “Gemba walk” usually explained using the Genchi genbutsu translation.

There is a more substantial distinction in theory behind the discrepancies in terms. Whatever the word is, it is a manager’s visit to the office. Gemba, however, stresses the inspection and checking of evidence in its original version to make the right decisions. While the “Genchi genbutsu” version, which is like the “management by wandering around” American version, insists more on the casual side and listening to the visited employees [47].

11. Heijunka (Level Scheduling):

Leveling, which means smoothing the preparation or workload in the industrial, is the Heijunka translation. This approach is important to the success of the development of “continuous flow” in practice. It compensates for the fact that orders seldom arrive at a regular pace, in practice [46].

There are two forms of grading:

Volume leveling: the smoothed output produces the average of the orders over a given time, as the orders are of different amounts per day,

leveling by product type: Smoothing is a little more complex, it is a matter of mixing the various items every day according to their processing period to achieve an equal (or nearly identical) average time every day.

The two strategies are merged in practice. The Heijunka box has been developed as a visual medium: it consists of boxes, each representing the type of product (in columns) and the day of the week (in rows), the number of sheets per box being the number of products of the type considered to be manufactured on that day, the sum of the products in the same column being the date of manufacture.

12. Hoshin Kanri:

Hoshin Kanri's literal translation is 'management of the direction'. It means that implementing organizational policy or strategy, or of implementing major improvements, such as restructuring projects, in a wider context. It is the contrary, or rather a supplement to continuing change.

There are three pillars to this method [48]:

A cascaded implementation based on the vision definition: management sets the key directions that are implemented across the organization ("top down" process).

An iterative and participatory process at each hierarchical level: it helps the teams at each level to learn, adjust to reality and appropriate; this process is also called "catchball".

Short and long PDCA cycles: enabling the deployment to be corrected and improved over many time horizons.

13. Plan-Do-Check-Act (PDCA):

The PDCA emerged from a seminar sponsored by the Japanese Union of Scientists and Engineers (JUSE), where W. Edwards Deming updated Shewhart Cycle. It is a method of designing and developing a product according to specifications; it has been introduced by JUSE, and by Kaoru Ishikawa, to be used as a more general method called PDCA. It has become a central component of the Lean theory of quality improvement. It is called the Deming Wheel as well. It is composed of four steps [49]:

Plan: After determining what you want to implement and the targets, plan the actions,

Do: Execute the acts,

Check: Monitor the achievement of acts and goals, understand the outcomes,

Act: Act, apply corrective or enhancement measures [50].

14. Single Minute Exchange of Die (SMED):

It is developed at Toyota by Shigeo Shingo. Its mission is to decrease as much as possible tool changeover times in production [51].

The procedure consists of five stages.

Identify the activities performed: it is important to identify and quantify all activities performed, with waiting times,

Determine inner and outward behaviors:

- Inner activities are relevant to the process of modification that involve the cessation of output.
- Outward activities are performed during the manufacturing or before the manufacturing: component or tool preparation, presetting, etc.

Group external tasks together: Grouping can be eliminating the downtime of output by removing the downtime of processes.

Reduce internal operations time: Detailed analyze can be done for every operation and removed or updated the unwanted things.

Reduce external running time: It has not affect directly but it will increase performance or reduce costs.

15. Standardized Work:

Operation standardization was invented by Henry Ford, and it is backbone of the TPS. It includes the standardization of systems, tools, operating procedures, and even the extension of parts and components [40, 44].

16. Takt time:

Takt originates in German and means rhythm.

It is not a technique strictly talking; it is the basic measurement component of the method of non-stop flow output. This is the manufacturing amount of all item, which in principle essential be equal to the sales price. If all development phases are perfectly balanced at a period equal to Takt time [44] (according to the Heijunka method).

17. Total Productive Maintenance (TPM):

This technique is based on two main concepts which are included in its name [40, 44].

- Productive: To perform the maintenance without disturbing the production flow.
- Total: Contains very variables that influence the correct working of the machines and involves one and all.

JIPM has established eight TPM pillars [52]:

i. Independent maintenance: Basic processes carried out by production managers (cleaning, lubrication, inspection, etc.) and the avoidance of breakdowns or the detection of irregularities as early as possible.

ii. Kobetsu-Kaizen: In the TPS system, it is the equivalent of Kaizen.

iii. Scheduled maintenance: By preventive work it avoids breakdowns.

iv. Training and of knowledge management: Trained the technicians and machine operators to improved maintenance.

v. Maintenance at design stage: In the design of machines or goods, maintenance is considered to promote maintenance processes.

vi. Quality maintenance: Quality is improved by proper maintenance by removing defects.

vii. Health, Safety and Environment: This pillar provides workers with a healthy working conditions and support to build a community that attracts equipment consideration.

viii. Office maintenance: Ensuring that the support functions recognize the maintenance issues and, in addition to developing a sense of change of their own processes, can provide support.

18. Value Stream Mapping (VSM):

VSM is the analysis technique that allows all the knowledge flows of a process to be defined and visualized in a synthetic way.

A unreal and visual feature is likely to use of standardized symbols and a definition which, without being exhaustive, must remain at a macroscopic stage [53, 54].

In flow mapping, many pieces of understanding are characteristic:

- The mutual representation of basic and information flows.
- In addition to the other pure development phases, the representation of the journeys and stock phases.
- The identification of key figures for volume for each phase.
- By specifying the processing times and the times between operations, the cumulative time line.
- Identifying the challenges.

19. Waste reduction.

To elimination of waste, which is often more of a Lean concept than a Lean process, is one of Lean core principles. Three forms of waste exist, according to Taichi Ohno [13, 18]:

Muda: Activities with no added value to the finished product; some of its activities, such as quality controls or modifications, are still important [13].

Muri: Tasks that are unnecessary or too difficult [13].

Mura: Variability undergone [13].

1.5 Conclusion

In this study, an overview of the research background has been provided. Eight types of lean waste, nine types of lean manufacturing principles, and nineteen types of lean tools and techniques were identified to eliminate the industrial waste. It concludes that kaizen and 5S are mostly implemented in industries due to no cost or very less cost is required for implementation.

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Chapter

Effect of Lean Practices on Organizational Performance

Lokpriya Mohanrao Gaikwad and Vivek K. Sunnapwar

Abstract

The study focuses on the analysis of the direct effect of Lean Manufacturing (LM) practices on operational performance in manufacturing industry. A model for evaluating the effect of LM is developed taking into consideration as a fundamental variable that affects the causal relationship between LM practices and operational performance. A structural equation model was proposed and investigated across the manufacturing industry in India. A structured survey questionnaire was used to collect empirical data from 400 Indian companies. A total of 203 usable responses were obtained giving a response rate of 53%. The data was analyzed using SPSS-AMOS software. The results revealed that LM practices directly and positively affected operational performance. The results indicated that the structural equation model remained invariant across the Industry. The study provides further evidence to managers and practitioner on the effect of LM practices on operational performance in developing countries like India.

Keywords: Lean Manufacturing, Lean practices, organizational performance

1. Introduction

The present powerful market is described by more limited item life cycles and the expanding individualization of items. Along with expanding worldwide rivalry, this puts pressure both on manufacturing organizations' adaptability and on asset effectiveness to satisfy customer need and stay serious [1]. To address these difficulties, manufacturing organizations are compelled to persistently look for new ways to deal with improve their operational performance. Lean manufacturing has over the most recent twenty years seemingly been the most unmistakable approach for improving the operational performance in manufacturing organizations [2, 3]. Based on the straightforward thought of wiping out waste in all forms by focusing in on the exercises that make an incentive for the client [4], it is a low-tech constant improvement approach that centers on representative strengthening and the smoothing out of manufacturing practices. As of late, the innovation situated Industry 4.0 idea is being marked as the following empowering influence of performance improvement.

Manufacturer work in organization to present new plans of action and advances to improve their manageability execution which coordinates the financial, environmental and social responsibilities. Lean manufacturing is a coordinated arrangement of socio-specialized practices planned to consistently dispose of waste to make value and construct a smoothed out, excellent framework [5]. Attributable to the interrelationship among Lean practices, some Lean groups are framed, e.g., just in time (JIT), total quality management (TQM), and human resource management (HRM). They form the basis of Lean creation, every one of which contains a bunch of interrelated and inside steady Lean practices [5, 6]. For instance, JIT incorporates arrangement decrease and little part size. For the most part, manageable execution is worried about a firm's capacity to at the same time consider and balance financial, ecological, and social issues in the conveyance of items or administrations in order to augment esteem [7–9]. It ought to be noticed that practical exhibition in this investigation is characterized as far as its financial and ecological execution measurements. The social performance measurement is excluded. Accordingly, we try to look at if our investigation can discover a route for sustainability minded manufacturer to adjust benefit improvement and natural manageability, which has been at the focal point of consideration among policymakers and the scholarly community [10, 11].

2. Literature review

Lean manufacturing targets reducing waste and non-value added exercises [4]. Inside, underway, this is showed through, in addition to other things, smoothed out, stable, and normalized measures; insignificant inventories; the one-piece stream of items; creation dependent on genuine downstream demand; short setup times; and workers being associated with continuous improvement endeavors [12]. Gaikwad and Sunnapawar [13] opined that if Lean, Green, and Six Sigma strategies help the manufacturing firms to compete in global markets through the impact of sustainable strategy for their business.

Every one of these angles can uphold upgrades in various components of operational performance, for example, item quality and manufacturing cost, lead time, adaptability, and dependability [14]. Since Lean manufacturing was advocated and turned into a standard administration approach, there have been various investigations targeting estimating the real impact of Lean manufacturing on operational performance [15]. Krafcik [16] begat the term Lean and introduced one of the primary examinations to contrast Lean manufactures and common large scale manufacturing firms. Mackelprang and Nair [17] did a meta-examination of 25 articles exploring the connection between Lean practices and execution. While the operationalization of Lean manufacturing rehearses and operational execution will in general shift between examines, the agreement is that the appropriation of Lean manufacturing is emphatically connected with operational execution improvement [17]. Aims of Lean production are to recognize and dispense with the production process wastages for quality improvement, cost decrease, on-time delivery, for example to make effective production processes to confront the most noteworthy rivalry level, so Lean is the most recent device to accomplish it and it getting increasingly remarkable to improve operational and competitive performance [18].

3. Methodology

The empirical data used in this study were collected through a survey distributed to Indian manufacturers that already implemented total quality management practices. The underlying example comprised of all the manufacturing organizations which were on the mailing rundown of an information sharing stage for manufacturing logistics. This underlying example comprised of 400 Indian manufacturing organizations, addressing a wide scope of sectors and company sizes. To the most awesome aspect our insight, the underlying example reflects the Indian business. The link to the survey was disseminated through email, and an aggregate of 212 responses were gathered through an online survey tool. Of these, one of the returned responses needed answers for a few inquiries and was consequently eliminated from the final sample. This examination consequently wound up with a final sample of 203 respondents and a response pace of 53% was noticed.

The study instrument was approved by researching three perspectives: content validity, construct validity, and reliability. To guarantee content validity, a draft survey was pre-tried by two free scholastics with experience in both research project and industry. Also, the survey depended on all around tried and perceived things that have been utilized effectively in different examinations. To evaluate the construct validity, we thought about two viewpoints: convergent validity and discriminant validity [19]. To evaluate convergent validity, we initially examined the unidimensionality of the measures through principal component analysis.

Following the proposals of Carmines and Zeller [20], the things for every one of the constructs were researched independently. For the entirety of the constructs, the Kaiser-Meyer-Olkin measure of sampling adequacy was over the suggested limit of 0.5, and Bartlett's test of sphericity returned p-values beneath 0.001. For all of the autonomous constructs, the items loaded on a single factor, the eigen value surpassed 1.0, the complete difference clarified surpassed half, and all the items' factor loadings were above 0.5, supporting unidimensionality. As added test of convergent validity, the average variance extracted (AVE) and composite reliability (CR) were determined. The recommended thresholds for good convergent validity for these two tests are AVE > 0.5 and CR > 0.7 [21]. For the autonomous factors, the values are over the recommended variables. The dependent variable, operational performance is made out of numerous, unique performance measurements. This implies that the loading factors and thus, AVE and CR will fundamentally be to some degree lower for this construct yet at the same time adequate, as recently proposed by Prajogo and Olhager [22]. To survey discriminant validity, we followed the proposals of Fornell and Larcker [23]. They recommend that to guarantee discriminant validity, the AVE for each construct ought to be more prominent than the square of the construct's bivariate relationships with different constructs. In all cases, this rule was fulfilled. In light of these tests, we expected adequate build legitimacy. To test reliability, the Cronbach's alpha coefficient was determined for every one of the summated scales. All the summated scales have values over the proposed limit of 0.6 Forza [19] and, as needs be, ought to be dependable for additional investigation.

4. Results and discussion

Following **Figure 1** represent the conceptual framework of Lean practices in which Lean practices such as just in time, total productive maintenance, 5S, value stream mapping, single minute exchange of die, etc. plays important role to enhance social, environmental, financial, and operational performance that results overall business excellence in manufacturing industry.

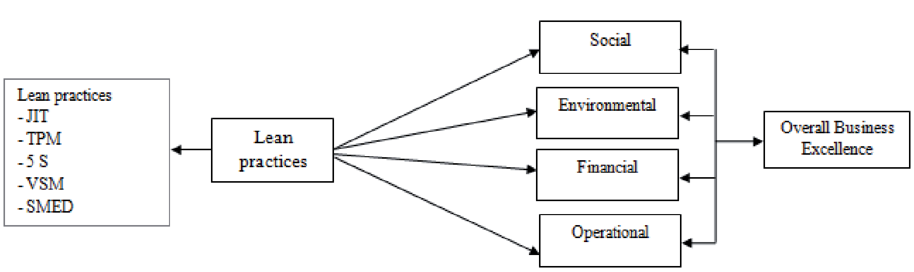

Figure 1.
Conceptual framework of Lean practices.

Structural Equation Model (SEM) for Lean practices and performances:

Figure 2 shows the Structural equation model for Lean practices and its effect on operational, financial, social, and environmental performances.

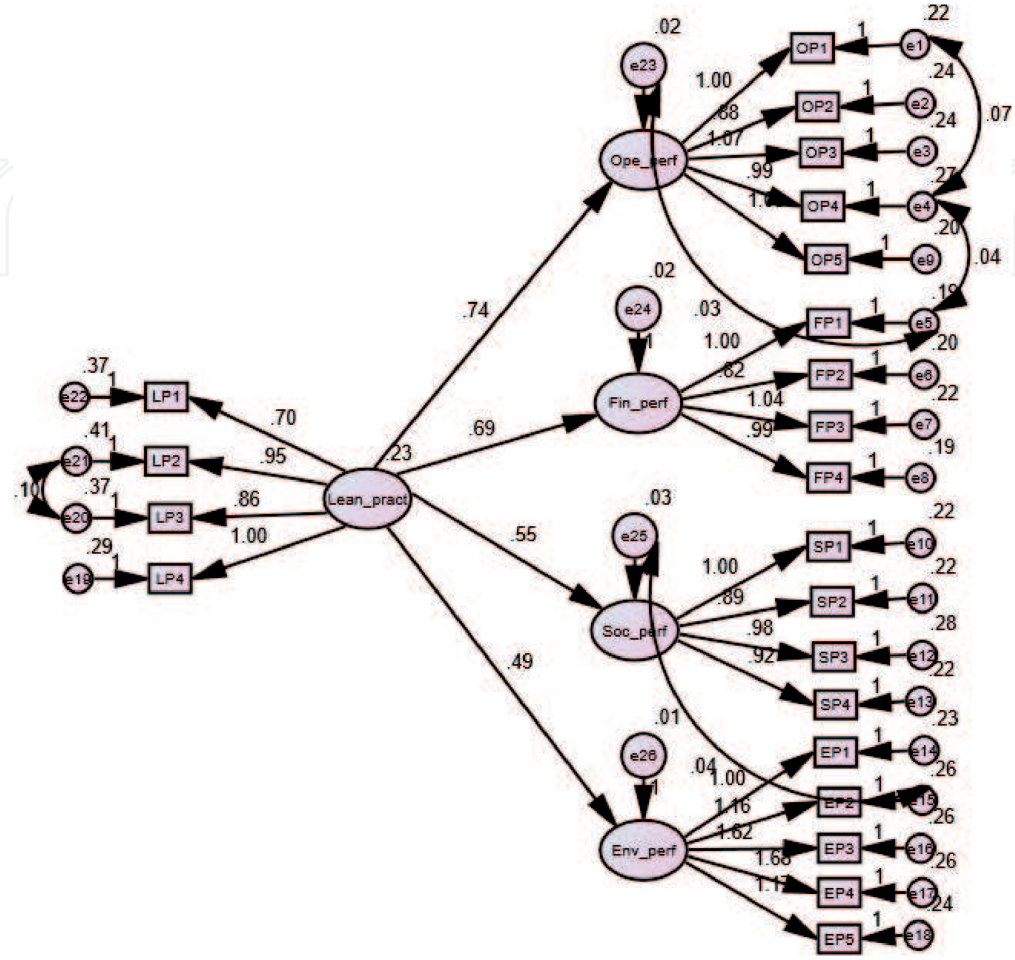

Figure 2.
Structural equation model for Lean practices and performances.

Model Fit Summary
CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	53	239.859	200	.028	1.199
Saturated model	253	.000	0		
Independence model	22	1488.573	231	.000	6.444

CMIN/DF = 1.199, in this case less than 3 is good; less than 5 is sometimes permissible [24].

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	.020	.903	.877	.714
Saturated model	.000	1.000		
Independence model	.116	.333	.269	.304

Goodness of fit indices (GFI) is 0.903, should be higher than 0.9 [24].

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.839	.814	.969	.963	.968
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

Comparative fit indices 0.968, (higher than 0.95 great; higher than 0.9 traditional; higher than 0.8 sometimes permissible) [24].

Estimates: Maximum Likelihood Estimates

Regression Weights: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
Ope_perf	<---	Lean_pract	.742	.099	7.498	***	
Fin_perf	<---	Lean_pract	.694	.095	7.331	***	
Soc_perf	<---	Lean_pract	.555	.089	6.244	***	
Env_perf	<---	Lean_pract	.493	.086	5.744	***	
OP1	<---	Ope_perf	1.000				
OP2	<---	Ope_perf	.878	.128	6.861	***	
OP3	<---	Ope_perf	1.069	.141	7.599	***	
OP4	<---	Ope_perf	.992	.117	8.460	***	
FP1	<---	Fin_perf	1.000				
FP2	<---	Fin_perf	.821	.126	6.514	***	
FP3	<---	Fin_perf	1.040	.145	7.175	***	
FP4	<---	Fin_perf	.991	.137	7.228	***	
OP5	<---	Ope_perf	1.027	.132	7.769	***	
SP1	<---	Soc_perf	1.000				
SP2	<---	Soc_perf	.893	.162	5.497	***	
SP3	<---	Soc_perf	.976	.179	5.456	***	
SP4	<---	Soc_perf	.919	.164	5.606	***	
EP1	<---	Env_perf	1.000				
EP2	<---	Env_perf	1.160	.225	5.150	***	
EP3	<---	Env_perf	1.619	.279	5.794	***	
EP4	<---	Env_perf	1.676	.286	5.853	***	
EP5	<---	Env_perf	1.175	.224	5.239	***	
LP4	<---	Lean_pract	1.000				
LP3	<---	Lean_pract	.857	.122	7.046	***	
LP2	<---	Lean_pract	.954	.131	7.277	***	
LP1	<---	Lean_pract	.698	.113	6.155	***	

From the above table, it is observed that Lean practices are positively affected on operational, social, environmental, and financial performances ($p \leq 0.05$).

Notes for Model

Computation of degrees of freedom (Default model)

Number of distinct sample moments:	253
Number of distinct parameters to be estimated:	53
Degrees of freedom (253–53):	200

Result
Minimum was achieved
Chi-square = 239.859
Degrees of freedom = 200
Probability level = .028

5. Conclusion

A significant territory to explore is the role Lean manufacturing will play in this new modern period. This examination has reviewed the utilization of various arising advanced innovations just as set up Lean manufacturing practices to explore their relationship with operational performance in manufacturing. It reveals how Lean practices impact sustainable performance. By analyzing data from 203 manufacturing firms, we show that the firm should manage Lean practices in an integrated and coordinated way.

This study adds to explore on manufacturing improvement activities by researching the impact of both Lean manufacturing on operational performance. This examination pointed toward covering the exploration gap with respect to the intelligent impacts of Lean manufacturing on operational execution recently called attention to by Buer, Strandhagen, and Chan [25], just as tending to a portion of the impediments in the prior, comparative investigations. Lean manufacturing has for quite some time been viewed as the 'go-to' answer for improved operational execution and making an improvement culture in the organization. Rinehart, Huxley, and Robertson [26] undoubtedly recommended that Lean manufacturing 'will be the standard production method of the twenty-first century. The operational advantages of utilizing Lean manufacturing have been demonstrated in various past examinations and the aftereffects of the current investigation uphold those discoveries.

The discoveries from the structural equation model confirmed that Lean is as yet an important wellspring of competitive advantage. Albeit large numbers of the thoughts and techniques in Lean manufacturing can be followed far back, the emphasis on making an incentive for the client and decreasing waste are thoughts that will not get old, paying little mind to the mechanical advances that occur.

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Chapter

Enhancement of Textile Supply Chain Performance through Optimal Capacity Planning

Imen Safra and Kaouther Ghachem

Abstract

Manufacturing companies in the textile and apparel field face stiff competition due to the globalization of trade between suppliers, producers and customers. To meet this challenge, they need to be efficient by adopting new lean manufacturing approaches and new analysis and management tools leading to more flexible and agile production and distribution processes. For the textile and apparel industry, where products' life cycle is short due to fashion changes, a new integrated approach of production and distribution planning is needed. Based on linear programming techniques and integrating subcontracting activities, our approach takes into account the characteristics of demand, including its short life cycle, seasonality and fashion effect. For these reasons, a sequential approach is adopted, combining tactical and operational decision levels for production and distribution activities, in order to satisfy customer needs at lower cost by reacting quickly to changes and delivering on time. The deployed approach is structured according to the DMAIC lean tool. Validated on real instances, this approach proves its efficiency by achieving cost reduction when internal production capacity is adequately and efficiently planned.

Keywords: DMAIC lean tool, production-distribution planning, tactical and operational planning, Linear programming, textile and apparel case study

1. Introduction

The success of textile and apparel companies depends largely on supply chain management, which ensures the smooth flow of products to different markets and their availability to customers on time and at the lowest cost. However, this task has become increasingly complex with the expansion of supply chain actors that must be coordinated to ensure a final offer to customers at the desired time and place. There is therefore a need to improve the performance of the supply chain and optimize its management, which requires the simultaneous planning, coordination and management of production and distribution activities to ensure that customer demands are met in a cost effective manner by ensuring the delivery of products on time and at the required location. In this context, lean tools and approaches contribute to the development of the supply chain decision-making process in order to achieve better performance of textile and apparel companies in today's complicated world. That is why, in this chapter, we consider the DMAIC lean approach and we focus on the integration of production and distribution operations managed by a textile and apparel supply chain manufacturer.

Our choice of the textile and apparel sector corresponds well to the problematic we are studying of a production chain with multiple actors geographically spread all over the world. The activities of these actors must be optimized in order to determine the adequate offer of each unit of the production chain. Moreover, the nature of the textile product, which is not a homogeneous good but highly diversified, short-lived and subject to the effects of fashion as described in the bibliographical references [1–7]. For these products, we distinguish two types of orders: (1) pre-season orders (PO) that include products for the next season with a medium delivery time and (2) replenishment orders (RO) that include products for the current demand season with a short delivery time. In addition, the textile and apparel industry is highly competitive worldwide and is rapidly changing due to the complexity of demand, which is subject to the effects of fashion and marketing. This results in changes on the supply side, with some businesses disappearing and others expanding depending on the degree of rapid reaction to demand and customer tastes, as an inadequate response to demand can result in unsold inventory and lost sales opportunities.

We considered in this work a planning approach integrating tactical and operational decision levels and taking into account textile and apparel industry specificities. Using a rolling horizon, the proposed approach identifies the quantities to be produced, stored and delivered while minimizing the total cost of production and distribution. Production flexibility is ensured by the consideration of low-cost overseas subcontractors to whom standard products with predictable demand can be assigned. Local subcontracting and overtime are short-term solutions to deal with the unpredictability of demand related to ROs at the operational level. This work is structured according to the DMAIC approach and will be detailed accordingly while defining the specifics of each phase.

2. Phase "define"

As detailed by [8], the 'define' phase of the DMAIC methodology presents a definition of the problem and what the customer requires. Hence, it is the backbone of a successful project. The define phase starts with clarifying the problem statement and analyzing the customer requirements and ensures that the project goals are aligned to these requirements.

2.1 The problem statement

Facing a worrying decline in market share for textile-apparel manufacturers in the context of the competitive battle, these manufacturers must act by creating new offers combining low prices, reduced lead times and improved services. This can be ensured by carrying out adequate resource planning at different levels of decision making and coordinating activities associated with the various stakeholders in the chain. Moreover, in regard to more selective consumer behavior, the emergence of customized products with short life cycles and taking into account the different types of orders, manufacturers must satisfy customers by being reactive, fast and more and more flexible while offering a better quality, price and lead time performance. In this context, a coordinated control of flows between suppliers, producers and customers can only lead to a fast, personalized and optimal response, in accordance with the expectations of end consumers. Traditionally, the various supply chain actors manage their resources independently, and the planning and management of production and distribution resources is done with little or no coordination. This decentralized management can lead to additional costs due to the placement of unexpected and urgent orders at subcontractors' units or by scheduling costly overtime. On the other hand, additional delays may be caused by re-planned resources and the delayed arrival of a few productions due to the arrival of these urgent orders to be placed as soon as possible. Similarly, large inventories and long product cycles may occur as soon as the producer opts for large production quantities to anticipate demand for the entire season, not to mention the risk of increasing unsold stock.

Our work focuses on a global approach that integrates production and distribution activities. The related literature review is presented by [9–13]. In this work, we are interested in addressing the problem of production-distribution coordination applied to the textile and apparel field. A presentation of the different types of coordination at the supply chain level and a review of the literature dealing with this aspect are detailed by [14, 15].

Indeed, most studies on integrated production and distribution have focused on products for which demand is stable because they have a long-life cycle [16, 17]. But this is not the case for apparel products that have a short life cycle and whose demand can only be accurately estimated once the product is on the shelf once the season has started. Similarly, few production planning models have taken into account the flexibility of production capacities. However, our models provide this flexibility through outsourcing and overtime [18, 19]. Therefore, it is necessary to adapt production and distribution planning models to the reality of textile and apparel supply chains in order to optimize them, taking into account the unpredictable and unforeseen aspect of demand while aiming to reduce production and distribution lead times to better match production to demand. In this way, production can be flexible and can be adapted to market needs. Thus, it is necessary to define production and distribution planning models that take into account the specificity of the apparel supply chain. The objective of this study is to start filling this gap.

It applies to the case of a large Tunisian textile company (see **Figure 1**) that owns several units of apparel production and two warehouses located in Tunisia. It may also use outsourcing with local or overseas subcontractors in China to meet part of its demand. The company adopts a business model of delivery commitment. It commits to a delivery date for any order received and is responsible for shipping costs. Finished products are stored in warehouses until they are delivered on time to customers. The transportation modes used are trucks, ships and airplanes. The transportation cost includes fixed and variable fees. Each product has a production set-up cost and a variable cost.

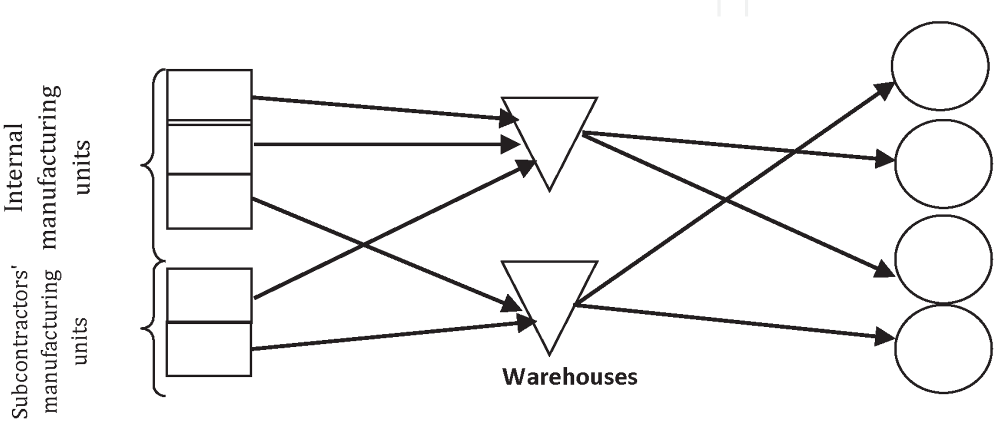

Figure 1.
The textile and apparel supply chain.

Received orders, over a season, cover a large number of product references. The number of product groups exceeds 100. The company receives two types of orders from local and overseas retailers: POs and ROs. POs, which have a lead time of several months, are planned and scheduled to satisfy the following season's collections. However, urgent ROs, which have shorter delivery times, must be produced to fill retailer shortages or to replace unsold inventory. Due to changing fashion trends and the short life cycles of textile and apparel products, historical data alone cannot accurately predict next season sales [20]. Moreover, it is very difficult to forecast specific customer needs for apparel products, leading retailers to use in-season replenishment after revising their forecasts based on demand observed in the first few weeks of the current season. Therefore, it is a periodic process of adjusting retailers' sales forecasts for different products taking into account new information from recent sales.

2.2 Challenges of the proposed planning approach

As detailed in **Figure 2**, the proposed approach is based on an integrated production-distribution planning at two decision levels while considering the specificities of the apparel supply chain. Thus, the approach involves decisions at the tactical and operational level and takes into consideration both POs and ROs. Also, the approach considers flexibility of production capacity to ensure a better match between supply and demand. We consider at the level of operational planning overtime and subcontracting activities to accommodate the internal capacity shortage caused by fluctuations of demand and short lead time of customer orders. The main goal of the current study is to reduce overall supply chain costs by approximately 10%.

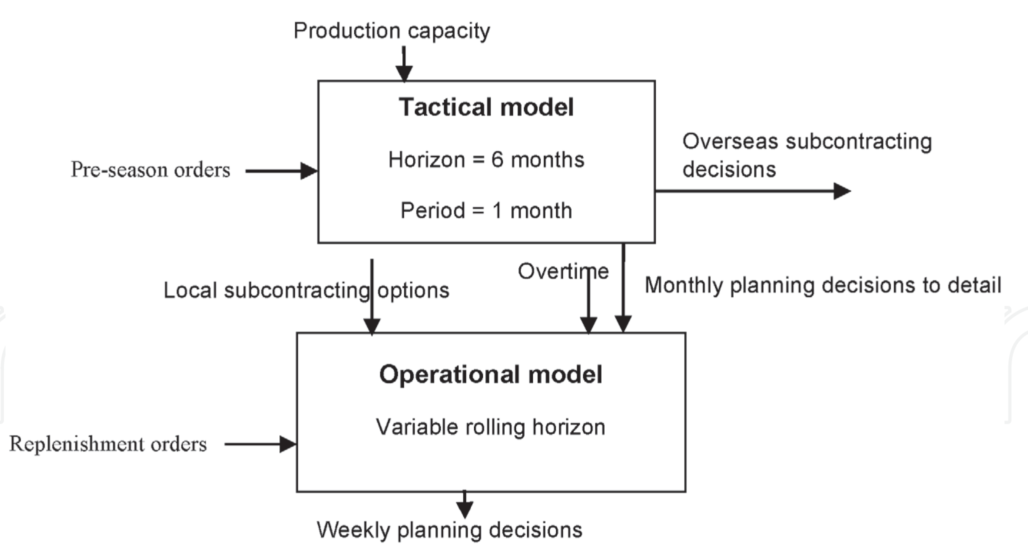

Figure 2.
Hierarchical planning approach.

2.3 The process definition

The definition of the high-level process map gives the team an eye of bird's view about the project. One of the most used high-level map is the SIPOC which details the Supplier, Input, Process, Output and Customers. By completing the SIPOC, the detailed map (Swimlane Map) can be developed after a series of Gemba walk and several discussions with the teamwork.

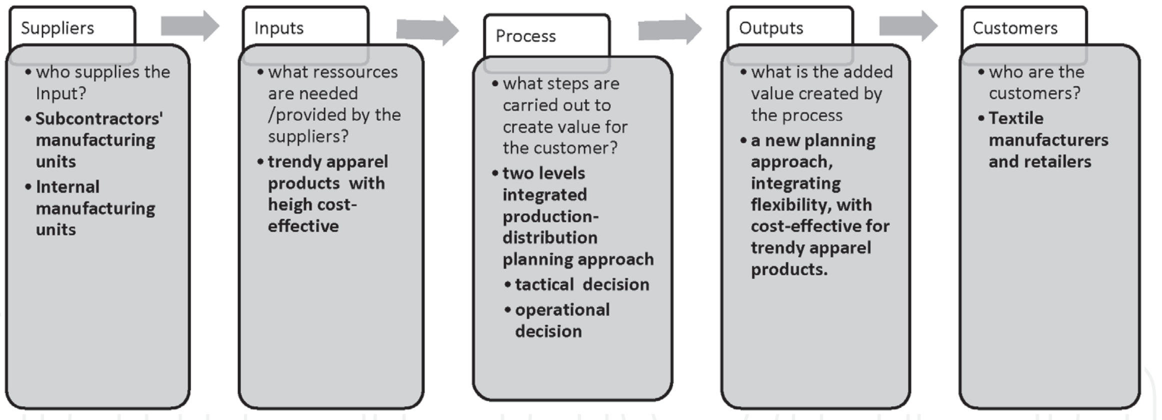

Figure 3.
SIPOC diagram.

The process definition of the SIPOC diagram, as detailed in **Figure 3**, ties the different steps of the new proposal solution to create the added value. In the current case, a new approach based on two level integrated production-distribution plan and composed of two level of strategies (tactic and operational) is developed. Knowing that textile and apparel manufacturers are currently dealing with unpredictable and short-term ROs when production for the next season is already ongoing. The company uses two types of sub-contractors: - overseas specialized subcontractors who offer products at very low prices but with long delivery times, and - local capacity subcontractors that the company uses in case of production saturation but who offer prices 20% higher than the internal production costs. In addition to this flexibility provided by subcontracting, the company can resort to overtime with higher costs than production in regular hours.

3. Phase "measure"

In this section, we will define the current state in order to analyze it and to identify the gap between the actual and the desired situations. To do this, we will structure this part in three phases. First of all, we will detail the developed measurement system. Then, we will detail our data collection plan and our experimental data. Finally, we will identify our desired situation and the gap with the current one.

3.1 The measurement system analysis

3.1.1 Approach description

Our measurement system aims to define our sequential production and distribution planning approach while evaluating the current situation of the company. The objective is to satisfy POs and ROs within the required deadlines, while minimizing the production, subcontracting, capacity under-utilization, storage and distribution costs.

Our approach is based on two mathematical models that are developed at two different decision levels [21, 22]. The first model focuses on a tactical level of a 6-month horizon with a monthly periodicity and decides on pre-season quantities to be placed internally and with overseas subcontractors with long lead times. Each time a new order arrives, it is inserted with a rolling horizon in order to be placed optimally on the available resources.

The second operational model considers a monthly horizon with a variable periodicity between 8 and 11 weeks. This model is used to detail tactical confirmed quantities over weeks and to insert new urgent orders arriving through a rolling horizon.

At the operational level, urgent orders with short lead times are inserted progressively. However, when a new order with a long lead time for the pre-season arrives, the tactical model is run and the order is inserted on the rolling horizon to study the possibility of subcontracting it to overseas subcontractors. Thereafter, the production will be refined over weeks using the operational model, if the decision taken at the tactical level affects production internally. This operation is repeated until all orders for the season have been placed.

Our approach results in a production, storage and distribution plan that takes into account the assignments of overseas subcontractors and the assignments of new orders that arrive at the operational level. The latter are detailed by week during the first 2 months. Given the principle of the rolling horizon, decisions taken during the first week are fixed and the related costs are recorded. However, decisions taken in following periods will be revised once the model has been run in the second week.

3.1.2 Mathematical formulation

3.1.2.1 Tactical planning model

As detailed in appendix A, at the tactical level, the model decides on: - monthly quantities to be manufactured internally and at subcontractors, – monthly quantities to be stored, – monthly quantities to be distributed per period, taking into account the different modes of transport. The objective is to minimize the total cost of production, storage and distribution. It should be noted that for this current situation, the parameter α_{kt} considered in Eq. (3) and Eq. (6) is equal to 100%. Means that we are considering all the available production capacity at the tactical level.

3.1.2.2 Operational planning model

As shown in **Figure 4**, the operational horizon ranges from 8 to 11 weeks. The length of this horizon is defined according to the position of the first week in the month.

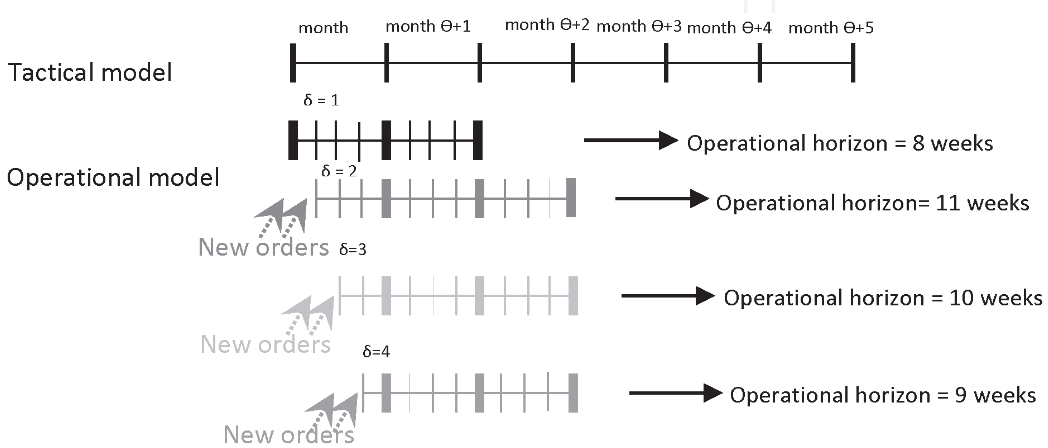

Figure 4.
Variable operational planning horizon.

For example, if the first week of the planning horizon corresponds to the second week of the month Θ, then the length of the planning horizon is set to 11 weeks because tactical decisions related to the month $\Theta + 2$ must also be taken into account.

We denote by a couple (t, s) the weeks in the operational planning model, where s is the position of the week in month t. Operational planning includes a set of periods $TS_{\Theta\delta}$ and takes place at the beginning of week δ of month Θ (as detailed in appendix B).

For the operational planning model, detailed in appendix C, the length of the planning horizon is justified by the fact that POs resulting from tactical planning should be reliably detailed at the operational level. Hence, to properly place decisions made at the tactical level, the operational planning horizon must reach the end of the month.

3.2 Data collection plan

Based on company reports translating historical data, Gemba walks and after meetings and team benchmarking, we were able to collect the necessary information to set the required parameters for the proposed models.

Before detailing experimental data, it is important to identify the established planning assumptions:

- Demand is dynamic and deterministic,
- Storage cost is defined according to the average level of storage between the beginning and the end of the period,
- Under-utilization capacity cost is estimated according to the average hourly cost of labor/machine.
- In the operational model, we consider only local subcontractors.
- Overtime is considered to allow greater flexibility when managing the unpredictability and short lead time of ROs.

3.2.1 Experimental data

The relevant company delivers about 200 references of products to 30 retailers per year through 3 knitting manufacturing plants located in Tunisia. Products are transferred to customers through two local warehouses storing finished products ordered by local and overseas retailers. These warehouses are characterized by their limited storage capacity and a storage cost of approximately 5% of the unit production cost per unit.

The shipments can be carried out by trucks, for local deliveries, or by aircraft and by ships, for overseas connections. Our mathematical models decide on the mode of transport to be adopted according to the delivery times involved. Indeed, a delay of at least 5 weeks is necessary to deliver the products by ship. However, aircraft shipments are made within the same week. The considered transportation costs are composed of fixed costs, depending on the number of shipments made, and variable costs depending on the shipped quantities.

Considering the 200 variety of manufactured products, the internal production costs vary from 3 to 35 euros. In order to accommodate the limited internal capacity, flexibility is ensured by scheduling overtime. However, overtime activity is limited to 25% of production capacity after regular working hours and costs 40% more. The internal flexibility is reinforced by a subcontracting activity with 10 local subcontractors and one overseas one located in China. The local subcontractors have enough capacity to meet the ordered quantities and fill the limited capacity of the internal production sites. The latter offer products at prices 20% higher than the cost of internal production. As for the Chinese subcontractor, it can manufacture large volumes of products but with delivery times exceeding 2 months. The latter offers basic products at costs that are about half the internal production cost. Our planning models decide on production allocations based on available capacities and assigned lead times. The overall focus is to meet customer orders on time and at lower cost.

Our proposed approach is run over 6 months, generating a weekly production schedule identifying the quantities to be manufactured, stored and distributed. The proposed models are solved using the package ILOG OPL Studio V6.3/ Cplex 11 and are run on an intel Core i5 PC with a 2.3 Ghz processor and 512 MB of memory. The planning model at the tactical level takes into account approximately 122,000 constraints and 66,000 variables, of which more than 5,000 are binary. However, the operational model contains 55,000 constraints and 3,000 binary variables among the 25,000 considered variables in the model. An almost optimal solution, with a deviation of 10^{-4} from optimality, is obtained for all the executed models.

3.3 Current situation and the gap with the desired one

Our approach evaluates the current situation of the apparel manufacturer who incurs a logistic cost equal to 2864 k€ obtained for the 6 months.

In order to improve the situation, we aim at considering additional flexibility at the tactical planning level in order to better accommodate the unpredictable orders that will be placed at the operational level. A decrease of the overall logistic cost is expected.

4. Phase "analyze"

At the end of the six-month simulations, we obtain a weekly production, storage and distribution schedule for the various products, taking into account the tactical model's assignments and the unforeseen and urgent demands that arrive at the operational level. The cumulative costs obtained for the first few weeks of the operational model applied on a rolling horizon, added to the tactical cost of production at overseas' subcontractor, obtained by the tactical model, represent the total cost of production, storage and distribution for the six months. This cost, as reported in **Table 1**, is evaluated to 2 864 K€.

Period	Cost (K€)	Period	Cost (K€)	Period	Cost (K€)
Overseas sub Mars	320	May S 1	92	July S 1	86
March S 1	79	May S 2	69	July S 2	90
March S 2	99	May S 3	93	July S 3	105
March S 3	84	May S 4	92	July S 4	91
March S 4	98	Overseas sub June	223	August S 1	113
April S 1	83	June S 1	83	August S 2	106
April S 2	83	June S 2	90	August S 3	93
April S 3	87	June S 3	89	August S 4	108
April S 4	76	June S 4	218	Total cost	**2864**

Table 1.
Weekly logistics costs.

	Quantities	%
Internal manufacturer's production	259359	90,5
Internal overtime production	1833	0,6
Subcontractor's production	25507	8,9
Total produced quantities	286699	100,0

Table 2.
Production assignment

Weekly costs represent the sum of production costs in regular hours, overtime and at local subcontractors added to the costs of storage, underutilization of internal production capacity and product deliveries.

Obtained results for the current situation show that production is mainly affected to Internal manufacturing units 90.5%. However, 8.9% are affected to overseas subcontractors as shown in **Table 2**.

Based on these obtained results, we notice, on one hand, a production allocation that leads to an overload of internal production capacity and costly overtime. On the other hand, some productions get started in overtime, especially when the internal production capacity over regular hours is partially used. This is mainly due to the due dates position of the POs through the month. Indeed, since the productions planned in the internal units over a month are detailed at the operational level by week, it seems mandatory in some cases to massively produce during the first weeks of the month to meet the predefined delivery dates. Consequently, it is necessary to produce in overtime some products that the production capacity during regular hours cannot meet. Meanwhile, for the remaining weeks of the month, the capacity of the internal production is under-utilized. In this case, the ROs, which arrive at an operational level, are assigned to the subcontractors since the internal capacity of production is fully used by the production of the pre-season items decided at the tactical level.

This obtained cost seems to be too high because decisions at the tactical level are made without taking into account what may arrive at the operational level as urgent and unforeseen ROs. This cost can be improved to be more competitive in the market through greater flexibility at a tactical level. This flexibility could positively affect the allocation of orders that arrive at an operational level.

To analyze the current situation of the textile and apparel supply chain and try to identify the root causes of the performance decrease in this field, we establish the following Ishikawa diagram shown in **Figure 5**.

Based on this analysis, we confirm that it is necessary to reduce lead times through better resource management and better planning that will reduce the operational workload on operators. Taking into account the specificities of this sector and the requirements imposed by markets and customers, it is essential to adjust to needs, as soon as they are presented, through a better flexibility of resources at a tactical level.

The 5 P tool (**Figure 6**) is also used to identify the root cause of the problem so that the required actions can be taken to improve performance.

It is quite clear now that the solution is to provide some flexibility at the tactical planning and not to allocate rigidly anticipated productions without allowing sufficient flexibility to place the orders that arrive at the operational level.

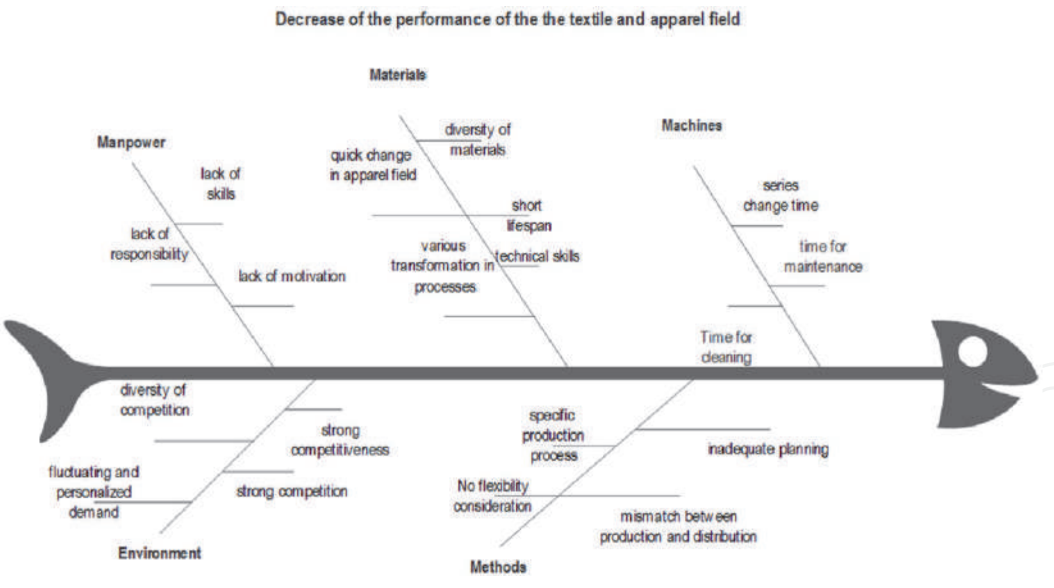

Figure 5.
Ishikawa diagram.

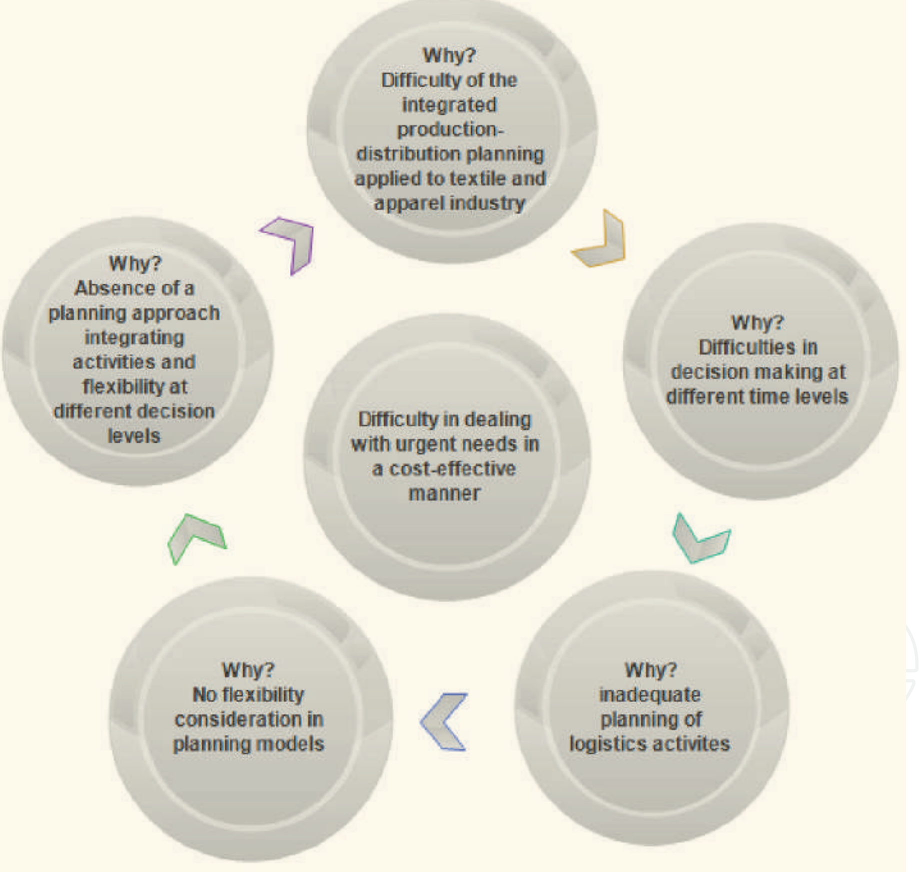

Figure 6.
5P tool.

5. Phase "improve"

To solve the root cause, at this phase, we have to introduce more flexibility at the tactical level by considering only a percentage of the production capacity. The other part of the production capacity is considered as reserve capacity. Thus, it can be used only at the operational level to efficiently meet RO with short due dates without disrupting the ongoing production. During this study, we need to achieve one main objective: how to satisfy the retailers' pre-season in addition to the ROs that must be in time. This objective will be reached by minimizing the internal capacity underutilization, storage, distribution operation and also the overall supply chain cost incurred by internal production, subcontracting.

The availability of products based on ROs during the season is risky for the retailer since it largely depends on the flexibility, responsiveness and efficiency of the suppliers involved. Therefore, to meet retailer orders and ensure deliveries on-time, production flexibility becomes crucial and a key competitive issue for any textile or apparel manufacturing company.

At the tactical model a reserve production capacity (RPC) is considered. We denote the percentage of internal production capacity that can be used to fulfill POs by $\boldsymbol{\alpha}$. $\boldsymbol{\alpha_{kt}}$ is the reserve related to an internal site k over a period t. As it can be noted, $(100 - \boldsymbol{\alpha_{kt}})$ represents the percentage of internal capacity reserved to fulfill in-season ROs.

Meaning that the parameter α_{kt} considered in Eqs. (3) and (6) is less than 100%.

At the operational level, the RPC considered at the tactical level is released and the entire internal capacity can be used in addition to overtime. This will provide more flexibility to accommodate unforeseen and urgent ROs.

Let us now consider the operational level, the RPC considered at the tactical level is released. In addition, all internal capacity can be used to overtime. This will result in greater flexibility to respond to unexpected and urgent ROs.

5.1 The reserve production capacity estimation

The impact of considering the RPC at the tactical planning level on supply chain costs is investigated. During this experimentation, the same value for this RPC for all internal manufacturing units is used. Firstly, for each month of the six-month tactical planning horizon, a fixed RPC is considered. The percentage of the available internal production capacity for PO planning is therefore a fixed value (α). Secondly, a RPC with monthly variation is considered. The percentage of internal generation capacity at the tactical planning model level is therefore a value that varies monthly and is noted (αt), with t indexed to the month.

The RPC needs to be estimated. Afterwards, the available two-years historical demand data is used to estimate the RPC (1-α or 1-αt). Thus, it is obtained by calculating the ratio: reserve production/total internal production during regular hours. The resulting internal production capacity rates are shown in **Table 3**.

Month →	M1	M2	M3	M4	M5	M6	Average
Rate year N-2 (%)	62	90	89	71	61	76	75
Rate year N-1 (%)	75	91	72	91	87	95	85
Average rate	69	91	81	81	74	85	80

Table 3.
Observed internal production capacity rates used based on 2-year historical demand data

Hereinafter, different values of the RPC are tested. The objective is twofold. The first one is to underline the importance of integrating RPC into tactical planning to improve flexibility. The second one is to emphasize the need to develop adequate methods based on historical demand data and can provide an efficient estimation of the RPC.

5.2 Production and distribution planning using a fixed reserve production capacity

Different values of α are tested. These values vary from 70% to 100% with a difference of 5% between two consecutive values. The curve depicting the variation in supply chain cost as a function of α is plotted in **Figure 7**. The curve is characterized by an almost convex shape. In addition, for α values equal to 70%, 75% and 100% higher costs are observed. Indeed, the reserve of 30 to 25% of production capacity for ROs leads to the allocation of many orders to subcontractors at the tactical level. Consequently, a significant underutilization of capacity is observed at the operational planning level. If no reserve capacity is being considered at the tactical planning level (which is the current practice in the company), We note that, at the operational planning level, many ROs are assigned to subcontractors or produced during overtime as internal production capacity is used during regular working hours to accommodate POs.

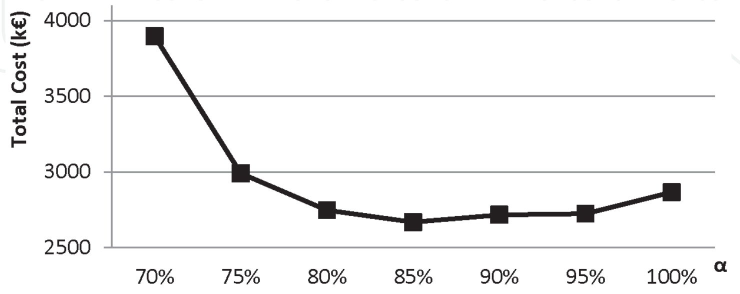

Figure 7.
Supply chain cost variation with α.

Note that in the considered real case study, the optimal supply chain cost is reached at a value α around 85%. Hence, a RPC of about 15% ensures a production flexibility that minimizes the cost of the supply chain. The average value obtained from the historical database (presented in **Table 3**) is equal to α = 80%. The cost of the corresponding supply chain is equal to 2,746 k€. This translates into a saving of 4% compared to current practice (α = 100%). When the proposed planning approach is used with α equal to 85%, the cost saving over current practice is equal to 7%.

5.3 Production and distribution planning with a variable monthly reserve production capacity

In this section, it is proposed to evaluate the monthly variable RPC. For each month t of year N, we take for each year N - 1 and N - 2 the average of the percentage of internal production capacity used as the value of αt (represented in **Table 3**). A supply chain cost equal to 2575 k€ is obtained by introducing the values of αt into the tactical planning model and sequentially applying the tactical and operational models. The cost of the supply chain is, as observed, less than that obtained when considering a fixed RPC equal to 20%. This method used to estimate the RPC leads to a 6% cost reduction compared to the previously used method. Furthermore, there is a saving of 10% compared to current practice (**Figure 8**).

This cost saving resulted from allocating six months of production to internal manufacturing units and subcontractors, as illustrated in **Figure 9**.

Firstly, when considering a monthly variable RPC at the tactical level, there is a better use of internal production capacity. Second, we find that some production is performed during overtime when the internal production capacity is not fully used during regular hours.

The reason for this can be explained by the position of PO due dates within the month. Since production in the internal manufacturing units over 1 month from tactical planning is detailed per week at the operational level, massive production in the first weeks of the month is sometimes necessary to meet the delivery due dates.

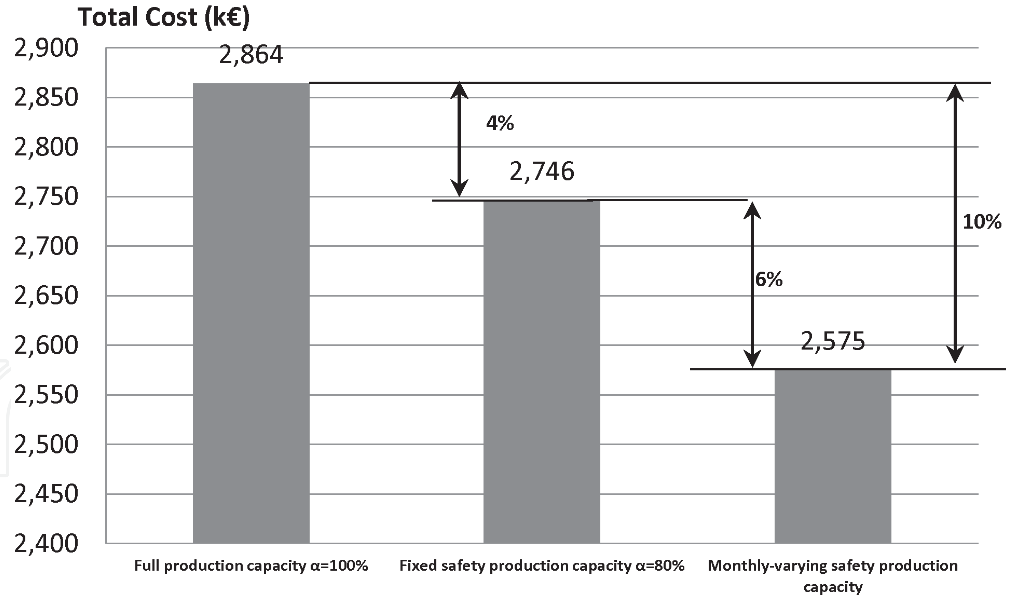

Figure 8.
Supply chain cost comparison.

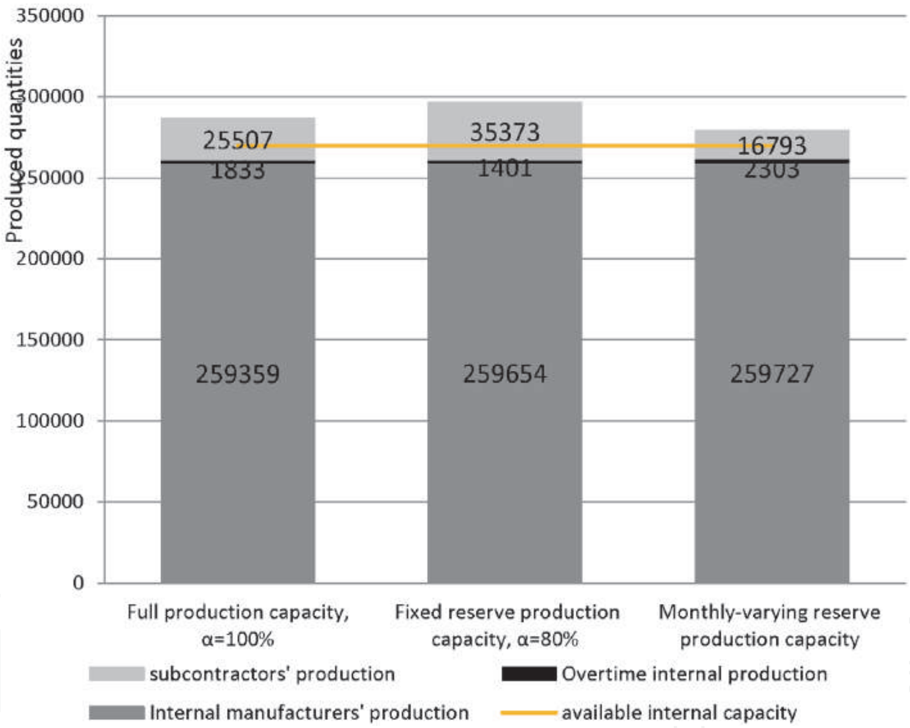

Figure 9.
Production assignment.

As a result, overtime is needed as production during regular hours cannot reach the requested quantities. Internal production capacity for the remaining weeks of the month may be underused.

When we consider a fixed RPC (for α = 80% and α = 100%), the quantities produced at subcontractors' manufacturing units are bigger than those performed when a variable monthly RPC is considered. Consequently, the allocation of production to subcontractors is better optimized for a monthly variable RPC.

Considering this result, we emphasize the importance of the monthly variable RPC. This reserve is adjusted to ROs by assigning, at the tactical level, some productions to subcontractors while maintaining sufficient and accurate internal production capacity at the operational level to appropriately handle ROs.

However, the quantities produced in the subcontractors' manufacturing units are particularly high when we consider, at the tactical level, a fixed α, equal to 80%.

Meanwhile, the total produced quantities over the 6 months are higher than those produced when considering α equal to 100%, or a monthly variable RPC. This is due to the demand monthly variation. Actually, when we consider a fixed α equal to 80%, two situations can arise. Firstly, the ROs to be satisfied during the month require more than the available capacity and consequently more than the RPC considered. In such a case, the subcontracting activity is the main solution. Second, ROs to be placed during the month require less than the available capacity and so less RPC. Therefore, ROs to be filled for next few weeks are processed in advance to minimize capacity under-utilization. When α is equal to 100%, ROs are assigned to subcontractors since internal production capacity is overloaded by POs.

As conclusion, the use of a variable RPC at the tactical level, allows efficient use of internal production capacity and optimizes the allocation of production to subcontractors. Nevertheless, the performance of capacity planning can be improved if more accurate and reliable historical demand data is used and if forecasting methods for predicting the monthly variable RPC are carried out.

By studying the three cases mentioned above, we underline the important effect of taking into account a suitably defined RPC on the supply chain cost.

6. Phase "control"

Due to intense competition, variable economic and environmental conditions, changing wage rates and fluctuating oil prices, the control phase of the DMAIC methodology will be focused on establishing the changes and standardizing the results given in the previous phases. Consequently, sensitivity analysis is chosen to assess the effect of changes in demand and variations in subcontracting and transportation costs on the supply chain cost. Three parameters are examined in this sensitivity analysis: demand, transportation cost and subcontracting cost to assess their impact on planning decisions and supply chain performance.

During our experimentation, fifteen scenarios are considered by varying (1) the demand, (2) the cost of transport and (3) the cost of subcontracting between −50% to +50% of their current values. By considering the three scenarios (α = 100%, monthly fixed α, monthly varying α), the cost of the supply chain is calculated for each case.

6.1 Sensitivity analysis of demand

A 50% increase in demand leads to an increase in supply chain costs, as explained in **Table 4**. Nevertheless, if we consider a RPC, a decrease in this total cost is recorded. For all considered scenarios, the best cost is obtained when a monthly variable RPC is considered.

	D−50%	D−20%	D	D+20%	D+50%
α = 100% (k€)	1658	2152	2864	3285	3794
α = 80% (k€)	1632	2020	2669	3067	3581
α variable (k€)	1596	1981	2575	2972	3389

Table 4.
Cost variation according to demand

These results confirm the importance of our approach and encourage the idea of using RPC to reduce supply chain costs. We note a saving of 4% compared to current practice when demand is reduced by half. This proves that the use of a monthly variable RPC yields better results. If demand is increased by half, the gain is 11%. The proposed approach becomes essential when demand is relatively high. If demand is low, the internal capacity will accommodate the demand without any additional costs. As a result, the RPC becomes less important and will avoid situations of under capacity due to urgent orders arriving at the operational level.

6.2 Sensitivity analysis of transportation and subcontracting costs

Identical trends are observed in transport and subcontracting costs savings are also obtained when we consider a RPC at the tactical planning level (**Figure 10**). It is worth noting that the greatest savings are achieved when considering a monthly variable RPC. Moreover, savings become more important with increases in these two costs. Lower transportation costs lead to the outsourcing of some internal production to overseas subcontractor's manufacturing unit, as the latter offers very competitive prices, especially for most basic products. Subsequently, at the tactical planning level, some internal production capacity is unused; therefore, enforcing a RPC is meaningless. For this reason, the lowest savings are observed when transport costs are halved. Nevertheless, outsourcing abroad is no longer the preferred option when transport costs increase. This promotes the use of a RPC to avoid the use of full production capacity at the tactical level. Internal production (regular and overtime) and locally subcontracting are the adequate options to cover capacity requirements.

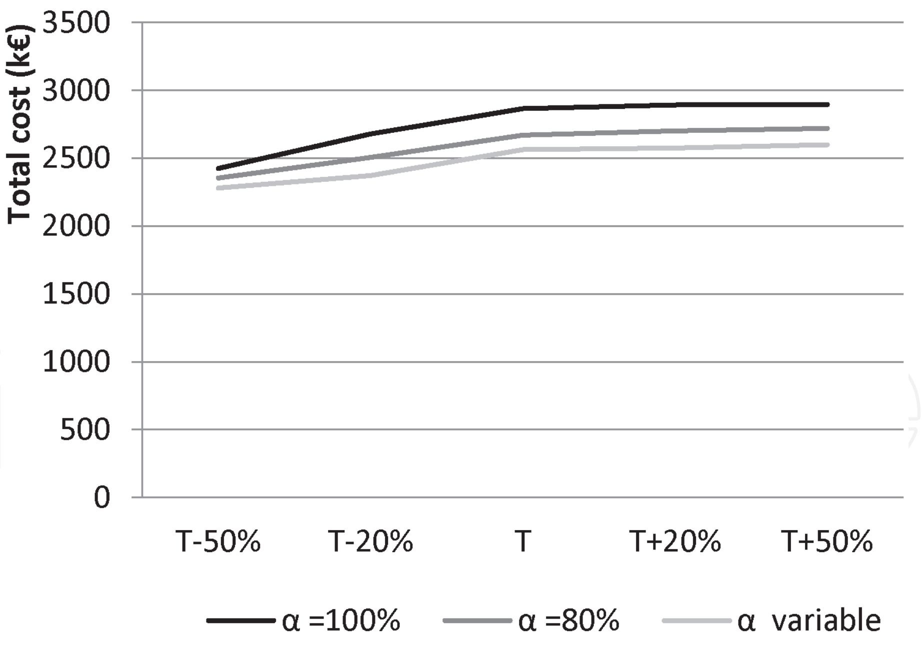

Figure 10.
Transportation cost variation.

When the cost of subcontracting is reduced by half, this activity is more profitable than the internal production. In this case, part of the internal production is manufactured at local subcontractors. In addition, the under-utilization cost prevents the full transfer of quantities to local subcontractors' plants. Internal production capacity is currently under-utilized; however, this situation results in lower supply chain costs due to lower production costs. In this case, the consideration of a RPC is no longer significant.

Nevertheless, increased supply chain costs are noted when the cost of subcontracting increases, especially for α = 100% (current situation). In practice, subcontracting is prevented until internal production capacity is completely used; thus leading to local subcontracting at higher costs (**Figure 11**). In these situations, reserve capacity appears to be a substantial consideration in ensuring the use of foreign subcontracting (which is cheaper than local subcontracting) at the tactical level. If the cost of subcontracting is increased by half, taking into account a RPC that varies on a monthly basis makes it possible to achieve a cost savings of 11% regards current practice.

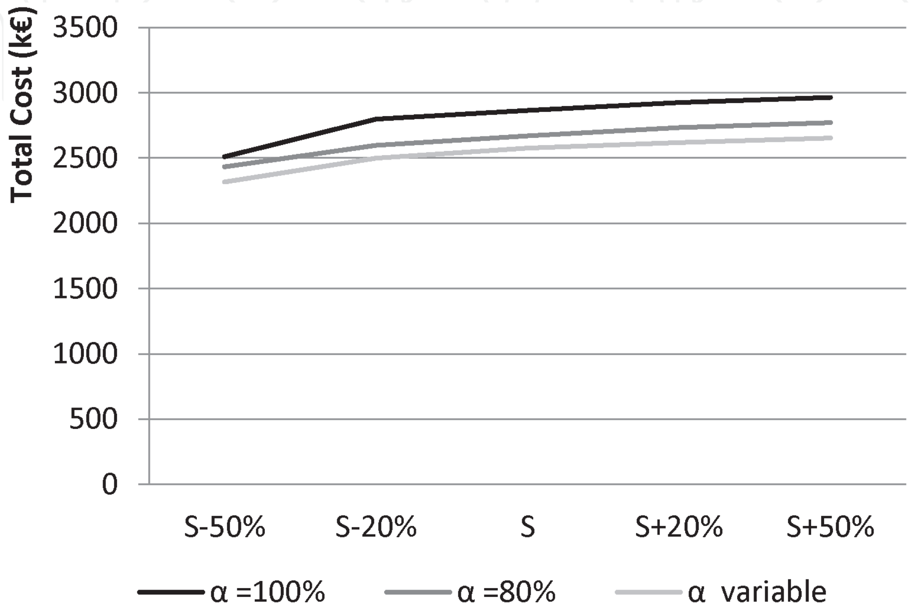

Figure 11.
Subcontracting cost variation.

The sensitivity analysis confirms the interest of our approach taking into account a RPC. Indeed, when demand or transportation or subcontracting costs increase, our approach allows us to adequately place urgent and unpredictable orders that arrive at the operational level at the lowest cost.

This approach provides a decision tool for textile and apparel manufacturers who are constantly faced with two types of orders: long lead time orders dedicated for the next season and urgent and unpredictable orders that are related to the current season. Moreover, this approach is applied to any type of industry where there are two types of customers: - premium customers with short lead time orders, – classic customers with long lead time orders. Indeed, through flexibility and responsiveness to needs, our approach will be able to place orders in the right location and at the lowest cost, taking into consideration a RPC and a rolling horizon. This will guarantee customer satisfaction that will gain in competitiveness, on both cost and lead time aspects, in today's highly competitive environment.

Furthermore, taking into account the type of information introduced, the performance of the supply chain can be improved. The more reliable this information is, the better the performance. Indeed, it is important for the customer to share his sales information with the producer so that the latter can prepare in advance, using adequate forecasting methods, to best accommodate these orders. In this case, the estimate of the RPC can be adjusted for more reliability and flexibility in order to forecast future orders that may come in. This is one of the perspectives and ideas to be explored for this work.

7. Conclusions

In this chapter, the DMAIC methodology was chosen and applied to perform a complicated problem of a textile company. Our aim is to satisfy customer needs at lower cost while ensuring prompt and punctual deliveries. To achieve this, a sequential approach integrating tactical and operational decisions for textile and apparel supply chain planning has been implemented with an emphasis on the flexibility provided by the consideration of RPC at the tactical level. As a result, newly arrived urgent orders, with short lead times, can be placed optimally at production sites, via the rolling horizon.

During the definition phase of the DMAIC methodology, we have defined the problem statement and presented the proposed planning approach. Then, we established the SIPOC diagram in order to identify the different steps of our approach which ensures flexibility of production and distribution activities' planning considering textile and apparel sector specificities: fashion effect, demand fluctuations.

In the first step, we have detailed our measurement system analysis by introducing the two mathematical models used to evaluate the performance of the current situation of the apparel company, taking into account the full available production capacity. Next, we presented our data collection plan by describing the experimental data that were collected. Finally, we outlined the desired situation taking into account additional flexibility at the tactical level.

In the "analysis" phase, we presented the obtained results when assessing the current situation by detailing production assignments over different locations. We also performed an extended analysis using the Ishikawa diagram and the 5P tool in order to underline the interest of our approach.

During the "improve" phase, we outlined the Improvements achieved in the current situation. To do so, we started by testing different RPC values in order to identify the optimal one to be taken into account at the tactical level. Then, we evaluated the performance of our approach by considering a fixed RPC then a monthly variable one. Finally, we evaluated the efficiency of our approach to optimally respond to urgent orders arriving at the operational level. Our approach is evaluated over a six-month planning horizon, but it remains applicable over longer planning horizons.

"Control" phase is devoted to sensitivity analysis while studying the effect of some parameters' variation on the cost of the supply chain. The three considered parameters are: demand, transport cost and subcontracting cost. The main focus of this section is to prove the interest of our approach to place, at the lowest cost, urgent orders that arrive at the operational level, even when demand and cost increase. For a better performance of the considered supply chain, the importance of cooperation between the manufacturer and the retailers, based on information sharing, was also emphasized.

Appendix A. The tactical planning model

In model formulation, we consider the following sets and indices, parameters, and decision variables.

Sets and indices:

K: set of manufacturing units $k \in K$; $K = U \cup V$.

U: set of internal manufacturing units, $k \in U$.

V: set of subcontractors' manufacturing units, $k \in V$.

I: set of retailers, $i \in I$.

J: set of warehouses, $j \in J$.

P: set of products, $p \in P$.

L: set of transportation modes, L = {trucks, ships, aircraft}, $l \in L$.

T: set of periods included in the planning horizon, $t \in [1 .. |T|]$.

Parameters:

In the tactical model, the parameter (D_{pit}) expresses the need of retailer i, in product p, to serve during period t. During period t, the quantities to be delivered are manufactured in production sites k characterized by a limited capacity (U_{kt}). Production incurs variable and fixed production costs per product per period (C_{pkt}, S_{pkt}) or subcontracting costs (G_{pkt}). A monthly cost of under-utilization of internal production capacity (CSU_{kt}) is also considered to penalize the non-utilization of available internal resources. Each product is characterized by a production lead time (Tp_p) and a product unit volume (V_p). The quantities manufactured are then transported to warehouses and incur inventory holding costs (KP_{pjt}). The warehouses are characterized by a limited storage capacity (W_j). The delivery lead time is noted by (e_l). Each means of transport has limited capacity (Cap_l). Variable and fixed distribution costs from sites to warehouses (CT_{kjplt}, CF_{kjplt}) and from warehouses to retailers (CS_{jiplt}, CFS_{jiplt}) are also addressed.

Decision variables:

$Z1_{kjplt}$: quantity of product p to deliver, via transportation mode l, from manufacturing unit k to warehouse j over period t,

$Z2_{jiplt}$: quantity of product p to deliver, via transportation mode l, from warehouse j to retailer i over period t,

X_{pkt}: produced quantity, of product p, in manufacturing unit k over period t.

SU_{kt}: unused production capacity at internal manufacturing unit k over period t.

J_{pjt}: inventory level of product p in warehouse j at the end of period t.

Y_{pkt} =1 if product p is produced in manufacturing unit k over period t; 0 otherwise.

$N1_{kjlt}$: transported quantity from manufacturing unit k to warehouse j over period t by use of transportation mode l.

$N2_{jilt}$: transported quantity from warehouse j to retailer i over period t by use of transportation mode l.

Model formulation (M1)

The tactical production–distribution planning model is formulated as an ILP that aims at minimizing the overall cost in the considered supply chain network.

$$\begin{aligned}
\text{Min}\Bigg(& \textstyle\sum_{t\in T}\sum_{p\in P}\sum_{k\in U} C_{pkt}X_{pkt}+\sum_{t\in T}\sum_{p\in P}\sum_{k\in U} S_{pkt}Y_{pkt} + \displaystyle\sum_{t\in T}\sum_{p\in P}\sum_{k\in U} G_{pkt}X_{pkt} \\
&+\sum_{k\in U}\sum_{t\in T} CSU_{kt}SU_{kt}\sum_{j\in J}\sum_{t\in T}\sum_{p\in P} KP_{pjt}\left(J_{pjt-1}+J_{pjt}\right)/_2 \\
&+\sum_{t\in T}\sum_{p\in P}\sum_{k\in K}\sum_{l\in L}\sum_{j\in J} CT_{kjplt}*V_p*Z1_{kjplt}+\sum_{t\in T}\sum_{p\in P}\sum_{k\in K}\sum_{l\in L}\sum_{j\in J} CS_{jiplt}*V_p*Z2_{jiplt} \\
&+\sum_{t\in T}\sum_{p\in P}\sum_{k\in K}\sum_{l\in L}\sum_{j\in J} CF_{kjplt}*V_p*Z2_{jiplt}+\sum_{t\in T}\sum_{p\in P}\sum_{k\in K}\sum_{l\in L}\sum_{j\in J} CF_{kjplt}*N1_{kjlt} \\
&+\sum_{t\in T}\sum_{p\in P}\sum_{k\in K}\sum_{l\in L}\sum_{j\in J} CFS_{jilt}*N2_{jilt}\Bigg)
\end{aligned}$$

Subject to

$$J_{pjt}=J_{pjt-1}+\sum_{l\in L}\sum_{k\in K} Z1_{kjplt-e_l}-\sum_{l\in L}\sum_{k\in K} Z2_{kjplt},\ j\in J; p\in P; t\in T \text{ and } t\geq e_l \tag{1}$$

$$\sum_{p\in P} J_{pjt}\leq W_j,\ j\in J \text{ and } t\in T \tag{2}$$

$$\sum_{p\in P} Tp_p*X_{PKT}\leq \alpha_{kt}*V_{kt}, k\in K \text{ and } t\in T \tag{3}$$

$$X_{pkt} \le M * Y_{pkt}, k \in K, p \in Pandt \in T \tag{4}$$

$$Y_{pkt} \le X_{pkt}, k \in V, p \in Pandt \in T \tag{5}$$

$$SV_{kt} \ge \alpha_{kt} * V_{kt} - \sum_{p \in P} Tp_p * X_{pkt}, k \in Kandt \in T \tag{6}$$

$$X_{pkt} = \sum_{j \in J} \sum_{l \in L} Z1_{kjplt}, k \in Kandt \in T \tag{7}$$

$$D_{pit} = \sum_{j \in J} \sum_{l \in L} Z2_{jiplt-e_l}, i \in I, p \in P, t \in T, t \ge e_l \tag{8}$$

$$\sum_{p} V_p * Z2_{jiplt} \le N2_{jilt} * Cap_l, j \in J, i \in I, l \in Landt \in T \tag{9}$$

$$\sum_{p} V_p * Z1_{kjplt} \le N1_{kjlt} * Cap_l, j \in J, k \in K, l \in Landt \in T \tag{10}$$

$$Y_{pkt} \in \{0, 1\} k \in K, p \in Pandt \in T \tag{11}$$

$$\begin{aligned} &Z1_{kjplt} \in \mathbb{N}, Z2_{jiplt} \in \mathbb{N}, X_{pkt} \in \mathbb{N}, J_{pjt} \in \mathbb{N}, N1_{kjplt} \in \mathbb{N}, \\ &N2_{jiplt} \in \mathbb{N}, SV_{kt} \in \mathbb{N} \;\; k \in K, j \in J, p \in P, t \in T, l \in Landi \in I \end{aligned} \tag{12}$$

The objective function aims at minimizing the total cost composed of set-up cost, variable production cost, subcontracting cost, internal capacity underutilization cost, inventory holding cost, transportation costs from manufacturing units to warehouses and transportation cost from warehouses to retailers. Transportation costs are composed of variable and fixed costs. The first, depends on quantity to deliver using transportation mode. While the second is proportional to the number of shipments.

The constraints (1) determine the stock level of product p in warehouse j at the end of period t. Constraints (2) guarantee that over each period, the total stored quantity is limited by the storage capacity. Constraints (3) ensure that the produced quantities do not exceed production capacity. Constraints (4) and (5) establish the relationship between binary and integer variables. Constraints (6) with the objective function identify the underutilized internal production capacity. Constraints (7) guarantee the delivery of all produced quantities to warehouses. Constraints (8) ensure that delivered products from warehouses to retailers meet on time demand. Constraints (9) and (10) guarantee the respect of transportation capacity. Constraints (11) and (12) are integrity constraints.

B. The set of periods in the operational planning model

The set of periods in the operational planning model used at week δ of month Θ is presented at the table below. For example, to construct an operational planning at the beginning of the second week (δ = 2) of month Θ, the periods involved are (Θ,2), (Θ,3), (Θ,4), (Θ + 1,1), (Θ + 1,2), (Θ + 1,3), (Θ + 1,4), (Θ + 2,1), (Θ + 2,2), (Θ + 2,3), and (Θ + 2,4) and they are listed in the third column of table below ($TS_{\Theta 2}$).

Set of periods in the operational planning model used at week δ of month Θ.

	δ = 1	δ = 2	δ = 3	δ = 4
(t, s) *in*	(Θ,1)	(Θ,2)	(Θ,3)	(Θ,4)
	(Θ,2)	(Θ,3)	(Θ,4)	(Θ + 1,1)
	(Θ,3)	(Θ,4)	(Θ + 1,1)	(Θ + 1,2)
$TS_{\Theta\delta}$	(Θ,4)	(Θ + 1,1)	(Θ + 1,2)	(Θ + 1,3)

	δ = 1	δ = 2	δ = 3	δ = 4
	(Θ + 1,1)	(Θ + 1,2)	(Θ + 1,3)	(Θ + 1,4)
	(Θ + 1,2)	(Θ + 1,3)	(Θ + 1,4)	(Θ + 2,1)
	(Θ + 1,3)	(Θ + 1,4)	(Θ + 2,1)	(Θ + 2,2)
	(Θ + 1,4)	(Θ + 2,1)	(Θ + 2,2)	(Θ + 2,3)
		(Θ + 2,2)	(Θ + 2,3)	(Θ + 2,4)
		(Θ + 2,3)	(Θ + 2,4)	
		(Θ + 2,4)		

C. The operational planning model

The same predetermined parameters of the tactical model are maintained for the operational planning model except few adjustments. Since the tactical and operational models consider different periods, w has been added here to the parameters and decision variables to indicate that they are related to a one-week period. The operational planning model determines the weekly quantities to be produced, stored and delivered $(t,s) \in TS_{\Theta\delta}$. It is worth knowing that the production plans obtained from the tactical model, for month t such as $(t,s) \in TS_{\Theta\delta}$, represent inputs to be considered at the operational level and must be weekly detailed.

In addition to the notation introduced in the tactical planning model, we consider the following two parameters and two decision variables related to overtime:

Parameters:

UHw: overtime production capacity in internal manufacturing unit $k \in U$ at week s of month t with (t,s) in $TS_{\Theta\delta}$.

CHw_{pkts}: overtime production cost in internal manufacturing unit $k \in U$ at week s of month t with (t,s) in $TS_{\Theta\delta}$.

Decision variables

XHw_{pkts}: quantity of product p produced during overtime in internal manufacturing unit $k \in U$ at week s of month t with (t,s) in $TS_{\Theta\delta}$.

$YHw_{pkts} = 1$ if there is production of p during overtime in internal manufacturing unit k at week s of month t; 0 otherwise with (t,s) in $TS_{\Theta\delta}$.

Model formulation (M2)

The main objective is to minimize the overall cost composed of: -weekly production cost, − weekly set-up cost during regular working hours and overtime, − weekly subcontracting cost, − weekly internal production capacity underutilization cost, − weekly holding inventory cost, − weekly variable and fixed transportation costs from manufacturing units to warehouses and from warehouses to retailers.

$$
\begin{aligned}
\text{Min} \Bigg(& \sum_{(t,s) \in TS_{\theta\delta}} \sum_{p \in P} \sum_{k \in V} Cw_{pkts} Xw_{pkts} + \sum_{(t,s) \in TS_{\theta\delta}} \sum_{p \in P} \sum_{k \in V} Sw_{pkts} \left(Yw_{pkts} + YHw_{pkts} \right) \\
& + \sum_{(t,s) \in TS_{\theta\delta}} \sum_{p \in P} \sum_{k \in V} Gw_{pkts} Xw_{pkts} + \sum_{(t,s) \in TS_{\theta\delta}} \sum_{p \in P} \sum_{k \in V} CHw_{pkts} XH_{pkts} \\
& + \sum_{(t,s) \in TS_{\theta\delta}} \sum_{k \epsilon V} CSVw_{kts} SVw_{kts} + \sum_{j \in J} \sum_{(t,s) \in TS_{\theta\delta}} \sum_{p \in P} KPw_{pjts} \left(Jw_{pjts-1} + Jw_{pjts} \right) / 2 \\
& + \sum_{(t,s) \in TS_{\theta\delta}} \sum_{p \in P} \sum_{k \in K} \sum_{l \in l} \sum_{j \in J} CTw_{kjplts} V_p Z1w_{kjplts} \\
& + \sum_{(t,s) \in TS_{\theta\delta}} \sum_{p \in P} \sum_{i \in I} \sum_{l \in l} \sum_{j \in J} CSw_{jiplts} V_p Z2w_{jiplts} \\
& + \sum_{(t,s) \in TS_{\theta\delta}} \sum_{p \in P} \sum_{l \in L} \sum_{k \in K} \sum_{j \in J} CFw_{kjplts} N1w_{kjplts} \\
& + \sum_{(t,s) \in TS_{\theta\delta}} \sum_{l \in L} \sum_{p \in P} \sum_{i \in I} \sum_{j \in J} CFSw_{kjplts} N2w_{kjplts} \Bigg)
\end{aligned}
$$

Constraints (1), (2), and (8)–(12) of the tactical model are also included at the operational level while introducing weekly parameters and decision variables. They ensure the balance of production flows, the respect of storage capacity, the satisfaction of retailer demand, the respect of transportation capacity [(9) and (10)], and guarantee the integrity of the decision variables [(11) and (12)]. Constraints (3)–(7) are changed to incorporate full production capacity and overtime as follows:

$$\sum_{p \in P} Tp_p * XHw_{pkts} \le VHw_{kts}, \mathcal{k} \epsilon\, \mathcal{U}; (\mathcal{t}, \mathcal{s}) \epsilon\, \mathcal{TS}_{\Theta\delta} \tag{13}$$

$$\sum_{p \in P} Tp_p * Xw_{pkts} \le Vw_{kts}, \mathcal{k} \epsilon\, \mathcal{K}; (\mathcal{t}, \mathcal{s}) \epsilon\, \mathcal{TS}_{\Theta\delta} \tag{14}$$

$$XHw_{pkts} \le M * \left(YHw_{pkts} + Yw_{pkts}\right),\ \mathcal{k} \epsilon\, \mathcal{U}; \mathcal{p} \epsilon\, \mathcal{P}; (\mathcal{t}, \mathcal{s}) \epsilon\, \mathcal{TS}_{\Theta}\delta \tag{15}$$

$$Xw_{pkts} \le M * \left(YHw_{pkts} + Yw_{pkts}\right),\ \mathcal{k} \epsilon\, \mathcal{K}; \mathcal{p} \epsilon\, \mathcal{P}; (\mathcal{t}, \mathcal{s}) \epsilon\, \mathcal{TS}_{\Theta\delta} \tag{16}$$

$$YHw_{pkts} + Yw_{pkts} \le 1,\ \mathcal{k} \epsilon\, \mathcal{U}; \mathcal{p} \in \mathcal{P}; (\mathcal{t}, \mathcal{s}) \epsilon\, \mathcal{TS}_{\Theta}\delta \tag{17}$$

$$YHw_{pkts} \le XHw_{pkts},\ \mathcal{k} \epsilon\, \mathcal{U}; \mathcal{p} \epsilon\, \mathcal{P}; (\mathcal{t}, \mathcal{s}) \epsilon\, \mathcal{TS}_{\Theta}\delta \tag{18}$$

$$Yw_{pkts} \le Xw_{pkts},\ \mathcal{k} \epsilon\, \mathcal{K}; \mathcal{p} \epsilon\, \mathcal{P}; (\mathcal{t}, \mathcal{s}) \epsilon\, \mathcal{TS}_{\Theta\delta} \tag{19}$$

$$SVw_{kts} \ge Vw_{kts} - \sum_{p \in P} Tp_p * Xw_{pkts}, \mathcal{k} \epsilon\, \mathcal{U};\ (\mathcal{t}, \mathcal{s}) \epsilon\, \mathcal{TS}_{\Theta\delta} \tag{20}$$

$$XHw_{pkts} + Xw_{pkts} = \sum_{l \in L} \sum_{j \in J} Z1w_{kjp\ lts},\ \mathcal{k} \epsilon\, \mathcal{K};\ \mathcal{p} \epsilon\, \mathcal{P};\ (\mathcal{t}, \mathcal{s}) \epsilon\, \mathcal{TS}_{\Theta\delta} \tag{21}$$

Constraints (13) and (14) guarantee the respect of the production capacity in regular working hours and on overtime. Constraints (15), (17) and (18) ensure that the cost of overtime is only taken into account if the same products are not previously produced. Constraints (16) and (19) establish the relationship between binary and integer variables. Constraints (20) with the objective function set the underutilized internal production capacity. Constraints (21) ensure that all production quantities are delivered to the warehouses.

Constraints (22)–(26) are also considered at the operational model:

$$\sum\nolimits_{(t,s) \in TS_{\theta\delta}/\delta \ge 1} Xw_{pkts} = X_{pk\theta} - \sum\nolimits_{s=1}^{\delta-1} Xw_{pk\theta s},\ \mathcal{k} \epsilon\, \mathcal{K}; \mathcal{p} \epsilon\, \mathcal{P}; \mathcal{t} = \Theta \tag{22}$$

$$\sum\nolimits_{(t,s) \in TS_{\theta\delta}/\delta \ge 1} Xw_{pkts} = X_{pk\theta+1},\ \mathcal{k} \epsilon\, \mathcal{K}; \mathcal{p} \epsilon\, \mathcal{P}; \mathcal{t} = \Theta + 1 \tag{23}$$

$$\sum\nolimits_{(t,s) \in TS_{\theta\delta}/\delta \ge 1} Xw_{pkts} = X_{pk\theta+2},\ \mathcal{k} \epsilon\, \mathcal{K}; \mathcal{p} \epsilon\, \mathcal{P}; \mathcal{t} = \Theta + 2 \tag{24}$$

$$YHw_{pkts} \in \{0, 1\},\ \mathcal{k} \epsilon\, \mathcal{K};\ \mathcal{p} \epsilon\, \mathcal{P};\ (\mathcal{t}, \mathcal{s}) \epsilon\, \mathcal{TS}_{\Theta\delta} \tag{25}$$

$$YHw_{pkts} \in \mathbb{N},\ \mathcal{k} \epsilon\, \mathcal{K};\ \mathcal{p} \epsilon\, \mathcal{P};\ (\mathcal{t}, \mathcal{s}) \epsilon\, \mathcal{TS}_{\Theta\delta} \tag{26}$$

Constraints (22), (23) and (24) guarantee coherence with the tactical decisions made. Finally, constraints (25) and (26) ensure the integrity of the new decision variables.

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Chapter

From Lean Manufacturing to Lean Construction: How Principles, Tools, and Techniques Evolved

Sevilay Demirkesen

Abstract

Lean manufacturing first emerged in the automotive industry. However, low productivity and low efficiency in production are major problems for the majority of industries relying on a heavy workforce. Being one of these, the construction industry suffers from low productivity rates along with inefficient work practices. To prevent those, the industry has shifted its focus from the traditional approach to a more innovative one, which is called Lean construction. Lean construction aims to maximize value while minimizing waste. Therefore, it intends to create safer, smoother, and more efficient processes to eliminate waste. This chapter focuses on Lean construction and highlights the generic Lean tools and techniques practiced in the construction industry indicating its historical journey from Lean manufacturing. The chapter aims to raise awareness towards the efficiency of Lean methods in the construction industry with respect to practices observed in manufacturing.

Keywords: lean manufacturing, productivity, efficiency, lean construction, lean methods

1. Introduction

The foundation of Lean thinking dates back to the 1900s, when Henry Ford, founder of Ford Motor Company, came up with an entire production process relying on interchangeable parts with standard work and moving conveyance for creating a flow production [1]. Melton [2] defines Lean as a revolution indicating that Lean is not just utilizing tools and techniques or making a few changes in processes, rather he defines Lean as a complete change in businesses to observe supply chain operations, managerial decisions, and daily work of employees in an organization. The authors of the book named "The Machine that Changed the World", which is one of the most influential books implied that the Lean way results in better products at a lower cost as well as encouraging employees to overcome challenges in production processes [3]. Even though Lean manufacturing has first found its roots at Ford, it was later investigated by Toyota Motor Company. The Japanese engineer Taiichi Ohno, who had several visits to Ford factories to observe production processes. However, Taiichi Ohno found some methods implemented at Ford as needing improvements. Therefore, Sakichi Toyoda, his son, Kiichiro Toyoda, and Taiichi Ohno came up with the concept of Lean Manufacturing, which was first called just-in-time (JIT) production [4]. Taiichi Ohno was responsible for implementing the new ideas that evolved into the Toyota Production System (TPS). Then, Taiichi Ohno hired Shigeo Shingo to work on the setup reduction problem at Toyota. Shingo later named this successful process the famous Single Minute Exchange of Dies (SMED) system. This is how production ideas evolved at Toyota leading to technical innovations.

The lean manufacturing concept was first articulated as a shop floor practice to reach higher efficiency in processes being implemented with JIT and Toyota Production System (TPS) [5, 6]. It was also mentioned that Lean manufacturing in the 1980s rather focused on shop floor techniques and inventory reduction as well as value-added processes in the supply chain [7, 8]. Lean manufacturing is now implemented as a popular manufacturing practice in various countries and industries [9]. The ultimate goal intended by Lean organizations is to have a high-quality organization responsive to customer demands with no waste. On the other hand, most manufacturing organizations fail to realize the transformation for Lean due to a range of challenges faced [6]. The majority of the previous studies implied that even though most Lean organizations aim to implement Lean in the best way, they fail at some point as a matter of fact [10, 11]. However, the organizations are still seeking ways to improve their Lean approach and effectively practice Lean methods.

The success of Lean thinking in the manufacturing industry positively affected the construction industry. However, the construction industry is a conservative and fragmented industry, which makes innovations less welcomed by industry practitioners [12]. On the other hand, low productivity rates and intentions to improve workforce efficiency led the construction industry to implement innovative technologies.

The term 'Lean Construction' was first articulated by the International Group for Lean Construction (IGLC) in 1993. Glenn Ballard and Greg Howell, the two construction practitioners who first considered Lean in construction projects, started the Lean Construction Institute (LCI) in 1997 to provide and share information about the management of construction projects in the most effective way. They observed that only 50% of the tasks on weekly work plans in construction projects are completed on time by foremen in a given week [13–15]. They proposed that construction practitioners can avoid these problems with active management of variability, starting with the structuring of the project (temporary production system) and continuing through its operation and improvement" [16]. This indicated that the construction industry is facing similar challenges to the manufacturing industry. Hence, the principles of the TPS and methods of Lean productions started to have been practiced in the industry by adapting them for construction.

Considering the similarity of challenges and need for improvement in both manufacturing and construction, the Lean methods have evolved with the methods for implementing. Hence, the main purpose of this chapter is to provide the background of Lean thinking in both manufacturing and construction along with presenting a bunch of Lean methods, which are widely practiced by industry practitioners. The chapter also mentions how Lean methods in production have changed when they are being implemented in the construction industry.

2. Background of lean production and lean construction: Interaction in terms of tools, techniques, and methods

Due to the quick industrialization after the industrial revolution, the world has become a place, where natural resources are unconsciously consumed and environmental problems increase. All these negative conditions have caused the run out of natural resources, distortion in the ozone layer, decrease in biodiversity, increase in environmental contamination, and global warming. Therefore, the removal of all these problems and negative conditions is one of the most important challenges of today's world. This leads to a considerable increase in the number of studies regarding the prevention of environmental problems, conscious use of natural resources, and a cleaner and healthier environment to be inherited by the next generations. In this context, Lean is a newly emerging concept for the majority of industry encouraging the effective use of resources. One of the major challenges of today's world is to execute projects more efficiently with respect to project objectives. At this point, Lean thinking aims to minimize waste while maximizing value to the customer.

Lean Production was the term coined by [17] to refer to Toyota's offering of high value, low-volume, and cost-competitive production to best address customer desires [18]. After the success of lean production in the automotive industry [19], Toyota's Lean thinking was applied in other industries. The construction industry produces more waste than any other industry in the entire world [20]. The waste oftentimes occurs in the form of workforce loss, safety breaches, material waste, and low efficiency. To avoid these, Lean construction has proven to be an effective means of production management for project delivery, i.e., designing and building capital facilities. Lean Construction is important in that it adopts the principle of minimizing waste and maximizing value while improving the total project performance per customer expectations. The need behind Lean construction comes from the failure of mass production and the persistence of craft-based production in the construction industry. Due to the changing needs of the customer, Lean construction is essential to provide the desired variety. To minimize waste and maximize value, researchers have previously focused on several different Lean construction methods. For example, it was implied that modular construction is effective in reducing waste and achieving resource efficiency [21]. This study also demonstrated that modular is reusable, which evidences the essential function of modular construction. In another study, it was indicated that there are several waste factors in mid/high-rise building projects and the determination of those waste factors is essential [22]. Therefore, Lean construction has proposed an opportunity for estimating the impacts of waste on overall project performance [23].

Sacks et al. [24] implied the importance of Lean production management systems in reducing waste in construction. Kalsaas [25] highlighted that measurement of waste and workflow is essential for the achievement of continuous improvement in construction projects. El.Reifi et al. [26] emphasized that Lean thinking is essential in the briefing process, where the design team develops their designs with respect to clients' desires. Fullalove [27] provided that the use of Lean techniques resulted in significant benefits such as an increase in return on investment and efficiency savings in UK road constructions. Marhani et al. [28] indicated that the application of Lean thinking into the construction industry provides a tremendous opportunity for the reduction of waste and an increase in production. Zhao and Chua [29] demonstrated that the reduction of non-value adding activities has a significant contribution to the construction productivity improvement. Aziz and Hafez [30] concluded that lean projects are safer, easier to manage, completed sooner, cost-effective, and are of better quality by referring to the impact of lean in minimizing waste in construction. Boyce [31] investigated the aspects of Lean thinking and concluded that it helps to improve the design phase of complex projects by emphasizing the essential function of a collaborative planning process in highway design. Going Lean is needed for the defective processes in mass production and craft production. Hence, Lean is an effective approach for customer satisfaction and enhanced project performance as previously implied by several studies [32, 33]. However, there is still a need for more effective Lean techniques to be applied in the construction projects especially given that the industry generally is reluctant to embrace and slow to adopt change.

Given this background, this chapter presents the most applied methods of Lean in the construction industry with inference to Lean production. The construction industry is utilizing most of the Lean techniques developed for manufacturing. Hence, it is essential to present these tools and techniques to guide industry practitioners for the proper implementation of the methods.

3. Lean methods: how tools and techniques are evolved

Lean methods have been heavily implemented in the manufacturing industry. Over time, the efficiency and reliability of the methods have been proven. This encouraged other industries to benefit from Lean methods. Since the construction industry relies on a heavy workforce, it is essential to utilize safer, reliable, and efficient methods and technologies.

In production, it is of utmost importance to eliminate 'waste'. Waste or 'muda' in Japanese is simply defined as anything other than the minimum amount of parts, materials, equipment, and work time specific to production [34]. There are seven waste types defined as overproduction, waiting time, transportation, inventory, processing, motion, and product defects. Lean manufacturing aims to manage processes without waste. However, it was evidenced that several companies are still challenging with staying Lean [35]. Kongguo [36] implied that Lean thinking helps conceive the Lean principles better, which first starts with realizing the customer value and continues with identifying value-added activities, generating flow, implementing the pull system, and sustaining continuous improvement. To improve the efficiency in those, various Lean methods and techniques are developed and practiced in manufacturing organizations. Some of them have been more effective in other industries such as construction.

Below are the widely implemented Lean techniques that have evolved and be used in the construction industry.

3.1 The last planner system (LPS)

LPS was originally developed by Glenn Ballard in 1993 in accordance with Lean construction principles. LPS is a Lean construction tool that focuses on increasing productivity by creating weekly work plans. The weekly plan includes tasks related to work and the individuals executing these tasks are called the Last planners [13]. LPS allows quick monitoring of the work-related issues for all construction personnel. LPS also provides an environment, where mistakes are visible. However, problems might occur, and timely actions are not taken in traditional construction management leading to late delivery of projects [36]. The Last planner is the person, who directly supervises the work. This person is usually responsible for production capability. The Last planner can be anybody like a project engineer, department manager, or foreman [37]. **Figure 1** presents the Last Planner System.

The tasks are split into two as needed and weekly. As needed tasks involve 'should' tasks, whereas weekly tasks include 'can', will', 'did' tasks. In 'should', the tasks include work to be done to reach the determined milestones according to the project plans. These tasks are created from different data such as customer demands, project goals, and information, planner stuff's former experiences. In 'can', the fundamental tasks are reflecting the actual work that is executed with respect to the constraints of the project. In this process, the required materials and labor are ready, where the previous project stage is completed. In 'will', the tasks ensure the work to be completed after all constraints are assessed. In 'did', the tasks refer to completed work [39].

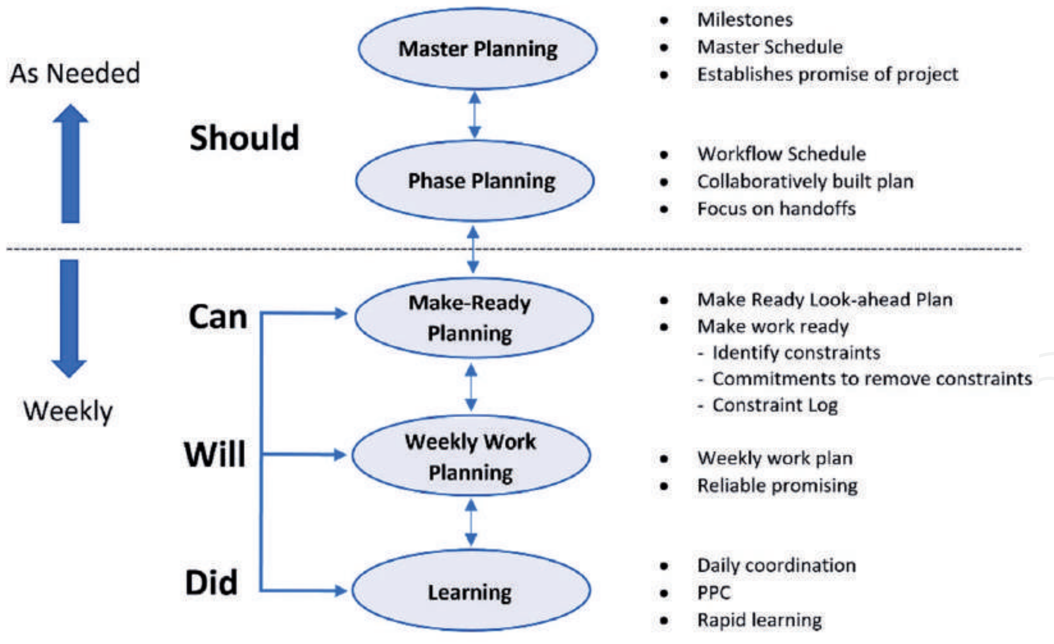

Figure 1.
Last planner system (adapted from [38]).

3.2 5S method

5S is a Japanese method of organizing the workspace in a clean, efficient, and safe manner to create a productive work environment. The 5S is a starting point for any company aiming to be recognized as a responsible and reliable producer [40]. In Japanese, the 5S methodology represents 5 different words, which all start with the letter S. **Figure 2** presents these five steps, respectively.

Sort (Seiri): Sorting is the first stage of 5S. It is the process of sorting out (separating) materials and equipment needed or unneeded. This process might result in fewer complaints, improved communication among employees, and an increase in the quality and efficiency of production. This process allows workers to take the next steps such as tagging the items.

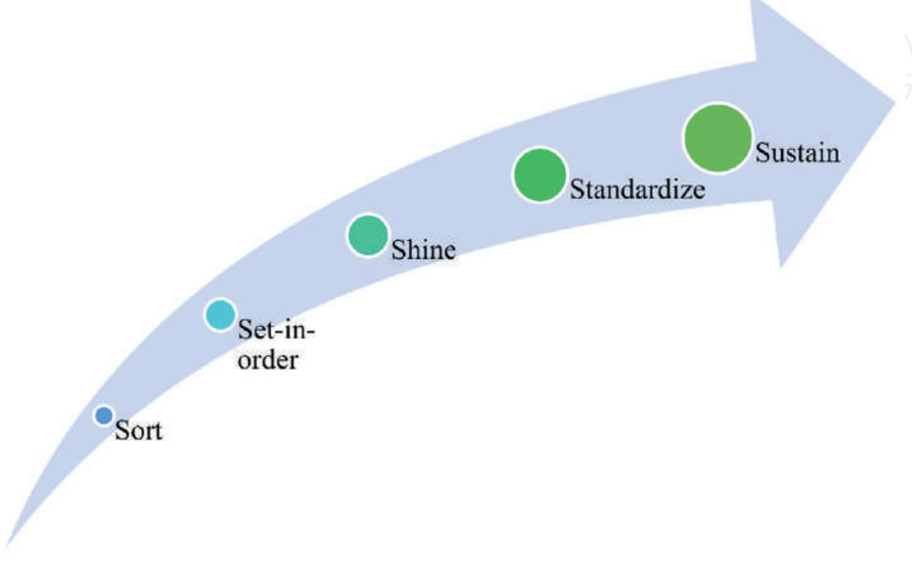

Figure 2.
5S stages.

Set in order (seiton): This stage refers to make all equipment needed for production accessible and prepared for use. This step also refers to organize all equipment and material for easy access and facilitation for production. This step requires the work area to be organized for production. A map can be drawn to represent station and equipment places.

Shine (seiso): This step refers to cleaning polluted equipment and work area. Pollution can be detected by sense organs and this might help find out the problem before it occurs. This stage also refers to sweeping everywhere cleanly and taking all kinds of unwanted objects away from the working environment. Thus, abnormalities can be noticed immediately, and the decision to clean materials after separation becomes easier.

Standardize (seiketsu): This stage refers to cleaning and maintaining the arrangement and standardizing that. The main purpose of this step is to fully meet 3S requirements and to detect and eliminate the root cause of problems. The way to ensure these is to constantly check the environment and detect deficiencies.

Sustain/self-discipline (shitsuke): This step encompasses all stages. It includes checking the existing system, training the employees, establishing good communication, and rewarding. The main purpose of this step is to get into the habit of maintaining the correct procedures [41].

3.3 Mistakeproofing (Poka yoke)

"Mistake proofing, or its Japanese equivalent poka-yoke (pronounced PO-ka yo-KAY), is the use of any automatic device or method that either makes it impossible for an error to occur or makes the error immediately obvious once it has occurred" [42]. Mistake proofing is an effective quality control technique to avoid human error, which might cause mistakes or defects [43]. Shingo [44] defines three inspection techniques for quality control, namely the judgment inspection, informative inspection, and source inspection. Judgment inspection is for discovering defects, whereas informative inspection is used to lower defect rates by controlling the process and prevent defects. Source inspection rather searches the conditions that exist for an error-free action.

Poka yokes might be grouped into three as shutdown poka-yoke, control poka-yoke, and warning poka-yoke in terms of their functions. The poka-yoke devices check different and important parameters and detect whether the process has an improper action. This check allows detecting whether the product manufactured has defects or not. The shutdown of poka-yokes constitutes an important part to prevent defects eliminating the possibility of error. The control poka-yoke is built into the production equipment and works as a redactor. When the device finds an unwanted condition that occurred during manufacturing processes, it signals production to avoid defects. The warning poka-yoke warns the operator with either visual symbols or sound signals for errors. The warning poka-yokes rely on human factors, where it is not quite certain to avoid defects in the production processes [45].

Mistake-proofing has six principles namely elimination, prevention, replacement, facilitation, detection, and mitigation. The first four principles intend to prevent the occurrence of human error, whereas the last two principles are to minimize the effects after the occurrence of human error. **Figure 3** presents these six principles along with their tasks.

The use of mistake-proofing devices also provides various advantages in terms of safety at the workplace [46]. It is possible to create fail-safe approaches in manufacturing with the use of such tools and devices. Considering the high accident rates in the construction industry, the use of mistake-proofing devices is also effective means of enhancing safety performance and avoiding human errors leading to work-related accidents.

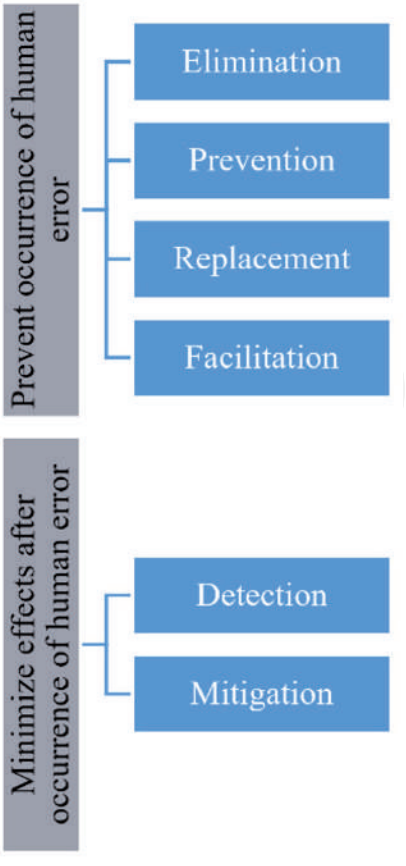

Figure 3.
Mistake proofing principles.

3.4 Visual management

Visual management is a broadly implemented Lean technique in the manufacturing industry. This technique helps to make information visible for all showing the information through visual signals [47]. Visual management has recently been used as a system enabling employees to better understand their role and contribution with respect to organizational values and customer needs. Nevertheless, the critical role of visual management has not yet been understood well by the construction industry. For example, two types of visual means such as 3D and visual planning are utilized in construction design [48]. Visual management helps increase communication, transparency, and stakeholders' capabilities [49, 50]. Therefore, construction companies must make use of these techniques to provide a better environment for their employees increasing efficiency and productivity.

3.5 Target value design (TVD)

Target Value Design (TVD) is simply defined as "a management practice that steers the design and construction of the project to the customer's constraints while maximizing the value delivered within those constraints" [51]. TVD is an emerging practice in the U.S. construction industry for cost predictability during design, construction, and delivery. It is adapted from the Target Costing method of manufacturing, which first appeared as a profit planning and strategic management approach in the 1930s [52]. This technique is promising for several benefits for the construction industry, where the companies are still struggling with project constraints such as cost, quality, and time. Therefore, TVD is an effective means of collaborative Lean approach in terms of reducing construction costs [53]. It was further indicated that

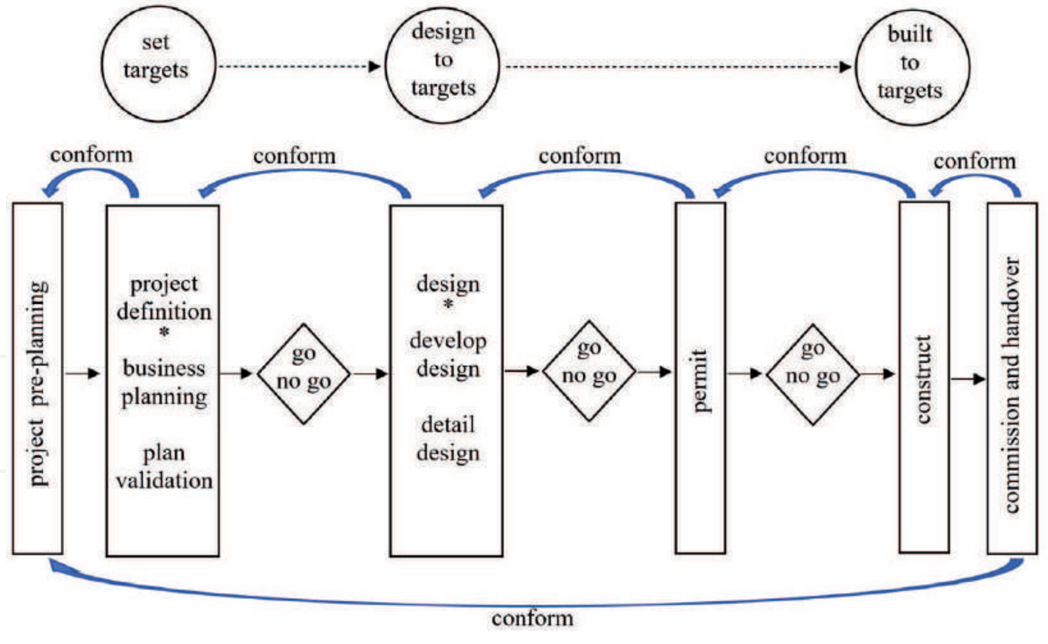

Figure 4.
TVD process scheme [53].

the systematic application of TVD resulted in significant improvement in project performance based on 12 construction projects, where TVD was introduced. **Figure 4** presents the TVD process with respect to construction project phases.

3.6 Value stream mapping (VSM)

Value Stream Mapping is an essential tool to identify and comprehend the productive stream focusing on the identification of waste sources, such as waiting for products and inventories, rework, information lost in the process, non-value-adding activities besides the identification of opportunities for improvement [54]. With VSM, it is possible to improve the information stream in the design process through the inclusion of alternative methods of control. This creates a base for incentives and future actions to generate value [55].

VSM helps visualize the whole rather than isolated parts of the process as well as monitoring the products, documents, and information. It also allows simultaneous visibility of streams of materials and information; visualization of indicators such as throughput time, percentage of value aggregation, lots size, and cycle time for the performance of activities [56].

VSM consists of several steps such as mapping activity for a family of products, defining the current state map of the value stream, and creating the future value stream map, where improvement takes place based on the proper identification of problems [54, 56]. **Figure 5** presents the steps for VSM.

3.7 5 whys and root cause analysis

5 Whys is a quality management tool of problem-solving aiming to find the root cause of an event [57]. It directs that one needs to ask five times repeatedly to identify the root cause of a problem for the fact that the solution is clear. This procedure aims to eliminate the root cause to prevent its recurrence [58]. **Figure 6** shows the 5 Whys procedure for finding the problem's root cause.

Considering the risky nature of construction projects, it is of utmost importance to determine the root cause of the problems leading to unwanted situations. Therefore, 5 Whys analysis is an essential method for preventing problems either

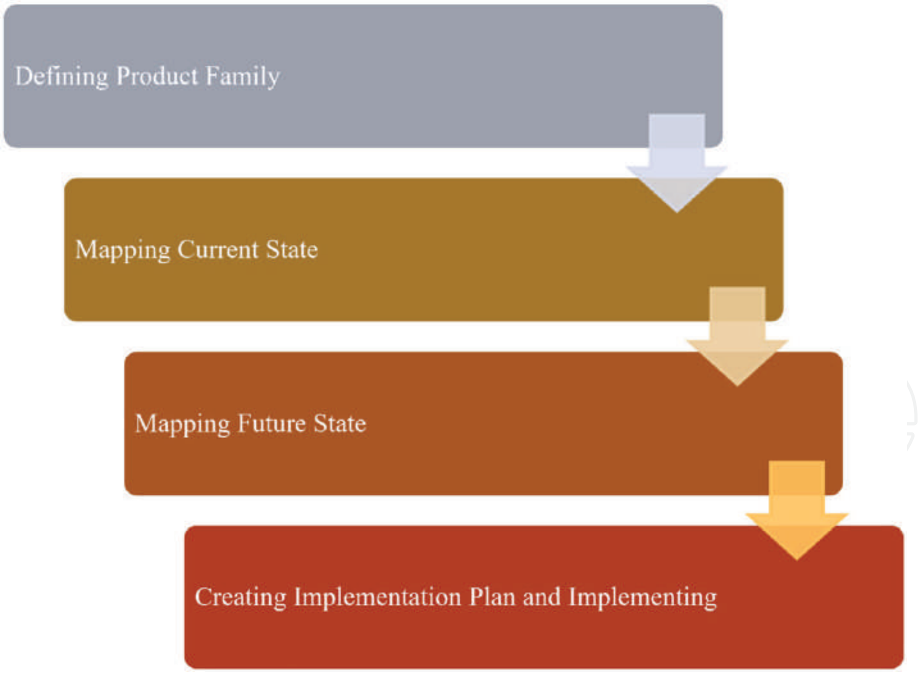

Figure 5.
VSM processes.

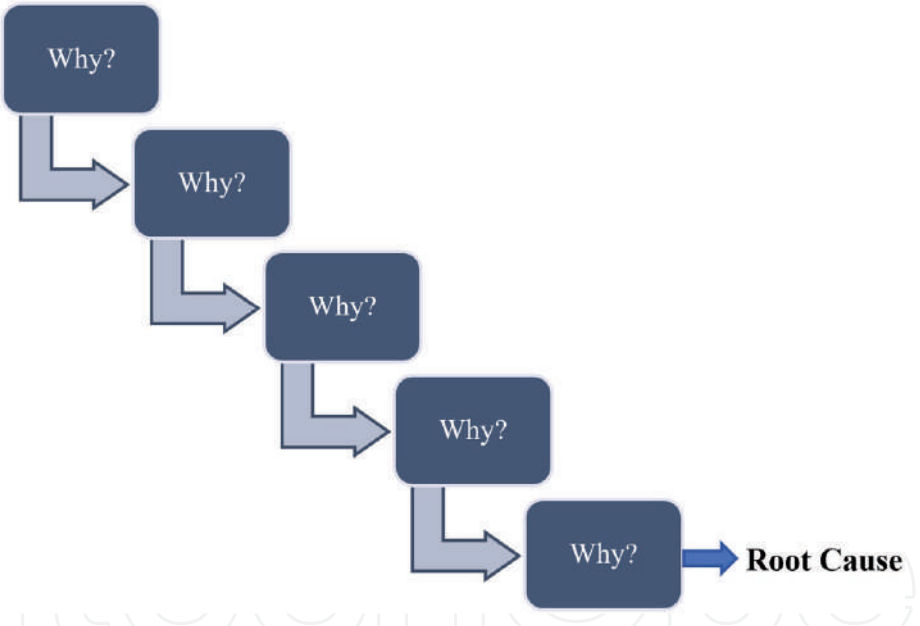

Figure 6.
5 whys analysis procedure.

from occurring or recurring. Therefore, utilizing the 5 Whys method might result in higher efficiency and productivity, where risky conditions are eliminated.

3.8 Gemba walks

Gemba is a Japanese word and it stands for the "actual place" [59]. For creating value in the organization, the actual place must enable employees to manufacture with less waste, fewer challenges, less overload, land ess overproduction. At this point, Gemba walks are essential to go and see the current situation and understand the root cause of the problem. In the Lean construction context, walking means "go see, ask why, show respect" [60]. Gemba walks help making the problems visible and create improvement ideas with the proper consideration of the root cause.

It also allows collecting data regarding the root cause leading to problems. In the construction industry, it is clear that Gemba walks constitute an important part since the majority of the processes in construction need improvements and require the proper identification of the root cause for problems.

3.9 Daily huddle meetings

Daily huddle meetings take place, where team members are ready to share what they achieved and what they challenge. A huddle meeting can also be organized as a weekly work plan meeting highlighting the completion of assignments for the following week in addition to discussing the work to be done that day [61]. The huddle meetings enhance the job satisfaction of employees while strengthening two-way communication among the team [62]. Daily huddle meetings create an opportunity for employees to involve in discussions and indicate the positive and negative sides of their tasks. The employees also find room for solving problems together during those meetings. These meetings also help detect the causes of accidents, which are associated with poor communication and coordination [63]. Hence, daily huddle meetings must be organized, and employees are encouraged to speak up on the tasks listing good and bad sides.

4. Conclusions

This chapter presented the historical evolution of Lean management and how Lean is adopted in the construction industry. The study presented the core principles of Lean along with the most widely adopted practices. According to the information presented in this chapter, one may advocate that the construction industry still struggling with the adaption of various Lean manufacturing practices into construction. Therefore, it is apparent that more research has to be conducted to provide a guideline for the industry practitioners in terms of benefitting from Lean practices at maximum. On the other hand, the methods, tools, and techniques presented in this chapter are expected to lead industry practitioners in terms of scrutinizing Lean concepts and evaluate those in the context of project conditions. As future work, the efficiency of Lean methods both applied in manufacturing and construction might be compared based on different operating processes.

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Chapter

Model-Based Enterprise Continuous Improvement

Bruno Vallespir and Anne Zouggar-Amrani

Abstract

The enterprise reengineering based on enterprise modelling is usually carried out within the framework of conventional projects. This leads to relatively long projects that are not compatible with a highly variable economic environment. The objective of the evolution management presented here is to use enterprise modelling and all the benefits it brings in a framework that allows for more continuous improvement than is generally observed. The proposed architecture is made up of three levels: a strategic level based on performance measurement, a tactical level that manages system migration and is based on enterprise models, and an operational level consisting of managing a portfolio of evolution projects. Together, these allow a shorter set of projects to be carried out, while remaining coherent and aligned with the company's strategy. This approach puts enterprise modelling methods and continuous improvement/Lean management approaches into perspective, allowing complementarities and opening up interesting perspectives concerning enterprise re-engineering methods.

Keywords: enterprise modelling, evolution management, continuous improvement, lean management, performance

1. Introduction

Since the 1970s, enterprise modelling has developed into an effective methodological source for improving business performance. Some of the proposed approaches simply provide a modelling language but others also present an implementation method. It appears that these methods adopt a classic project approach that leads to long and costly projects. Moreover, in the context of a rapidly changing economic environment, these approaches lack responsiveness. Faced with this, continuous improvement is pushing towards shorter projects that come from the field and are part of a permanent movement of evolution.

With this perspective in mind, the objective of this chapter is to show how enterprise modelling can be encapsulated in a continuous evolution approach of a strategic nature, the ultimate goal being to take advantage of the expressiveness and systemic approach of enterprise modelling while being part of a fluid and reactive evolution context.

The outline of this chapter is as follows. Section 2 will present the problem statement by insisting on the inadequacy of project-based approaches in a context of a changing environment. Section 3 gives elements of conceptualisation, on the one hand, on the evolving system itself and, on the other hand, on the system for managing this evolution. Section 4 will present the evolution management system in detail. Section 5 will give the main elements that argue in favour of such an approach. Section 6 will conclude the chapter.

2. Problem statement

Over the last few decades, enterprise modelling has provided a methodological set of tools for engineering and, more often, re-engineering organisations. Little by little, this scientific field has emerged as an effective methodological source for improving business performance [1–3]. Developments took place in several stages [4, 5]. After having proposed many modelling languages in the 70s and 80s, this field then sought to make these languages work together to obtain integrated methods (such as CIMOSA or GIM) with a large modelling coverage in order to approach companies in the most systemic way possible [6–8]. This work made it possible to define fairly stable modelling domains, often identified as views or points of view: informational view, process view, decisional view, etc. The next step consisted in organising all this input by analysing on the one hand the components of these methods and their organisation (GERAM) [9, 10] and on the other hand on the nature of the concepts handled. This last point was based on approaches such as meta-modelling and ontologies and had as a practical field of application the translation of inter-language models and the development of a Unified Enterprise Modelling Language (UEML) [11–13]. From a theoretical point of view, this point allowed the identification of the major concepts to be retained in enterprise modelling as well as the way to formalise and express them. Finally, it must be stressed that enterprise modelling corresponds well to current trends that advocate the use of models in engineering such as Model-Driven Architecture (MDA) [14, 15] in software engineering or all the approaches referenced under the term Model-Based Systems Engineering (MBSE) [16].

Applications of enterprise modelling methods show that they lend themselves well to project-based approaches. Project management in companies has grasped big attention since many decades to provide new insights to the practitioners. Early investigation through case studies in [17] provides a cross analysis between project management and the interest of Lean thinking. A key element in combining lean approach to project is "Planning and control by objectives" with fixed and accepted key dates. Then, the commitment and motivation from the team was quoted as leading to successful final project. This link requires precise organisation and timing, time and resources. A complete project of this type takes place over several months and can take up to one year.

It is emphasised in [18] that the efficient resources management is becoming a major challenge in the current context of volatility, uncertainty, complexity and ambiguity. In order to efficiently manage its resources, companies need to manage and deliver projects on time, on budget, inside the scope and in accordance with the quality requirements agreed with the customer. We are therefore faced with the two classic problems of this type of approach.

The first problem concerns the evolution of the environment, and therefore of the specifications, during the project. Like any project, a reengineering project using enterprise modelling is based on initial specifications and objectives. Even if it is possible to make these evolve during the project, it is more comfortable and efficient to ensure that they remain fixed for the duration of the project. In the end, a project-based approach is easier to implement in a stable context ensuring that the specifications do not change significantly during the project.

The second problem concerns the necessary breaks between projects. These are necessary for several reasons. Firstly, a re-engineering project is sufficiently intrusive and impacting that the system under consideration needs to "rest" between projects i.e., to return to a nominal regime during which the project results will be integrated into the day-to-day running of the company. Secondly, as this type of project requires a financial and time investment, this effort cannot last indefinitely. The break thus enables the company to reconstitute its resources before considering another project. Generally speaking, it can be envisaged that the return on investment must be sufficient before considering another project. In the end, since the break is necessary, the project will be all the more profitable if requirements do not change too quickly during the break. This brings back to the necessary stability of the environment.

In conclusion, the major problem is the stability of the environment. The project approach is difficult to apply in a turbulent context. **Figure 1** summarises these points.

The answer to this problem is therefore to reduce these two durations: project duration and the duration of break between projects. The solution is to move towards less ambitious and more targeted projects, even if it means multiplying them. A less ambitious project can be carried out more quickly. Because it is shorter, there is less risk of a gap between specifications and results. A less ambitious project also requires fewer resources, which makes it easier to make it profitable. Finally, a less ambitious project has less impact on the entire structure, which makes it easier to integrate the results in nominal mode. These last two points thus limit the need for break between projects. **Figure 2** shows how shorter but more numerous projects, with shorter breaks between projects, can make it easier to meet the company's expectations.

This orientation leads to a more continuous evolution of the system. Therefore, we are approaching methods referred to as continuous improvement. In [19] it is reminded that project management model suggests to systematically "address the actions and solutions to be implemented in order to keep, in the long run, the continuous improvement of the project management processes in the organization".

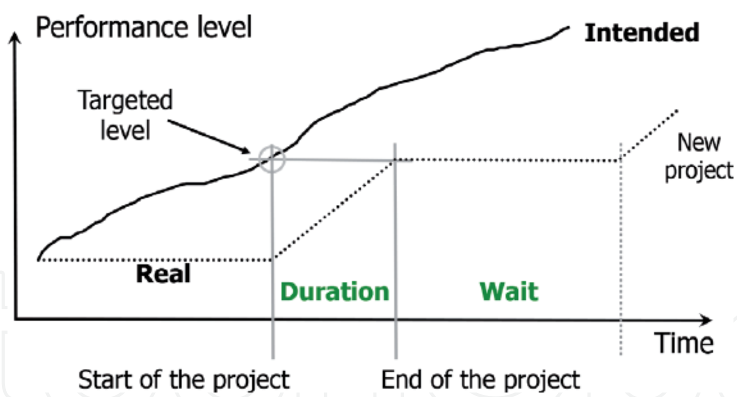

Figure 1.
The problems issued from a project-based approach in a turbulent environment.

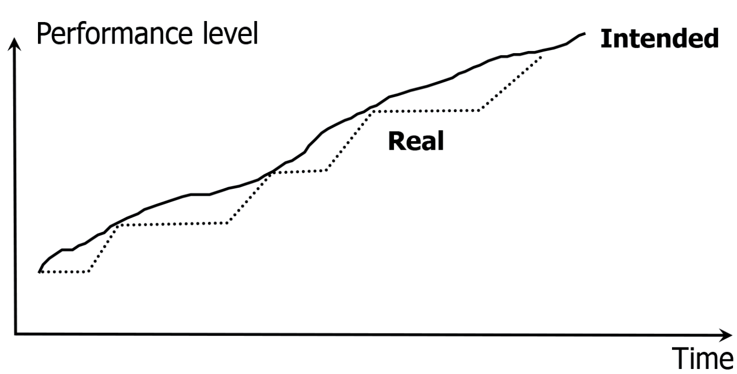

Figure 2.
Getting closer to the needs through shorter, more numerous projects and with less break between projects.

The DMAIC (define, measure, analyse, improve, control) is also sustained as being a cycle for conjoint continuous improvement framework [20]. The DMAIC methodology is seen as last generation of improvement approaches, adding concepts, methods, tools and removing limitations identified [21]. The model based on DMAIC allowed identifying company's main project management problems and associated causes and the selection of the causes to be first addressed [19]. It is closely linked to PDCA approach evoked further.

This field, which has a very strong intersection with Lean management [22, 23], proposes a philosophy and a set of methods that provide tools for improvement actions. The Lean thinking is a way of focusing on value from customer point of view and making people contributing to the improvement to ensure the quality at the source. When the actions carried out with Lean practices such as Value Stream Mapping, Kaizen, A3 approach are examined, it effectively shows that they are less ambitious and more focused on a specific problem. Starting from problems in the field and involving various company members, they generally focus on the physical system (in the industrial case) or, more generally, on the value-added process to get as much exhaustive vision of the flow as possible and to analyse operational dysfunctions. The analyses of the added value activities should and must be at the heart of the focus that leads to less interest in infrastructural items such as the information system.

In addition, they offer more problem-solving tools than enterprise modelling. Conversely, this results in a weaker systemic vision than with enterprise modelling (how do all these actions fit into a coherent whole?). Similarly, it presents very few representation tools unlike enterprise modelling. Only Value Stream Mapping (VSM) can be considered as a modelling language. As quoted in [24], VSM is a powerful tool of representation found as being able to eliminate Muda, bottlenecks across production line. The value stream mapping uses current state map to record current state of production line before implementation of improvements. Indeed, the VSM contains a specific pictograms code to represent steps of the flow along the considered scope (from suppliers to customers) with different technical data at each activity represented. The information and physical flows are modelled to visualise the flow progression and detect "bottleneck resources" that deserves attention and corrective actions. By the way, VSM modelling is also significantly interesting tool to perceive the durations of the added value actions and the waste undergone in the different steps because of storages, quality rate and processing times. VSM was efficiently proved to be interesting in the modelling production flow of an aeronautic company to improve the productivity and deliveries costs dropped by 50% [25].

Generally speaking, what most characterises continuous improvement is the continuous aspect of the actions carried out, as the name suggests. Here, there is no project with a beginning and an end, but a continuous improvement process, conceptualised in particular by the Plan-Do-Check-Act cycle (PDCA) which is a control framework for executing a series of activities for continuous improvement of processes, originally developed in the field of manufacturing [26].

Finally, the approach presented in this chapter aims to move towards an approach of continuous evolution of the system under consideration, while retaining the advantages of modelling as proposed by enterprise modelling. To avoid confusion with continuous improvement, the approach is referred to here as evolution management.

3. Conceptualisation

Several aspects concerning conceptualization are presented in this part. Firstly, the notion of evolution trajectory makes it possible to implement the conclusions of the previous part. Then, several levels of management are proposed to manage the evolution trajectory of the system. Finally, several ways of formalising the system are presented [27–29].

3.1 Evolution trajectories

The general principle is then to make the evolution of the system a process as continuous as possible. Practically, the evolution process is made up of a sequence of steps representing the evolution of the state of the system. The closer in time these steps are, the more continuous the evolution of the system will be. Two steps are specific. The first one corresponds to the state of the system at the time it is examined (t = 0). This step therefore corresponds to the *current state*. The second represents the state in which we would like the system to be in the future, at a time sufficiently far in the future but for which it is possible to make viable predictions about the system's environment. We refer to this step as the *target* and the moment at which it corresponds as the *strategic horizon*. The path between the current state and the target is punctuated by intermediate states that we call *steps*. These steps are the moments when the environment is reassessed and the target is redefined. If the environment has not changed, the target remains the same. This is equivalent to saying that the target is the desired state in the future, assuming the environment has not changed. However, we will consider that this is not the general case. Therefore, at each step, a new target is defined. The duration between two steps is usually fixed, we call this duration *strategic period*. It is clear that, because the steps are intended to be moments of redefinition of the target, the strategic period will be all the shorter as the environment changes rapidly.

Figure 3 summarises these concepts.

3.2 Management levels

On the basis of the trajectory of the system as we have just defined it, several levels of management can be envisaged.

The first one corresponds to the control of the path between the current state and the target. The target is a state envisaged at long term, based on the analysis of the environment and the company's major orientations with a significant degree of uncertainty. The concept of target is close to other concepts such as vision, mission or values which are the core elements of a strategic organisational foundation [19]. Therefore, it corresponds to a strategic level.

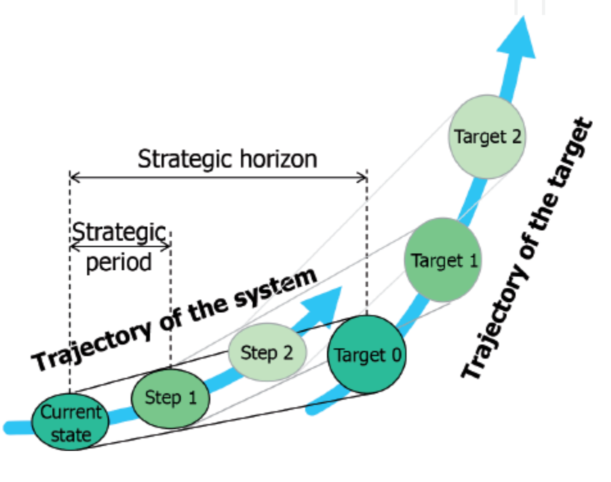

Figure 3.
Evolution trajectories of the system and the target.

As much as the target is considered to be generally unreachable, step 1 must be reached (there is no questioning planned before step 1). The management of the evolution between the current state and step 1 must therefore make it possible to precisely define the state of the system at step 1. This level is therefore considered tactical.

The level that has just been presented makes it possible to define towards which state the system must evolve, but it does not manage the actions to be implemented to do so. Therefore, a third level, concerned by concrete action, is necessary. This level is operational.

Figure 4 shows these three levels and the processes that they manage. Considering the role that they play in the approach, the current state is called *As-is*, the first step *To-be* and the target *Could-be*.

3.3 Formalisation modes

The states identified by the approach can be formalised in different ways. Three forms are envisaged: performance, model and project.

Performance. A system can only be seen as a source of performance. Once the set of performances of interest to the company has been defined, the system and its evolution will be characterised through these performances. The state of the system can therefore be considered to change each time a performance changes in value. Thus, the state of the system is characterised by the value of its performance vector. The evolution then becomes a trajectory in a performance space, the significant points of this evolution being the states of interest. The performance can be observed in the case of an existing system or targeted in the case of a future system. **Figure 5** illustrates this approach.

Model. The most classic way to represent a system is to make a model of it. The notion of model is very broad and the definition of this term changes according to the domains. In engineering, a model represents the structure or behaviour of a system and is intended either to understand and evaluate the system when it exists

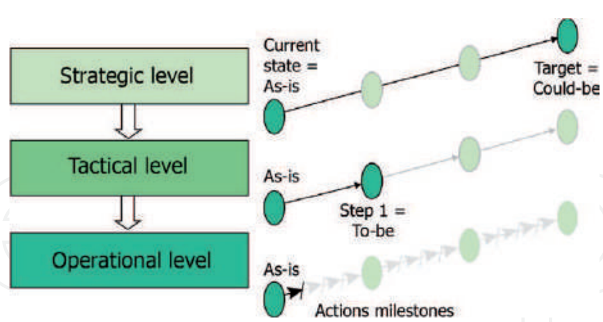

Figure 4.
The management levels.

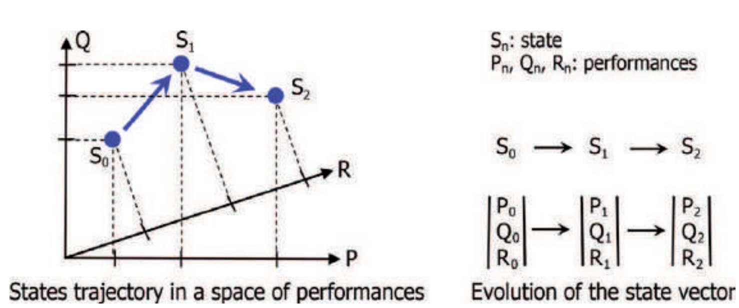

Figure 5.
The performance-based characterisation.

or to characterise it in order to design it. A model is based on a language. It can be formal, semi-formal or informal. A formal language is based on a mathematical formulation, whether continuous (system of differential equations for example) or logical (discrete event systems for example). At the other end of the spectrum (informal models), we can find models that are only drawings. A shop layout is an example of this. In between are semi-formal languages i.e., languages that have syntax and lead to less interpretation than natural languages but are not executable. This is the domain of enterprise modelling. The latter proposes a set of approaches and graphical languages that allow the system to be observed from several points of view. These languages include the IDEF suite, the business process modelling languages (BPMN, ...), the GRAI method, CIMOSA, etc. The aim here is not to define the language to be used, this depends on the objectives of the company and its culture. Finally, we should not forget simulation, which is quite similar to enterprise modelling but which proposes executable models.

Project. A final way of understanding the system is through the projects it undergoes. This way, less classical than the two previous ones, insists on the fact that an evolving system is the object of projects that act on it and that, therefore, the evolution of the system is characterised by the projects that allow it. Within this framework, future projects can be envisaged to support a targeted evolution and current projects can be analysed to understand the evolution in progress. Finally, looking at the projects means observing the evolution of the system in an operational way.

The three approaches are complementary. Seeing the system through its performances consists in considering it as a black box and in valuing the exchanges it implements. The model approach allows on the one hand to open the black box to observe the structure and, on the other hand, to observe the dynamics of the system (synchrony). Finally, the vision by project focuses on a diachronic approach by analysing the actions that lead the system to evolve.

4. The evolution management system

The general architecture of the evolution management system is based on the elements of conceptualisation presented by the previous chapter. It is structured on three levels.

The first level, entitled "*Strategic orientation*", is intended to propose a path leading from the current state (as-is) to the target (could-be) over the strategic horizon. This path is made up of regular steps. The strategic orientation level is expressed in terms of performances for two reasons. Firstly, given its nature, it makes it easier to link it to the strategy of the company. Secondly, because the target and all the steps following the first one will not be reached a priori, it saves an unnecessary effort of formalisation. The result of this level is a level of performances for each step.

The second level is called "*Migration plan*". Its objective is to express the path from the current state (as-is) to the first step (to-be) over the tactical horizon (that is equal to the strategic period – **Figure 3**). Knowing that this step must be reached, a modelling action deserves to be carried out. Therefore, this level works on the basis of models. This level leads to the definition of the models of the first step and of the set of actions to be implemented to reach it.

The third level is called "*Projects portfolio*". On the basis of the migration plan defined at the level above, the objective of this level is to define the projects operationally and to ensure the management of the entire projects' portfolio (over the tactical horizon) and all projects individually (over the project duration).

Table 1 shows the overall picture.

Name of the level	Nature	Expression mode	Initial state	Final state	Horizon
Strategic orientation	Strategic	Performance	Current state (As-is)	Target (Could-be)	Strategic horizon
Migration plan	Tactical	Model	Current state (As-is)	First step (To-be)	Tactical horizon (Strategic period)
Projects portfolio	Operational	Project	Current state (As-is) / Project start	Portfolio completion / Project end	Tactical horizon / Project duration (Operational horizon)

Table 1.
Architecture and principles of the evolution management system.

4.1 The strategic orientation level

As already explained (**Table 1**), there is several time milestones organising this level. Upstream, there is the existing state, corresponding to the system as it is now (as-is). Downstream, there is the target that is the representation of the system as we would like it to be at the strategic horizon, assuming that no significant element of the environment would change between now and then (could-be). The target is therefore positioned at the furthest point in the future at which it is possible to make assumptions about the system. In between, steps are distributed at regular intervals (strategic period). In theory, the number of steps is equal to the strategic horizon divided by the strategic period. The steps correspond to the moments when the trajectory to be followed is questioned.

All these milestones express the system in terms of performances. As explained above, that means that the system is positioned in a performances space.

The three main activities implemented at this level are as follows.

1. *Target definition*. This consists in translating the "key success factors" provided by the company's strategy into a valued technical performances vector. The nature of these performances is decided by the company itself. There is a double condition about these performances: in one hand, to be valuable on the basis of key success factors and, in another hand, to be operational enough to support the definition of change about the system.

2. *Current state evaluation*. This action consists of evaluating the existing situation in the same performance vector as for the target. As we are dealing here with the existing situation, this evaluation can be carried out on the basis of observations and measures. In comparison with the target definition, the distance in terms of performances can be calculated.

3. *Trajectory definition* (steps). On the basis of the distance value calculated in the previous action, the objective of this action is to define a steps trajectory between current state and target, knowing that there must be one step for each strategic period. The steps are expressed with the same performances vector.

Figure 6 summarises these activities.

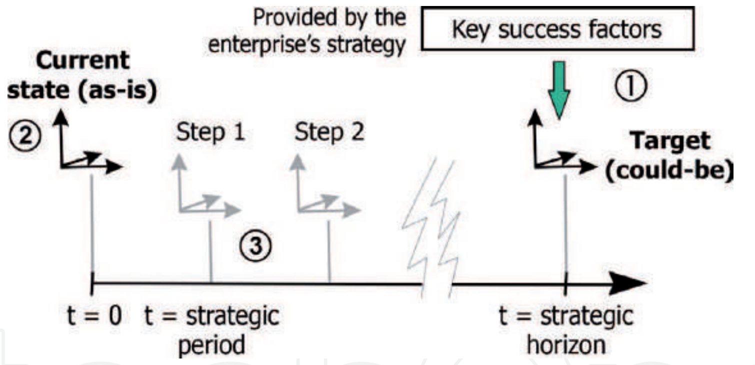

Figure 6.
The activities of the strategic orientation level.

The definition of the trajectory and, therefore, of the steps that constitute it, is not a simple task for two main reasons. Firstly, it can be difficult to translate the key success factors, often expressed in general terms, into operational objectives i.e., objectives that are valued and translatable into actions. Secondly, the performance space is not accessible in its entirety. The reason for this could be:

- the exogeneous limitation of the level of a performance (technical, legal, etc.);
- the deadly cost of making a certain level of performance accessible;
- the fact that some performances may be opposite: seeking to increase one inevitably leads to reducing the level of another;
- the fact that some performances may rely on the same type of resources (financial or other) that are inevitably limited, this leads to finding a compromise in the distribution of this resource between the two performances.

4.2 The migration plan level

The two time milestones structuring this level are the current state and the first step. These two milestones have already been explained and are present at the level above (**Figure 6**). The difference with the previous level is that here they are expressed in the form of models. This transition, from an expression in terms of performances to a representation by models, corresponds to an operationalisation process i.e., a willingness to move towards a concrete vision. This is justified at the level of the first step since this will be reached and therefore corresponds to an implemented state.

It is not the purpose of this chapter to propose one enterprise modelling approach over another. There are many business modelling methods and languages available and the choice will have to be made according to the culture of the company. It is always important to cover all the views considered important in a modelling approach: processes, data, physical system, decisions, organisation, etc. To do this, it will be possible to choose languages each corresponding to one of these views or to use multi-point of view methods that already integrate several languages (GIM or CIMOSA, for example). In any case, we consider that the approach proposed here works independently of the languages chosen.

The three main activities structuring this level are as follows.

1. *Current state modelling*. This action consists of modelling the system in its existing situation, in terms of structure and behaviour. This action concerns

the current state. Then, it is possible to use the whole set of instruments available to an analyst to build the model of an existing system: consultation of documents, analysis of computer application screens, field observations, interviews, etc. This action must be able to propose, in complement to the models themselves, an analysis of the system in terms of strengths and weaknesses.

2. *First step modelling*. This action consists in proposing a model of the system which, as a priority, allows to translate the level of performances defined for the first step by the upper level. This model must also take into account the shortcomings observed in the current state of the system (as-is model) and the possible evolution needs expressed by the company. In addition, the model will need to preserve the strengths identified in the previous action. Here we are in a totally different situation compared to the previous action. The modelling of the existing state was based on observation, the modelling of a future state is based on creativity. We are therefore here at the heart of the engineer's job, which is to propose the model of a future system, based on the expression of needs and expected performances, with all the uncertainty that it entails.

3. *Actions plan*. The evaluation of the difference between the model of the first step and the model of the current state enables the definition of a list of actions necessary to evolve i.e., to make the system moving from its current state to the first step. The aim here is not to carry out these actions but to define them, taking into account the fact that they are interdependent. Because of this interdependence (an action needs that another one must be proceeded before, for instance) and because the resources of the company are obviously limited, these actions must be sorted in terms of priority.

Figure 7 represents these activities.

We are here in the typical enterprise modelling context: an instance of the migration plan corresponds to an enterprise modelling project. Obviously, the objective here being to converge towards a continuous evolution, the migration between the existing state and the first step will thus correspond to a less ambitious evolution than what classically constitutes the perimeter of a project. Nevertheless, the principle remains the same. To illustrate this, **Figure 8** presents the general principle of conceptualisation followed by enterprise modelling [30], also known as the *"sun curve"* in information systems design (1. *modelling*: passage from the reality of the existing state to its model, 2. *analysis and design*: passage from the model of the

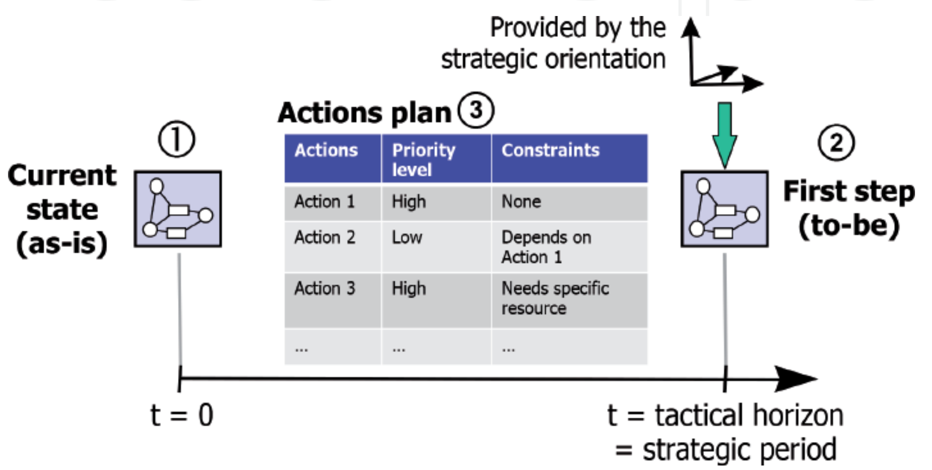

Figure 7.
The activities of the migration plan level.

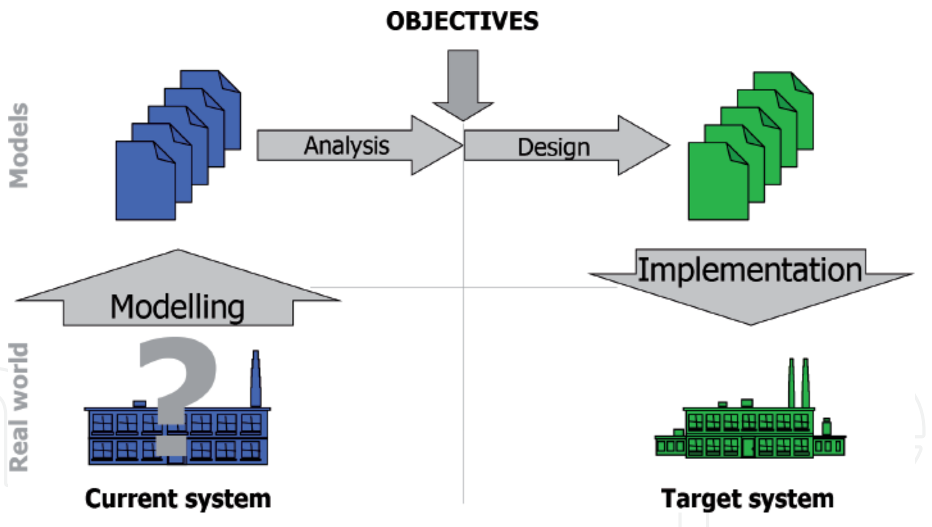

Figure 8.
The general principle of conceptualisation of enterprise modelling.

existing state to the model of the future one and, 3. *implementation*: passage from the model of the future state to the new reality). It is easy to see the analogy with what is proposed in the migration plan.

This principle also explains why the sequence followed by this level is opposite to that of the strategic orientation level. In this one, the first step concerned the formalisation of the target, with the existing state being dealt with afterwards. This sequence makes it possible to link all this level to the strategic analysis of the company. Within the framework of the migration plan level, the existing state is processed (modelled) first. This enables the model of the first step to be developed on its representation in terms of performance from the previous level (**Figure 7**) but also from the analysis carried out on the basis of the models of the existing state (first action: current state modelling).

4.3 The projects portfolio level

As for the previous level, the two time milestones structuring this level are the current state and the first step. The difference with the previous level is that here the two milestones are expressed in the form of projects. The change of modes of expression reflects the desire to move from a static vision (the models represent the states of the system) to a dynamic vision (the actions that need to be taken to move from one state to another). That is why the projects portfolio is called "To-do" **Figure 9**, in comparison with the "To-be" of the upper level.

Moving from a model to a list of projects is not an obvious task. This is why the last activity of the migration plan was to propose an action plan. Then, this action plan is the link between the models and the projects. However, the action plan was mainly aimed at analysing what the envisaged migration entails. That is why it was not very precise in terms of timing or resources mobilised. The project portfolio level must fill this gap in the sense that all the elements that make up a real project must now be defined.

The three main activities that must be carried out within this level are as follows.

1. *Current state evaluation*. The objective of this activity is to analyse the progress and results of recent projects i.e., those belonging to the previous version of the projects portfolio. This analysis has a double purpose. Firstly, it is to verify that the projects that have just been carried out have achieved their objectives. If this is not the case, corrective or compensatory actions in the form of projects

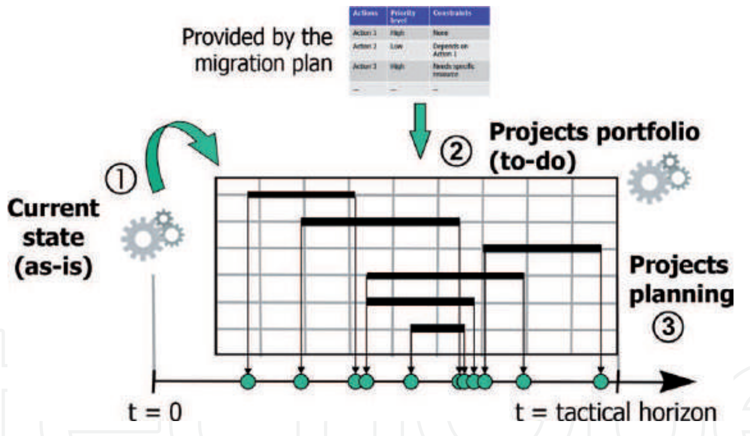

Figure 9.
The activities of the projects portfolio level.

will have to be integrated into the new projects portfolio. This assessment reflects the fact that two successive instances of the projects portfolio are not independent. It also corresponds to some extent to the Check and Act phases of the PDCA. The second reason for this evaluation is the fact that some projects may not have been carried out within the tactical horizon of the previous project portfolio, contrary to what should have been the case. This may be due either to a decision to run a project beyond this horizon, or to the fact that a project has been postponed for various reasons. In the end, this activity makes it possible to know perfectly the state of progress decided the previous time and to take this state into account for the definition of the new projects portfolio.

2. *Projects portfolio definition*. This activity is central at this level as it is the one that defines the projects portfolio. This is built on the basis of the action plan provided by the higher level. It is clear that the transition from actions to projects is not based on a bijective relationship: several actions can be grouped together to form a single project and, conversely, one action can lead to several projects. The latter case is classic and corresponds to a secondary need arising from the initial project. For example, a change in a management function (initial project) leads to the need to launch a computerisation project and a project to train the managers concerned (secondary projects). The difference between the actions plan and the projects portfolio is that this level takes into account various constraints that had not been considered at the higher level: financial resources, availability of human resources, negotiation with solution providers, etc. The second element to be taken into account is the evaluation carried out by the previous activity: definition of corrective or compensatory activities and integration into the portfolio of ongoing projects. The importance of taking this assessment into account is clear: ongoing projects consume resources that will therefore be unavailable for new projects and they may constitute precedence constraints for new projects.

3. *Projects planning*. There are therefore as many activities as there are defined projects. The tasks to be defined and planned are standard:

    - Drawing up specifications: definition of technical specifications in relation to the models provided by the Migration plan.

    - Design or acquisition: development or purchase on the market of the solutions identified during the previous phase.

- Implementation and integration of the components developed or purchased.

The main elements to be taken into account are also standard: positioning of projects over time, conditions of precedence between projects, organisation of the company's internal resources, and triggering the involvement of external resources.

The horizon of this management is variable since it corresponds to the duration of the project concerned. It falls between two time milestones corresponding to the beginning of the project and its end. All these milestones constitute a sequence of events that set the pace of the projects portfolio's evolution (**Figure 9**).

It is important to find the best compromise between independence in the management of each project and overall coordination within the projects portfolio.

Figure 9 shows these activities.

Finally, this level deals with project management with classical constraints and concepts. The important point is the existence of several concurrent and coordinated projects.

5. Argumentation

The proposed approach highlights several aspects that contribute to the competitiveness of enterprises. The main ones are listed here. On the other hand, taking the approach to its ultimate conclusion presupposes that the company develops self-assessment capacities. We will come back to this point in the second part.

5.1 Competitive aspects

Performance evaluation. The approach emphasises the notion of performance. It is a major element to be integrated into the management of modern companies because, in order to manage their evolution, companies need to evaluate their performance level (actual state) and compare it with a projected state defined in relation to the economic environment. This expected target with performance evaluation and the path to achieve is also evoked in A3 approach of Lean when targets are evoked to allow easier projection of corrective actions. Faced with competitive pressure, many companies have moved in this direction in recent decades. Nevertheless, knowing how to measure performance and how to choose the corresponding indicators is not yet a talent that all companies still possess. This is why many methods have been proposed to help companies move in this direction [31, 32].

Industrial strategy. Talking about performance also means talking about strategy, because it is strategy that allows to clearly define the performance to be monitored. Moreover, an improvement project requires a clear definition of the target to be reached through the formulation of an industrial strategy. This first requires the development of a strategic vision/target to ensure coherence and synergy between all the improvement projects carried out. This argument is not shared by all companies. Obviously, large groups build strategic plans but many SMEs do not for many reasons [33]. Whatever the arguments, the proposed approach encourages the definition of a strategy before any intention of evolution.

Models. To propose modelling is to encourage companies to acquire the means to know themselves. Models do not bring new knowledge about the company, but they allow it to be expressed, standardised and exchanged. As mentioned in [34], to model is to externalise knowledge. Self-organising means choosing one's trajectory and adapting accordingly; it presupposes being able to generate symbolic information, i.e. information about oneself [35, 36]. Models contribute to this. Also, pushing companies to model themselves means pushing them to know perfectly and permanently how they run and the behaviour of each of their components and to identify which part of the structure needs to be improved or changed. It means enabling them to be autonomous in managing their evolution.

Motivation. Employee motivation is linked to the significance of the work [37]. In terms of change management, this is expressed by the knowledge of the target (where the company is going) and the possibility of frequently see the results of projects. Then, proposing an approach organised in small projects that allow to reach a step of evolution, itself positioned in relation to a long-term target, allows everyone in the company to appreciate the path proposed and the results obtained. It is also important that employees be involved in the approach as much as possible, which is what continuous improvement and most enterprise modelling methods propose. Ali et al. [38] mentions the lack of training and planning as barriers to Lean projects implementation. These aspects have to be systematically taken into account in the projects portfolio.

5.2 Self-evaluation and learning capabilities

The current state (as-is) must be expressed at each level, in the three proposed forms: performances, models and ongoing projects. As the approach is presented, this expression is based on a fully-fledged activity at the three levels of evolution management, i.e. this state is reconstructed each time. This reconstruction can be carried out by the company itself or by relying on the services of an external company, which is often the case.

Pushing the logic to its ultimate conclusion means thinking in terms of *internalisation* and *continuity*.

Internalisation reflects the fact that the company must be able to do this on its own. Indeed, knowing how to evaluate its performance, model its own operations and monitor its projects are not these skills that every well-organised company should have within it? Just as it is normal for the company to turn to external service providers for design activities (because it may not have the necessary skills in IT, workstation organisation, etc.), it is also necessary for it to be able to express its current state.

Continuity is the principle that the company should not have to reconstruct its current state at each step of the process but should be able to know it at every moment. As regards the strategic orientation level, this means implementing a system of performance indicators (performance monitor) that is updated as often as possible and that can be adapted if strategic orientations require a change of indicators. For plan level migration, this means that the company has its own models and that there is someone responsible for updating them each time a change is noticed. By analogy with the technical data that the company necessarily possesses for its technical activities, this set is called organisational data here. Finally, for projects portfolio level, it means following and monitoring the evolution projects (ongoing projects portfolio), which in general is integrated into the company's operations and does not pose any problems. These three elements are grouped together in a set entitled "Enterprise monitoring and documentation". Finally, continuity reflects the obvious fact that in order to evolve continuously, the enterprise must be able to evaluate itself continuously.

In conclusion, the approach proposed here leads to advocate a vision of the enterprise that takes its evolution in hand and that provides itself with the means to constantly learn about and evaluate itself. In this way, the evolution management participates to the development of learning organisations [39, 40].

Figure 10 summarises this vision and shows the main activities.

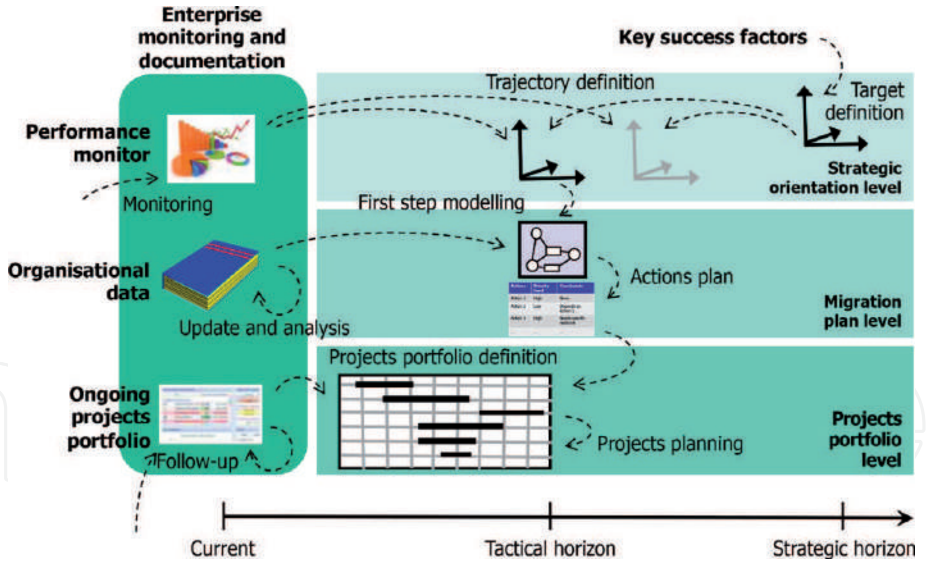

Figure 10.
The organisation of evolution in the self-evaluated, learning enterprise.

5.3 Evolution management and continuous improvement

The evolution management system entails many aspects consolidating the PDCA approach, well known and used in large groups and even SMEs to sustain quality. Even though strategy, as quoted in section 5.1 is not obviously formalised by SMEs because of their dependencies to big groups, they often use and admit efficiency of PDCA vision or DMAIC (often tightly linked to project approach and can also be assimilated to PDCA cycle). Indeed, PDCA is the fundament of continuous improvement because of the value given to the "Act" step to ensure continuous action on systems to make a progress. In the vision presented here, the actions to carry out are in step "Act" of the PDCA but are no more only corrective actions after "Check" step. They represent also new proactive ideas and prospective plans to improve the whole existing projects system regarding the "output" and "knowledge" got from ongoing projects portfolio and migration plan.

The evolution management reminds the importance for the company to continually formalise and display the targeted performances. The performance objectives are tightly linked to the defined "Strategy" that can be revealed in "Plan" step of PDCA. Updating with "performance targets" planned by company strategy is the potential inducer of "could be" situations.

Concerning migration plan, PDCA and Lean highlight that, whatever modelling approach considered, the "added value" is always the main concept to undertake to keep "efficient" model with the required added values processes, the expected relevant data, the prior decisions and the accurate organisations.

To model the current state (As-is), we should remind that the use of various instruments available to an analyst to build the model as consultation of documents, analysis of computer application screens, field observations and interviews are such many elements absolutely necessary to deal with "reliable" data. From Lean point of view, any process has to be produced respecting "Jidoka" notion which means ensuring the quality "at the source". The current state modelling is critical step that should be made as reliable as possible to avoid wasting times and retro-corrective actions. The more the system is reliably represented the better the "could be" system can be achieved in good conditions. So Jidoka, principle coming from Lean management, is an efficient support for the organisational data sustainability.

Lean practices and Continuous improvement are indubitably the result of human forces, company strategy and collective efforts. By the way, the motivation and involvement of the team project evoked previously is an important part defended by Lean and continuous improvement. Then, evolution management, if well described and explained to the team, is significantly able to strengthen the "Do" step of PDCA.

6. Conclusions

The approach presented here aims at repositioning the enterprise modelling approach in the context of continuous evolution, better able to respond to a turbulent economic environment.

Within this framework, it emerges that many tools and approaches are involved in the reengineering and improvement of companies: strategy, performance measurement, modelling, projects and the whole toolbox of Lean Management and continuous improvement. The approach presented here is an opportunity to bring these approaches closer together: strategy and performance measurement at the top level, Lean models and tools at the central level and projects at the operational level.

The ultimate goal is to take advantage of the benefits of all these approaches. For example, Lean insists on short projects, anchored in practice and part of a continuous improvement; enterprise modelling allows to document the company, to share knowledge and to propose a systemic vision.

Finally, the approach proposed here opens important perspectives concerning the integration of enterprise reengineering approaches.

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