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Alexander C. Tsigkas

The Lean Enterprise

From the Mass Economy to the Economy of One

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Foreword

The Lean Enterprise

A new book about lean organization needs something special, and the contents you are about to encounter present a new vision of this way of thinking. I am a mechanical engineer and I studied in Italy. After university, I had the opportunity to work worldwide and keep in touch with colleagues from many countries. One of these colleagues also became one of my best friends, Professor Alexander Tsigkas.

Lean production has a long history in Europe, but, in Italy, only large multinational companies have succeeded in applying it to some areas. The first opportunity I had to meet and work with Alexander Tsigkas was in 2003, while I was the Industrial Director of a large firm manufacturing electrical household appliances, based in Italy. I contacted him after the acquisition of the company by a French private equity fund; a new CEO was appointed and he set clear targets in terms of the global efficiency of the supply chain and a reduction in working capital. In the meantime, I was not confident that a consultant coming from a foreign country could help my team reach this objective. In any case, I gave Alexander all the information required for a brief evaluation of the factories and challenged him to help me reach my targets: an increase in production efficiency of 10 % and a reduction in the inventories (raw materials, working capital, finished products) by 20 % in 2 years. From his side, I received no objections, only a proper request to meet and analyse together more data and the actual situation of the plants. It is at this point that our friendship started. The first time I met Alexander, I immediately understood he was the right person to help me do this job: clear ideas on flow manufacturing, extensive experience in the execution of lean projects and, last but not least, a deep knowledge of people, which I strongly believe is the basis of every lean project.

We began the activity with a training course, creating a team of 5–10 engineers highly motivated in the new industrial approach. The company was well organized (I had been working there for 6 years), but we needed a new way of thinking and the right tools to increase value for customers and shareholders. Even though I had managed the factories for 6 years, I was and am still certain that there is always room for improvement. The application of the lean flow method to two factories yielded great results after 6 months. Professor Tsigkas was not only a teacher of lean enterprise but also a man of great experience and effective execution abilities. The book reflects this robust approach: a fixed theoretical basis, good methods of implementation and a wide strategic vision. In 2004, I remember us discussing mass customization and productivity. I felt, and Alexander shared my ideas, that many companies in the West, alarmed by low labour costs in China or other emerging areas, were forgetting customer needs. The companies that were successful in those turbulent years never failed to tailor products or services for their customers.

The lessons in lean enterprise I received from Alexander were precious instruments in my new professional challenge, which started in 2005. I completely moved from the market sector to the management and design of transport infrastructure. I was asked to apply industrial organization and managerial methods (customer focused) to a company in the service sector that had recently been sold to private shareholders. I worked in both the operational area and in the engineering activities, and for each case the results are impressive. I applied the same approach of lean enterprise to the areas of service, and, in less than a year, all the key performance indicators (Customer Satisfaction, Efficiency and Time of projects) showed double digit growth. My management approach is very simple: identification of a good team, clarity of ideas on market/customer value, design of a fast internal and external process and the removal of any barrier between the company personnel and the final consumer. Two rules are very important: few but significant performance indicators and sweeping action against waste in every area of activity.

I am sure you will enjoy reading this book, while looking forward to the future strategies of your company. Let us not forget that the secret of success to any changes in a management project is the choice of the right people in your team and a bottom-up approach to continuous improvement. This is the main lesson I received from Professor Tsigkas, for which I am really grateful to him.

Antonino Galata
Managing director SPEA
Ingegneria Europea
Autostrade per Italia

Acknowledgments

It is usual that writers acknowledge people who have contributed to the realization of a book, such as the one in your hands. Instead of acknowledgements, I wish to pay tribute to two philosophers, the influence of whom has been pervasive on my thoughts. Aristotle and Heidegger sealed indelibly my evolution, with the stimuli they generously gave me, so that I could see above and beyond pure science. Aristotle is the founder of lean thinking and not the Japanese of Toyota, as my research has proven, while Heidegger based on the great Greek philosopher led me to new ways of uncovering topos that surpass those of pure science and concern the art of management. During my professional career, another great teacher I had the opportunity and honour to work with was John Constanza, who helped me to improve in my work and whom I view as the father of contemporary Western lean thinking. After 30 years of experience working in the market, I decided to join the academic community. As a recent member of this community, I have had the opportunity and honour to teach talented young students of the engineering faculty. I devote this book to them. I also wish to thank Fred Wilbert from the Leonardo Group and Stephane Domange for providing me with material used in this book. Furthermore, I wish to thank de profundis my former customer and now one of my best friends, Antonino Galata, the CEO of the Engineering Group of Autostrade per l'Italia, for writing the foreword to this book. Last but not least, I wish to thank Paul Banham, who reviewed the manuscript and made sure that the language fulfils the high standards of Springer readers.

Contents

Part II Lean Enterprise in Theory

Abbreviations

TPS	Toyota production system
CBVE	Customer born value engineering
GDP	Gross domestic product
DFT	Demand flow technology
VSM	Value stream mapping
SME	Small and medium enterprises
VAC	Value adding community
JIT	Just in time
BPR	Business process reengineering
TPM	Total productive maintenance
GAP	Generally accepted principles
GAM	Generally accepted methodology
MRP	Materials requirements planning
WIP	Work in process
RMI	Raw materials inventory
FGI	Finished goods inventory
AR	Accounts receivable
AP	Accounts payable
WC	Working capital
CM	Cost of materials
CW	Cost of work
OH	Cost of overhead
COGS	Cost of goods sold
MCOGS	Material cost of goods sold
GOH	Cost of general overhead
LFI	Lean flow index
IP	Interaction point
ERP	Enterprise resource planning
MMSF	Mixed model synchronization flow
IPC	In process control
SOE	Sequence of events
Dc	Demand at capacity
TPct	Total product cycle time
Rwk	Rework
OPct	Operational cycle time
IPK	In process Kanban
BOM	Bill of materials
IT	Inventory turns
RIP	Raw and in process

MC	Mass customization
FIFO	First in first out
ICC	Inventory carrying cost
VDS	Value diminishing stream
VAS	Value adding stream
ROD	Replenishment on demand
3PL	Third party logistics
3PiL	Third party internal logistics
VMI	Vendor managed inventory
LLI	Long lead time items
IDSM	Integrated demand and supply management
LAI	Lean agile inventory
DTF	Demand time front
ART	Administrative response time
SKU	Stock keeping unit
CQLT	Customer quoted lead time
ECR	Engineering change request
WMIS	Work material and information stream
GAAP	Generally accepted accounting principles
OLESC	Open lean electricity supply communities
ICT	Information and communication technology
OES	Open electricity services
VPP	Virtual power plants
RES	Renewable electricity sources
NPP	Natural power plant
EPP	Engineered power plant
TSO	Transmission service operator
ISO	Independent service operator
CONWIP	Constant work in process
SC	Supply chain
SMED	Single minute exchange of die
IOC	International ordering center
PO	Purchase order
SO	Sales order

The Lean Enterprise

1

Abstract

New lean thinking and the term *open lean enterprise* are introduced in this chapter. In the case of *old* lean, value is created through one-way communication, while with *new* lean it is created through two-way communication. This distinction completely changes the value creation cycle. In contemporary manufacturing, the customer becomes part of the value creation cycle, production becomes customer-driven and the customer becomes a prosumer. Plato insists, and argues it should be enforced by law, that people should not ask about the price, but simply ask about the value of an object, underlining that value is an absolute quality incorporated into the object. Similarly, Aristotle in 'Politics' states that value is the ability to satisfy needs/wants. This is totally compatible with the new concept of *new* lean thinking: when asking about value, the customer is given the opportunity to get involved in the process and therefore become a stakeholder in the delivery cycle of the product. The focus is on creating value and eliminating waste.

1.1 The Short Answer

What is lean enterprise and why should it be studied? Briefly, a lean enterprise is a business entity in which the internal organization and operations are always in synchronization with the needs of the market and geared to creating sustainable value for all stakeholders while eliminating waste in all activities. Knowledge of how to organise such an enterprise has the following advantages:

1. Adaptation of production and administration processes driven solely by value adding, eliminating activities that do not add value
2. Self-regulated flows for work, material, information and cash

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Refinement of means and confusion of goals seem to characterize our century

Albert Einstein

A.C. Tsigkas, *The Lean Enterprise*, Springer Texts in Business and Economics,
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3. Direct decision-making at the point of value creation
4. Capacity for rapid displacement of the enterprise to cope with new market conditions

1.2 A Comprehensive Answer

The above definition of lean enterprise is consistent yet it leaves many other issues open which must be addressed. In order to provide a comprehensive and detailed description of what our subject of study is, we need to define where to focus and describe more closely the meaning and the purpose of lean enterprise in relation to the operational environment we will deal with.

1.2.1 Focus: Creating Value and Eliminating Waste

Before we answer the question of why we should be interested in lean enterprise, we must first answer why we should focus on how to add or create value. Do we have anything new to say on this issue?

Based on the principles of classical lean thinking and the Toyota Production System (TPS), adding and creating value is related to any action the customer is prepared to pay for. This way of thinking is what we call *old* lean thinking. However, this belief limits the perception of value to the level of a simple act of exchange and in this case a commercial exchange. Further analysis of the meaning of value allows us to understand the principles that govern what we call *new* lean thinking. A contemporary view of lean is that value is created at the interaction of the customer with the enterprise, a process called *value co-creation,* according to Frank Piller. Eberhard Rechtin claims that the value of systems is created at the interfaces of the components that compose the system. While in the case of *old* lean, value is created through one-way communication, in the case of *new* lean it is two-way communication. This distinction completely changes the value creation cycle. In contemporary manufacturing, the customer becomes part of the value creation cycle (value co-creation), production becomes customer-driven and the customer becomes a prosumer. Knowing that each customer is not only a single entity, but also unique, products become mass customized to cover uniqueness. Production includes goods and services.

Plato insists, enforced by law, that people should not ask about the price, but simply ask about the value of an object, underlining that value is an absolute quality incorporated into the object. Similarly, Aristotle in ‘Politics’ states that value is the ability to satisfy needs and desires. This is totally compatible with the new concept of *new* lean thinking: when asking about value, the customer is given the opportunity to get involved in the process and therefore become a stakeholder in the delivery cycle of the product.

While nowadays lean enterprise is *customer-oriented*, in the future it will be *customer-born*. For *new* lean enterprise we coin the term *open lean enterprise*. In old lean thinking, value creation is solely an internal company activity on behalf of the customer, while in *open lean organization*, the user has a direct relationship to the value creation of a product or service to be produced. Based on the contribution of the customer, the contribution of the enterprise is defined. In this case, the customer and the enterprise are not two separate entities with discrete roles and relations, but the relation customer-supplier is gradually turned into a relation of members of a value adding community without discrete roles from the point of view of space and time. In such market types, value is finalized and complemented by a network of community members and the goods created have a necessarily finalized, complemented, and mass customized value.

Mass Customization is the main characteristic of the emerging social system of production in many sectors of the economy and in social and business activities, replacing the one based on mass production and the division of labour. The new system is characterised by the concept of individual value creation at the point of production being a social activity contributing to social and economic wealth creation. In this type of production system, value is engineered dynamically though the direct involvement of the individual customer (CBVE—customer born value engineering), where the product reaches its final state and purpose with definitely less energy needs in comparison to the mass production paradigm. The mass consumer, a product of mass production, is fading away.

The old lean enterprise is the necessary forerunner of the open lean organization. The transition of a conventional production system to the new production system passes firstly through its *relocation* to the classical lean state. New enterprises wishing to go lean have the opportunity of directly implementing, without any intermediate stage, the new model of value engineering (CBVE). In this relocation, the customer-born approach is accompanied by the elimination of any waste that could influence value as a quality embodied in the product. Furthermore, becoming lean in manufacturing means becoming green as well, because the reduced work load and reduced waste lead to lower energy needs in comparison to mass production. In mass production, the needs for workload, materials, information, cash and ultimately energy are greater as a result of overproduction caused mainly by the willingness of enterprises to increase productivity. Overproduction as the main source of waste in workload, materials, information, cash and energy reduces the value returned to the customer.

The benefits of the relocation of a conventional enterprise to the lean state are numerous and multi-dimensional. Certainly, value creation is not always translated into achievable profit. Profit depends mainly on market conditions and the ability of an enterprise to differentiate itself from competitors who seek to profit from loss of market share of other entities. This is an area that goes above and beyond lean, but once open lean prepares the company for flexibility, agility and openness, marketing strategies can greatly profit.

1.2.2 Purpose: Displacement to a Lean State

The focus of this book is related to both method and path, of how to displace an enterprise from a non lean state into a lean state in production and the supply chain activities of products and services. The use of the word *displacement* and not *transformation* of a company has been preferred to state that, in reality, there is not a real change of a company into something else, but a displacement of standpoint and mindsets in the way of organizing and operating this entity. It concerns primarily a change in "place", metaphorically that is from the "place" of mass production to the "place" of lean production targeting a better positioning of the enterprise in the market. *The theory of topos* has been founded for the development of relations which in the case of an enterprise define activities. These activities focus on flows of work, materials, information and cash in the factory. The CBVE concept promotes the reviewed perception of value and sets the consumer up as an active co-creator of new and differentiated value. It is well known that production contributes to the GDP (Gross Domestic Product) of a country and is therefore a key contributor to the development and growth of macro-economies. Today, the majority of enterprises in many industrial and commercial sectors are organized, managed and measured based on the principles and rules of mass production. However, value creation is slowed down by the many types of waste inherent in the way organizations operate and account for performance. Production has a long history, passing through two industrial revolutions. Scientific Management and production as a science were contemporary with those of great revolutions and scientific changes at the beginning of the twentieth century and the wish of society at that time for change. Advances in mathematics and physics have brought everything they could under their umbrella. The development of operations research created hopes to enterprises which looked at advanced mathematics to solve the problems and challenges in managing production. However, the gradual distancing of researchers from the reality of every day practice and value creation, led operations research, in our opinion, to a highly theoretical level of research for the sake of research. At the same time, production management was deprived of practical use and support from operations research. The complete separation of the theoretical base from the practice of creating value did not help neither operations research nor businesses.

Nowadays, where concepts of production and value are reviewed, where the economy is increasingly individualized, the role of mathematics is not as exclusive as it was at the beginning of the twentieth century. In those days, most of the important algorithms and formulas were developed, laying the foundations for the development of businesses organisation. At the beginning of the 50s, classical inventory theory played a central role in production control, in times when whatever could be produced from a factory always had a customer waiting to buy it. In such practically unlimited markets, availability of inventory was an advantage and therefore the sole target of companies was the minimization of production costs through higher output in building and maintaining inventories. However, in the new economic environment where market limitation and downsizing prevail, availability of excess inventory (supply exceeds by far demand) is a big disadvantage for the organization. Investing, in the best case scenario in a slow moving inventory, essential resources from working capital necessary for operations sustainability are deducted. While market conditions have changed and sellers markets (everything production can produce is sold) have moved to buyers markets (only what can be sold is produced), enterprises loyal to the methods of managing production for maximizing inventory observed that their needs for working capital increased compared to the past. The way they chose to follow for acquiring working capital was to approach the banks, instead of looking for opportunities to eliminate the cause of the increased needs in capital. The cause was obvious and the solution even more obvious. Production must produce what will be sold according to demand and not according to forecast. Working capital was released mainly through the drastic reduction in finished goods inventories. Nowadays, there is widespread belief among many organizations that working capital comes only through loans. This belief is also carefully sustained by the banking system, the role of which should have changed to prepare itself for the new era. Lean production helps organizations to gain back their capital buried into finished goods and work-in-process inventories. Lean enterprises can achieve through zero working capital their gradual independence from the banking system. This event continues to be confirmed in numerous implementations of lean practices throughout the world.

Lean enterprise is a worldwide reality today, especially in the Western world, on both sides of the Atlantic. In Europe, lean thinking and practice has enjoyed immense recognition and it has become the means of survival for companies of any size in many countries nowadays, while for others it is becoming the vehicle for sustainability in value creation. The results achieved and delivered are undoubtedly remarkable. It is, however, important for companies that engage themselves on this journey to prove to themselves that they can achieve results as well. Above and beyond the use of tools and methods for redesigning production lines and supply chains, a great deal of lean implementation is effected through changing ways of thinking, operating, measuring and accounting for performance. This applies to all stakeholders inside and outside the company; owners, management, employees, workers, suppliers and even customers. Lean is the business model for lean markets characterized by reduced consumption and therefore reduced energy requirements. This is a different growth model than simply a capitalist model based on lean thinking.

In this book the following value chain activities are addressed: production operations and internal logistics, procurement and relations to suppliers, demand and supply based planning and the important issue of cost accounting and value creation in a lean environment.

1.2.3 Method: Lean Flow

The method which is presented and used in this book for the successful *displacement* of a conventional enterprise into a lean enterprise is called *lean flow*. It constitutes the extension and improvement of a method which was developed by John Constanza around 1980 in the USA with the name DFT (Demand Flow® Technology), the purpose being to create a complete business strategy (Costanza 1996). I had the great fortune and honour to work as a trainer and director of technology in his company in many countries in Europe and also in the USA. Colleagues from that time based their professional future partly on this method (Hobbs 2004). In 1990 Womack, Jones and Roos of MIT wrote a book entitled "The Machine That Changed the World", in which they present and explain the way in which Toyota and other enterprises in Japan were more productive, efficient, with much lower cost, higher quality and shorter delivery time than the corresponding factories in auto-mobile production in the USA (Womack et al. 1990). This method they called *Lean Production* as opposed to *Mass Production*. From the system of production management at Toyota known as Toyota Production System, a set of tools was created so that this new concept could be implemented in the USA, from where TPS found its way to Europe (Ohno 1988). Today it is a choice that has been implemented with recognized success in many industrial and non-industrial sectors. Although the Japanese never used the term lean production, many tools from their system began to be used in implementations in the West. Many kept the same name as in the language of origin. Terms such as Kanban, Kaizen, 5S, Visual Management, Gemba, are some of the most known tools used in implementations of lean production. Furthermore, new tools were developed, for example VSM (Value Stream Mapping) which helped to improve the way of implementing lean practices. In the meantime, lean production became a subject of study and research at many Universities both in the USA and Europe and there are already an increasing number of scientific and non-scientific publications on the issue. Over the last few years there has been a tendency towards an increased level of '*mathematicisation*' of lean production, in order to justify placing articles in scientific journals. Scientists researching the production sector have started developing complex mathematical approaches for modelling activities that should really be left lean and simple. The term *lean production* has survived all other potential alternative terms such as Demand Flow Technology or Flow Manufacturing while other terms such as agile or flexible manufacturing were incorporated into the term lean production, and are widely known today.

Studying the literature and various implementations of lean production based on the principles that Womack and his colleagues have developed in the Lean Enterprise Institute, the use of any implementation methodology is not obvious. It seems as if the way of implementing lean depends on the choices and the experience of the consultants who undertake to carry out the project. The method of lean flow presented in this treatise incorporates VSM in the method of Constanza in order to cover the complete supply chain. The same method is suitable and has been implemented in various manufacturing production environments such as: high quantity—low mix or low quantity—high mix products, advanced and high tech, customized and engineer to order products. Furthermore, the method has been successfully implemented in office environments as well as in health care organizations such as hospitals, medical centres and pharmacies. Recently, lean thinking entered the sector of electricity production and distribution, replacing the current paradigm of mass production, which we believe will lead to a truly liberalized electricity supply and not as it is propagated by the European Union, which is the replacement of state monopolies with private monopolies (Tsigkas 2011).

The essential contribution of Constanza was to adapt the production management methods he learned in Japan to fit Western industrial culture. He developed a method which is generally valid for almost all production types; it can be individuated for each particular implementation and is totally customer-centric. Adaptation was needed since the Japanese have quite different work environments and working conditions, as well as life beliefs, compared to the Western world. The basic difference lies, in our opinion, in the fact that in the West it is mainly engineers who are responsible for the creation and adding value, while in Japan it is the employees working on the production lines. This belief is consistent with Aristotle, who, as is known, influenced Western thinking and civilization. Aristotle in Politics, views workers as a species that has value but cannot give value (Younkins 2005).

It is an interesting fact that the philosophy of continuous improvement which constitutes the basis of Japanese lean practice, was introduced by the American statistics specialist Edward Deming in 1951, who went to Japan as a member of a group of American officials providing aid for the reconstruction of the devastated Japanese industry after the second World War. Deming introduced the philosophy of a practice known as Kaizen, which means *improvement* or *change for the better* part of the life philosophy of the Japanese people. The aim of this philosophy is work standardization and its continuous modification in order to improve productivity mainly by means of experiments and the use of statistical methods. Deming made a wise move in combining the Japanese philosophy of Kaizen with the use of scientific methods in conducting experiments. The success of such practices is based on learning how to trace and eliminate waste from all activities, not only in the area of production, but throughout the company. Productivity improvement is the responsibility of the workers who make production happen. This practice targets a more humane approach towards the workers, something which is not a priority in the West.

Transposing the practice of continuous improvement Kaizen in the West in parallel with the arrival of lean production which started to happen on a large scale around 2000, did not happen under the same circumstances and conditions comparable to those which were valid in Japan in 1950. In Europe, and to a lesser extent in the USA, management was not prepared to assign the responsibility for continuous improvement to the workers directly involved in the production process. The results of this policy were quickly seen. Many continuous improvement programs are still sustained through excessive effort without achieving the desired autonomation level in the improvement process.

Although the philosophy of lean production is not very compatible with Western ways of thinking and acting in managing companies, the number of enterprises which have chosen to implement lean techniques in production and the supply chain is increasing sharply, especially in recent years. Many of these companies implemented lean practices partly and piecewise, mainly for the short term improvement in productivity and efficiency of the employees (Tsigkas and Freund 2008). What they really did, was to use new methods in an old economy structure. However, the company, now and in the future, will apply lean methods to a new and robust economic era, the era of mass customization, where productivity and efficiency need reorientation in the case of the *open lean enterprise*.

The Japanese philosophy of continuous improvement finds its counterpart in the West in Aristotelian thinking defined in Topica[3]. According to the philosopher, the means of production are valuable because the final products are useful to people and the more useful and desired a good, the higher the value of the means of production. Therefore in the *open lean enterprise*, the process of continuous improvement is based on sustainable interaction with the prosumer through a continuously upgraded process. The purpose is the steady increase in the value of two-way communication. The value of the means of production and not the cost of production is the significant parameter. Productivity and efficiency are replaced by the usefulness of the services offered to the prosumer. This axiom sets the basis for *extroversion* in enterprises and introduces an extroverted way in managing companies as well as a new economic model of value coined here as *value socionomics*, taking at the same time distance from the *introversion* (the opposite of extroversion) that imposes and sustains the importance of conventional cost of production.

Displacement of a conventional enterprise to a lean topos begins in production. The reason is simple: production is the closest point to the customer. The method is applied initially to production through the development of activities that add value and the simultaneous reduction in waste until its elimination. The result is the achievement of synchronized mixed model flow lines as well as mixed model flow cells for machine environments leading to a new factory layout based on the implementation of lean flow. Once lean flow is put in operation in production, implementation of the method continues in the support departments of production, mainly in marketing and in purchasing. The aim is to put all the supply chain under lean flow. The department of product development follows in order to support the mixed model in production. In a lean flow environment, the enterprise must change the method in accounting for the cost of production. The main reason that leads to this change is the different way of thinking and practice in the factory. For example, abandoning production in lots or batches and moving to one-piece-flow, the conventional method of cost accounting is found to be misplaced. It is like wearing glasses for myopia while having presbyopia. We will not see the benefits resulting from the operation of lean production. Correspondingly, management will not be able to make the right decisions in using the new way of thinking and practice in the factory and the market. The main characteristics of *lean flow* are the following:

- Mixed model product synchronization
- Value adding work steps
- Rhythm of production based on demand
- Mixed model flow line design
- Balancing of flow lines against bottlenecks
- One piece flow eliminating batches
- Self-regulation material flow

1.2.4 Frame: Flow in Internal Logistics

Today customers desire everything: variety, low price, high quality service and speed. The greatest challenge facing modern production is in the way that the factory environment must be structured to achieve speed and agility of internal logistics for producing any combination on a daily basis as the customer demands.

In this book, we consider production environments for manufacturing and end-use of discrete parts mainly because these environments are the most frequently met in industry. Furthermore, this frame will enable us to study concepts of demand balancing and smoothing also in machine environments. Moreover, the frame of mixed model flow lines and material replenishment serves as a base for building a set of solutions to problems which can be implemented in different flow typologies.

1.3 Overview of the Book

The rest of the book is divided into three parts.

Part I. *The rising economy of one* explores what is changing in the social system of production, refers to the inferior role of central planning, the creation of value and reviews the development of the real and virtual economy.

Part II. The *Lean Enterprise in theory* refers to the principles of lean production, the transfer of lean philosophy from East to West and discusses its adaptation to Western ways of thinking and practice. It includes the theory and method to be applied to the integrated demand and supply chain and analyses in detail how it is implemented. Criteria for a successful transition to the lean state are presented.

Part III. The *Lean Enterprise in practice* provides a number of examples and applications. Based on the method developed in Part II, its application is presented step by step to different types of production companies. Each step is explained, making use of real case studies all derived from our personal experience and solutions are proposed for different scenarios. The goal here is not to provide exact recipes for the solution of problems, but rather to help the reader and scholar understand how the method of lean flow described in Part II can be applied to specific real and actual problems.

This tripartite approach parallels the three categories of the body of knowledge required by managers and engineers who will be involved in the development and management of lean enterprises: basic principles of the new social system of production, the method of lean flow and its use in practice. Part I focuses on the principles of the new way to create value and the emergence of the economy of «*one*». Part II focuses on the body of knowledge of a proven method for the design and construction of a transition path to a lean business situation. Part III is devoted to the road construction which leads to lean enterprise, developing a framework for how to create lean activities with emphasis on production and the internal supply chain. With this body of knowledge, a manager in the manufacturing business can understand how a production company can be shifted to and be managed in a lean state for sustainable innovation. Let us start the journey to discover the Lean Enterprise.

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Part I

Rising of the Economy of One

The Displacement of the Economy 2

Abstract

The economic system governing mass production and mass consumption has reached its sunset. The era of meta-capitalism characterized by the economy of *one* instead of a *mass* economy, has appeared as its successor. Wealth creation in meta-capitalism is due to value created by the interaction of individuals with other members of society. In meta-capitalist society, people undertake responsibility for their autonomation – a process coined by the term *socionomation*. Economics in meta-capitalism is not compatible with those driving mass production and so a new one should be developed, coined by the term *socionomics* reflecting the new reality. In the new era, growth is displaced to a new *topos,* where the cost of production is not the differentiating factor and profit must be redefined. This is the way to sustainable growth in a displaced economy.

2.1 A New Social System of Production

The economic system governing mass production and mass consumption has entered the phase of advanced ageing and has reached its sunset. The era of meta-capitalism, an era characterized by the economy of *one* instead of *mass* economy, appears as its successor. Wealth creation in meta-capitalism is not due to surplus created by labour, a characteristic of the era of aged capitalism, but due to limitless value created from the interaction of individuals within society. In meta-capitalist society, individuals undertake responsibility for their autonomation outside capitalist exploitation, a process coined by the term *socionomation*. *In this society* wealth is based on individualized value, the value of one and not of the mass. Economics in meta-capitalism is not compatible with that driving mass production and so a new one should be developed, coined here by the term socionomics reflecting the new reality. In the new era, growth is displaced to a new topos, where the cost of

from economics to socioeconomics and from capitalism to meta-capitalism

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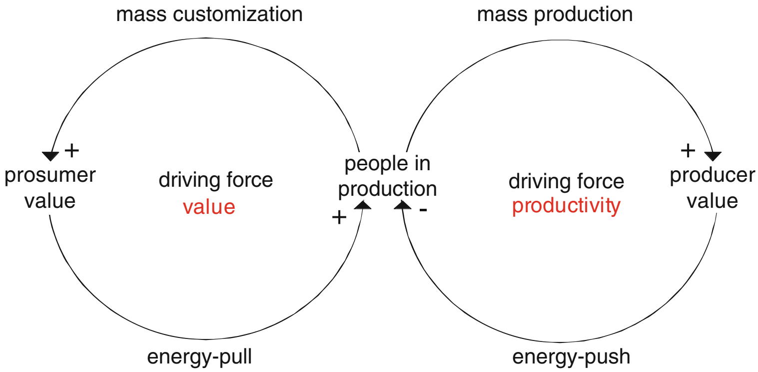

Fig. 2.1 Mass customization versus mass production

production is no longer the important differentiating factor and profit must be redefined. As a matter of fact, profit is a matter of definition and cost has no absolute meaning (Rechtin 2000). Socionomics needs to follow different paths than mass economics, leading to sources of knowledge, where profit is oriented towards co-creativity and co-producing value, and cost is displaced to measuring value degeneration, under the axiom that nothing has value if value is not assigned. Therefore, labour cost has neither *topos* in this social system of production nor is related to increasing competitiveness. It is really worth wondering why economists insist on theories from the era of Marx, the conditions of which are not valid today.

The meta-mass era, the era of *prosumer* becomes the leading standard for the new society of citizens, uniting society with technology, closing the gap between the two parts (Kondylis 1991). This happens because mass customization allows more and more people to use technology to obtain a higher standard of living through co-creativity.

The meta-mass social system of production evolves on the basis of two opposite running feedback loops shown in Fig. 2.1 (Tsigkas 2006). One loop with negative feedback, which due to productivity increase leads to less and less people in production (loop of mass production). A second loop with positive feedback, which due to value increase leads to more and more people in production (loop of mass customization). This loop uses forces (in the sense of potential) for value creation through the prosumer feeding back a new cycle of energy (in the sense of realization of the potential). The two loops, the one of mass production and that of mass customization operate in opposite directions, representing the old and the past world against the new and the future world respectively. They refer to two different world visions in terms of economy and technology. The mass production paradigm does not stop at the narrow meaning of production system, but extends to economic thinking, generally imposing accumulation of capital and separation from immediate gratification (Kondylis 1991). In contrast, the mass customization paradigm is

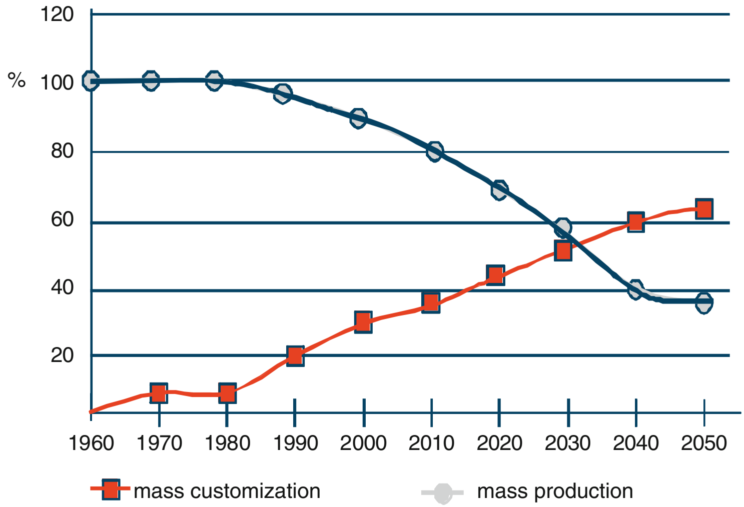

Fig. 2.2 Market shares of the two economies in the USA (Schuler and Buehlmann)

by definition against accumulation because it addresses the unique, the individual and it does not exist in reality without the active contribution of the autonomated person to value stream creation, an event that supports unification with immediate gratification. If Kondylis were alive today he would surely confirm this.

The two loops operate as follows. The more the loop of mass customization increases, the more the loop of mass production decreases until its complete elimination. Systems dynamics logic can be implemented in order to emulate the system response in the time axis in terms of socionomics and technology aspects with the systematic study of the phenomenon for facilitating evolution of the new way of wealth creation.

It is true that the co-existence of the two paradigms will last for some time in the future and maybe it will not be eliminated completely. An example of the future trend is illustrated in Fig. 2.2, based on research conducted in the USA, concerning market trends for all products sold in this country. The results of the research forecasts that around the year 2030, the number of individualized, non standardized products, will be equal to the number of products that are mass produced with an increased trend in favour of the individualized products.

Mass production and mass customization represent the day before and the day after of economic and social life respectively. Today it constitutes a field of controversy and conflict, not one of the classes, but a struggle for newly emerging environmental, social, economic and political values. Walking towards an *open lean enterprise* the path crosses the lean *topos* before arriving at mass customization and open innovation for continuous and durable value creation. This is the definition of sustainable growth.

2.2 Organization in the Post-Mass Production Era

In distributed and individualized markets where everybody cooperates with each other, the future is based on small sized, agile enterprises and factories serving local autonomated societies. In this production system, there is no central management or central control because operations are based on the interaction of entities involved in prosumer value creation, through value added communities in many cases (Tsigkas 2005). In mass production, central control exists with the purpose of full equipment load, aiming at reducing production costs. In this case the mathematical algorithmic logic undertakes the grouping and consequently the logistics of dividing standardized work in chunks or lots so that these can be loaded on individual resources, machines and people for the execution of orders. Lots are anonymous in the sense that there is usually no immediate link to customer order. Quite often a customer order is served by a number of different lots. This method of allocating and executing work fits the environment of mass production, far from the logic of customer centricity.

Many enterprises baptise the way they operate as *customer-centric*, when Marketing operates in this way. It is quite probable that Marketing approaches the customer individually, but this customer-centric strategy is not transferred to the way production and supply operates, an event leading with absolute certainty to production cost increase. While Marketing *thinks* in customers, production *thinks* in production *lots*, an event that often leads management to the false conclusion, that customer centricity increases the cost of production. The problem though does not relate to the customer-centric strategy, but to the fact that enterprises take partial decisions for parts of the company without the necessary harmonization with other parts of the company. A displacement in marketing strategy must be accompanied by the necessary displacements in all departments involved in the supply network for implementing the strategy, especially concerning production and purchasing. Otherwise it is certain that operating costs will increase with limited success, a fact that often leads management to abandon the strategy concerned.

Customer centricity is the inherent characteristic of the lean enterprise, which in today's market condition is not enough. With stable supply processes and production operations, as well as with relatively stable and predictable demand, enterprises can implement programs for the displacement to a lean environment. In almost all cases there are reports confirming that remarkable results have been achieved, with increased efficiency, drastic reductions in customer response times and finished products inventories. Local suppliers were sooner or later able to get aligned with *Just In Time* strategies demanded by their customers. However, in a globalized environment, as variation in demand and uncertainty in supply chains increase, markets instead of showing tendencies of mass-made become increasingly mass individualized, against the forecast of many leading economists. Pressures of open innovative markets of *one* on enterprises change scope and infrastructure in information technology systems are not suitable any more to cope with the new individualized needs and challenges. In order for an enterprise to continue to remain lean in this environment, it must prepare itself for moving beyond the limits of the classical lean principles defined by the Toyota Production System (TPS). Lean principles, when implemented and formalized through TPS, are no longer sustainable in such an unstable and uncertain environment. To achieve sustainability of lean operations under unstable conditions, companies should acquire the capacity to displace themselves into a new topos when needed as quickly as possible and with only a few and weak oscillations. The quicker this is achieved, the quicker the enterprise will improve its capacity for self sustainability. However, the question remains with respect to how an enterprise can sustain itself in such a dynamic environment, in other words, can become self sustainable (Zeleny 1997). Self sustainability is the main characteristic of the new lean enterprise. Lean self sustainable entities should be able to reproduce themselves and the knowledge required in a moving environment chasing moving targets. Furthermore, new lean enterprises should be capable of continuous learning and producing new knowledge, not only internally (Senge 2006), but also externally through immediate interaction with the market stakeholders as well as innovation sources. *Living Labs* (Chatzimichailidou et al. 2011) *will* operate as an open knowledge topos facilitating and accelerating the development of innovations through incorporating the customer-supplier into the value creation cycle (Reichwald and Piller 2006) extending this knowledge to the whole supply chain. The interaction may take many forms, depending on the relations defined between the enterprise and the customer-supplier. As far as supply of the new lean enterprise is concerned, this deviates from the classic model of constant co-operations that prevailed in recent years, as a basic principle of lean philosophy. The new lean model will move towards more volatile and unlimited relationships. It is totally reasonable that supply networks will be created for the satisfaction of concrete customer needs or a number of customers often only once. These types of supply networks are likely to be organized through value added communities.

In the following there is a description of the five basic principles on which the new lean enterprise should be based for achieving self sustainability:

- Open innovation and customer created value
- Displacement to a new topos
- Tolerance for mistakes
- Dynamic equilibrium
- Emerging characteristics

2.2.1 Open Innovation and Customer Created Value

The signifying difference between the new and the old lean enterprise is the nature of value. Old lean thinking and practice concentrate on activities that add value, instead of activities that create value. In the old lean environment, value is faced in a negative way, as a production *disadvantage (operational cost) instead of in a positive way as an advantage of marketing (market share)*. In the old lean enterprise, the customer-user is not part of the value creation cycle. In the era of open innovation and mass customization, the customer-user is part of an open structure of an expanded value stream and the energy is fulfilled either during the development phase or during the production phase, when the customer completes or issues instructions to the *host* company (mass customization). The incorporation of customer created value and of open innovation is the prerequisite for the absolute satisfaction of the customer-user. In a society where scarcity of goods has long been surpassed, differentiation can originate through customer involvement in the value creation circuit. The new lean extended enterprise is involved in two types of production: *eteropoiesis*, the production of other things, that is goods and services and *autopoiesis*, where it reproduces itself that is the ability to produce itself. Self sustainability critically depends on the reliability of the second type of production, that of autopoioesis. Only an enterprise which can continuously produce itself and in this way displace itself quickly to a new topos, can be regarded as self sustainable. Consequently, a new set of capabilities is required for the new lean enterprise to become self sustainable, an issue studied in a future volume.

2.2.2 Displacement to a New Topos

It is important to see the enterprise as a living system and not as a mechanical construct on the basis of Taylor principles (Taylor 1911). Taylor claims that human systems evolve via gradual changes, which introduce increased competitiveness in their environment. Unlike machines, human systems cannot be centrally programmed and do not submit to automation. Viable enterprises are by definition evolution capable organisms. According to Bergson, who was a supporter of creative evolution: *being means change, change means mature and mature means I create endlessly myself* (Bergson 1998). Rephrasing Bergson and according to Zeleny, an organism may exist only if it shows self confidence, which is the precondition for its viability (Zeleny 1997). The old lean philosophy, at least as implemented in the West, uses the enterprise as a machine, exactly as both Fordism and Taylorism look at it through the division of labour. Consequently, the lean enterprise must have the will to abandon control and begin encouraging variability and experimentation, essential elements for moving to a new topos. The old lean philosophy does not promote variability and experimentation is limited to the standardisation of products and processes. Initiatives undertaken in lean production target almost zero variability in process execution. Encouraging variability and experimentation means necessarily granting greater support for autonomation to management and individuals. If an individual or a group behaves in a way which improves the position of an organism as a whole, then this individual or group should be rewarded both monetarily and through development of career opportunities inside the company.

2.2.3 Tolerance to Mistakes

An organism improving itself must have high tolerance for mistakes. This can be achieved through duplicate groups in those operations that create value. The aim is to allow new ideas to prevail and, at the same time, protect customers from the influence of ideas which have not been tested with success. This approach is quite different from the approach of *zero-defects* for managing operations as the philosophy of the classical lean production or Six Sigma requires. An enterprise with zero tolerance at the operational level runs into the danger of discovering that there is no capacity for development. If an organism can function so that it tolerates deviations from fixed operational policies in the search for improvements, but it retains the ability to stop quickly before the change may create damage, then this is the right mixture for quick self displacement.

2.2.4 Dynamic Equilibrium

The ability to sustain a dynamic equilibrium is essential for an organization which pursues displacement. This means that an equilibrium must be achieved through movement rather than using the existing topos as a source of stability. In an operational environment requiring continuous movement, enterprises must learn to sustain their equilibrium while moving at increasing speed.

2.2.5 Emerging Characteristics

If a set of collaborative tools leads to a new level of solving problems which could not have been achieved through conventional meetings, this is an emerging characteristic, which must be recognized and used for the good of the enterprise (Taylor 1998). Anticipating, searching and extending new non-expected behaviour is the most important step towards displacement. It is also the step which is about to push the enterprise into the third level of viability – namely quick creativity for step differentiation.

2.3 Review of Lean Thinking

From the above mentioned, it is concluded that old lean philosophy must be reviewed in the post-mass production era, the era of meta-capitalism and a globalized economy. In the following lines, there is a categorization of production strategies according to the way an enterprise operates. As an independent variable the way the enterprise *thinks* is introduced, that is how its topos in the market is conceived, how it is reproducing itself. The way it acts must be aligned to the way of thinking (Fig. 2.3).

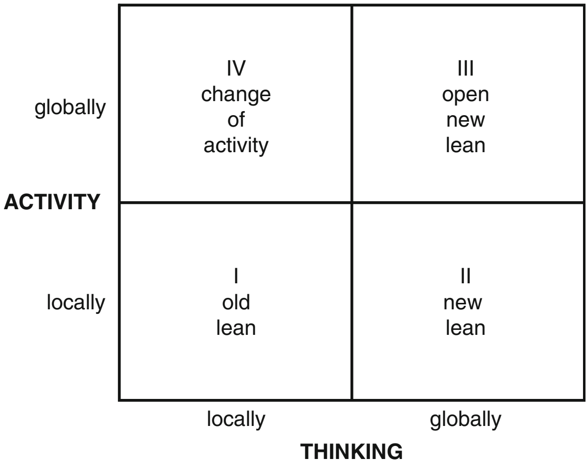

Fig. 2.3 Operations strategies of a lean enterprise

According to the above categorization, four possible types of enterprises are identified:

1. *Enterprises thinking locally and acting locally*. This category of enterprises can implement the old lean approach and attain impressive results. Most successful cases have been reported from this type of enterprise. However, the benefits very quickly reach their limits so that it is only a matter of time when these enterprises must reconsider and relocate to a new topos-category. The next logical and natural step to take is to start thinking on a world scale, although they will continue acting locally. It is exactly the point where the company must reposition from an old lean topos to a new lean topos through an internal and external learning process. A new lean approach gradually incorporating open innovation and mass customization is the way, as described above, for attaining sustainability benefits already achieved. Typical representatives of this category are small and medium enterprises (SME) wishing to expand their opportunities in the market.
2. *Enterprises thinking globally and acting locally*. For enterprises which have already started their displacement to implementing classical methods of lean production, this journey is certainly a learning experience. Nevertheless, it is also an opportunity to move quickly towards a new lean topos without waiting to evaluate the results of this movement. Learning to become more open, these enterprises will decrease the time interval for amortizing the investment and will accelerate the displacement of the enterprise towards an environment with new enterprise requirements. Typical representatives of this category are producers of consumer goods. Aiming to fully incorporate open innovation and mass customization into their operations is exactly what drives enterprises to attain sustainability.
3. *Enterprises thinking globally and acting globally*. The old lean thinking at this level loses its meaning. The supply chain is created on a concrete base with the

target of fulfilling single and singular needs. Value adding communities organized in a flexible way is a possible solution to the problem (Tsigkas et al. 2006). The creation speed of such networks seems to be the way through many enterprises will be able to fulfil concrete and individual demand. It is believed that good opportunities for SME in Europe exist for operating in the global market creating, in each case, networks in the form of value adding communities for individualized activities.

4. *Enterprises which think locally and act globally*. The enterprises of this category must redefine their strategies, because it is not clear if a strategy will have success and the company must relocate to a different category. From this point of view, the relative topos must be abandoned as soon as possible, if it has not already happened. New strategies and the respective paths must be defined and executed on the basis of the above mentioned.

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The Post-Mass Production Factory 3

Abstract

In the post-mass production enterprise the separation between mental and manual labour is evaporating. Instead of bourgeois ideology, autonomating activity of new knowledge creation will prevail as a new form of a new means of production. The meta-capitalist mode of production will be based on the principle of *unite and learn instead of divide and rule a characteristic of a mass production economy*. The meta-capitalist enterprise will consist of communities of citizens cooperating to produce goods and services of personal value. In this way knowledge becomes the catalyst in value creation. Such a community is called a value adding community.

3.1 Introduction

There seems to be an inherent contradiction when discussing factories in the post-industrial era. Although it is more than 200 years since the first industrial revolution, it seems that not a lot has changed since then in the factories of today. In those places where time has so much value, factories look timeless. But does the term *mass customization* not also include an inherent contradiction? Is it really a contradiction or a mirror of a changing society? If so, can traditional factories respond to the challenges that *mass customization* is imposing? These questions need to be approached in a different context. *Mass customization* is not simply the opposite of mass production, and it is definitely not only production. It is an evolution and at the same time, a revolution against mass production. It is argued that *mass customization* is a paradigm shift characterized by the displacement of industrial mass society to a more pluralist society in the post-industrial era. In order to support this argument, the problem is examined in the context of three different aspects: sociological-historical, technological-industrial and architectural aspects

. . .from operations research back to operations management

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(Tsigkas 2006). Although all three aspects are extremely important and influence each other, the discussion here focuses on the technical-industrial side. Before moving on to support the argument, a brief historical discourse on the events related to the academic research and the industrial praxis in the enterprises is presented.

The authors of Factory Physics (Hopp and Spearman 2001),[1] refer to the gap created between operations research and industrial practices: *In engineering schools, operations management became operations research and focused almost exclusively on methodologies, such as linear programming and probability modelling. Even in courses aimed at production topics, methodologies often came first. Many scheduling classes, reflecting the scheduling literature, virtually became mathematics classes as they concentrated more on the complexity of the algorithms than on the issues involved in real scheduling situations. The contents of many 'operations' texts emphasized operations research methodology over production applications. In business schools, students were less patient and less interested in mathematics for its own sake. Therefore, as operations management courses became collections of quantitative methods applied to a host of loosely related problems (*e.g.*, inventory control, scheduling, quality assurance, maintenance), they grew increasingly unpopular. In the 1970s and 1980s, some schools dropped Operations Management from the curriculum! Others watered down the courses until the courses were mere compilations of anecdotal case studies. The effect was that neither the engineering nor the business students were given much preparation for dealing with real-life operations problems. At best, this simply meant they were on their own to invent* ad hoc *solutions to problems as best they could. At worst, it meant they applied the mathematical methods they learned in school to situations for which the methods were ill adapted. (Our impression is that most industry practitioners have intelligently opted for the former and have largely ignored their academic training in production).*

These are the words of two specialists on the issue and we can also point to Ph.D. theses where concrete theories of operations research look to solve problems in production which in reality do not exist. There is a need for restructuring and refocusing syllabuses, not only in the technical universities, but also in schools of economics in order to face the challenges and needs of the post-mass production era. Furthermore, the direction of operations research and operations management should be converging. However, this objective cannot be achieved if operations research remains scientifically closed, practically isolated, and devoted to static beliefs and restraints that fit the 1970s or in the best case the 1980s. Management should acquire its own voice mainly through the involvement of real economy stakeholders in the university educational process, away from the mass economy, because in this case a reproduction of a non-desirable situation will occur. In the era of lean production and mass customization, management must be displaced to a new topos.

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3.2 New Way of Production

In some countries the displacement to the post-mass production era will be easier than in the rest of Europe. The establishment of a friendly climate towards enterprises will help, but will not solve the problem of growth, because growth comes only through the ability of the enterprises to produce value. However, how can this be achieved in the medium to long term? It is clear that the post-mass production era will be based on new beliefs about the role of the work force in the workplace. The work force is personalized on an individual basis. In the post-mass production factory the division between mental and manual labour is abandoned. The means of production will remain in the ownership and possession of constructing companies offering their use as a form of service to collaborative entities or communities for the production of goods and services. In this situation what is the role of the owner of capital? The capitalist mode of production is based on the principle of *divide and rule* achieved through the division of labour and capital accumulation, since this is the best way for its reproduction and expansion. While it is known what this means in politics, how is this principle implemented in production? The following example addresses the factory. The factory is organized and operates as a society in miniature, in which there are individuals that interact under a concrete organizational type and follow concrete labour processes. Nikos Poulantzas writes in relation to the mass production factory (Poulantzas 1975).

> Under[2] capitalist relations of production (ownership and possession both falling to capital), the organization of the labour process as a whole is bent to the requirements of capital. The separation and dispossession of the workers from their means of production, the characteristic of capitalist exploitation, means that there is no division or coordination of tasks that simply corresponds to purely 'technical' requirements of 'production', and exists as such. The work of management and supervision under capitalism is no more a technical task, than the division of labour within the working class, in particular the minute breakdown of tasks, is the effect of 'machinery' or 'large-scale industry' as such, but rather the effect of their capitalist form of existence. This domination of the social division of labour over the technical division is the basis of the specific organization of capitalist labour which Marx refers to as the despotism of the factory. If, then, the control of the capitalist is in substance two-fold by reason of the twofold nature of the process of production itself, – which, on the one hand, is a social process for producing use-values, on the other, a process for creating surplus-value – in form that control is despotic. As co-operation extends its scale, this despotism takes forms peculiar to itself. In a word, the despotism of the factory is precisely the form taken by the domination of the technical division of labour by the social, such as this exists under capitalism. The work of management and supervision, under capitalism, is the direct reproduction, within the process of production itself, of the political relations between the capitalist class and the working class. *Furthermore Poulantzas addresses the division between manual and mental labour*.
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> The[3] capitalist division of mental and manual labour is thus directly bound up with the specific nature of these relations, in particular with the separation and dispossession of the direct producer from his means of production, such as this is reproduced through the real

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subsumption of labour by capital: What is lost by the detail labourers, is concentrated in the capital that employs them. It is a result of the division of labour in manufactures, that the labourer is brought face to face with the intellectual potencies of the material process of production, as the property of another, and as a ruling power. This separation … is completed in modern industry, which makes science a productive force distinct from labour and presses it into the service of capital. Moreover, Poulantzas adds.

In[4] these passages Marx makes a connection between mental work and science, both of these being 'separate' from the direct producer and opposed to him. Let us simply say that this 'science' which we are dealing with, science appropriated by capital, never exists in a pure or neutral form, but always in the form of its appropriation by the dominant class, i.e. in the form of a knowledge that is closely interwoven with the dominant ideology. This is even the case with what is called 'basic research'. It is science as such that is subjected to the social, political and ideological conditions of its constitution, and not only its 'technological applications'. This is all the more so in that there is no essential separation, or at least there has not been since the industrial revolution (machinery and large-scale industry), between science and technique. Technological applications of science are in the direct service of capitalist production, in so far as they serve the development of capitalist productive forces, since the productive forces only exist dominated by the relations of production. These applications are thus interwoven with ideological practices corresponding to the dominant ideology. The dominant ideology itself, of course, does not just exist in 'ideas', i.e. articulated ideological ensembles, but is embodied and realized in a whole series of material practices, rituals, know-how, etc., which also exist within the production process. The technological applications of science are here directly present as a materialization of the dominant ideology. We can draw an initial conclusion here regarding the position of the engineers and technicians. Their work of technological application of science takes place under the sign of the dominant ideology, which they materialize even in their 'scientific' work; they are thus supports of the reproduction of ideological relations actually within the process of material production. Their role in this reproduction, by way of the technological application of science, takes the particular form under capitalism of a division between mental and manual labour, which expresses the ideological conditions of the capitalist production process. There is in fact no intrinsic 'technical' reason deriving from 'production' why these applications should assume the form of a division between mental and manual labour, and it is pertinent here that science itself is in the last analysis the result of the accumulated experience of the direct producers themselves. Of course, scientific work is not this alone; it also involves a specific work of systematization ('general labour' in Marx's formulation) and scientific experiment that is not reducible to 'direct experience'. But this specific work only exists as such in its capitalist form in the context of the division of mental and manual labour. This division is thus directly bound up with the monopolization of knowledge, the capitalist form of appropriation of scientific discoveries and of the reproduction of ideological relations of domination/subordination, by the permanent exclusion on the subordinated side of those who are deemed not to 'know-how'.

This leads on directly to a second point, concerning the actual content of capitalist mental labour in the production process, which links up with our earlier discussions. Although the technological application of science, in its capitalist ideological forms, is bound up with mental labour, it in no way follows from this that all mental labour under capitalism is connected with these applications. The capitalist division of mental and manual labour is not the product of a separation between science and the direct producers; this separation itself is only one partial effect of the separation of the direct producers from their means of labour, and it is this that is directly responsible for the relation between mental labour and the reproduction of capitalist ideological relations. Now on the one hand,

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> there is no such thing as a purely technological application of science; every such application is constitutively bound up with the materialization of the dominant ideology in the form of practical knowledge of various kinds. On the other hand, mental labour also comprises a series of practices that have nothing to do with technological applications; there is a long list of these within the enterprise, from the rituals of 'know-how' to 'management techniques' and various 'psycho-socio-technical' practices.
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> At this point we can already see the articulation of political and ideological relations breaking through in the specific form of mental labour. Let us concentrate for the moment, however, on the ideological relations. If the practices just referred to have nothing to do with the technological application of science (even as 'ideologized'), they are still legitimized, and not by chance, as being invested with a knowledge which the workers do not possess. We could thus say that every form of work that takes the form of a knowledge from which the direct producers are excluded, falls on the mental labour side of the capitalist production process, irrespective of its empirical/natural content, and that this is so whether the direct producers actually do know how to perform this work but do not do so (again not by chance), or whether they in fact do not know how to perform it (since they are systematically kept away from it), or whether again there is quite simply nothing that needs to be known. This relationship between knowledge and the dominant ideology which is expressed in the form of the legitimization of a mental labour separate from manual labour and possessing this knowledge, is quite specific to the capitalist mode of production and to bourgeois ideology. It is essentially based on the need for the bourgeoisie to constantly 'revolutionize' the means of production, which Marx explains in Capital. This relationship affects every domain of bourgeois ideology. Just to take one significant example: during the transition from feudalism to capitalism, and then in the stage of competitive capitalism, both these being marked by the establishment of the bourgeois state and by the dominance of the legal/political region within bourgeois ideology, The specific separation of mental and manual labour that the establishment of the bourgeois state and its agents as a body 'separate' from society involved, was founded on the encasement of knowledge in legal/political ideology in the form of 'science'. This relationship between bourgeois ideology and knowledge is, however, considerably reinforced in the stage of monopoly capitalism, marked as this is by the shift of dominance within bourgeois ideology towards the region of economics; this is where we come across the various theories of the 'technocracy'.

Summarizing Poulantzas and extending his thoughts, this is where we stand today. Divide and rule is the ruling ideology of the bourgeoisie, which is used for better return on investment and profit maximization. This division does not have technocratic, but solely ideological-political causes. Depriving the employee from the means of production was accompanied by the separation of mental from manual work, because in this way the power of the bourgeoisie over the working class becomes absolute. In revolutionizing the means of production capital is pursuing a displacement of bourgeois ideology towards the economic side, with all sorts of technocrats prevailing over the legal and political power of the bourgeoisie, that is spreading worldwide. The aim is the monopoly of knowledge. Based on the principle that knowledge is economic power and time is money, an information hierarchy is developing inside the mass-enterprise where knowledge transfer is filtered according to the wishes of the organization hierarchy. The same is also valid in political parties. In this way there is a reproduction of the mass production way even among white collar workers as members of middle management are colloquially called.

In the post-mass production enterprise, the separation between mental and manual work is evaporating. It will not exist since, instead of bourgeois ideology, autonomating activity of new knowledge creation will prevail as a new form of a new means of production. The meta-capitalist mode of production will be based on the principle of *unite and learn instead of divide and rule, a characteristic of the economy of mass production*. The meta-capitalist enterprise will consist of communities of citizens cooperating to produce goods and services of personal value. In this way knowledge becomes the catalyst in value creation. Such a community is called a value adding community (VAC). Below follows a short description of the structure of VAC.

3.3 Value Adding Communities

A value adding community (VAC) is a self-sufficient and autonomated entity providing products and services. The composition of the VAC depends on the needs of the market adjusting to market differentiations. Participant in the VAC may be any entity that fulfils the interfacing requirements needed and described below. Since response time is the key issue here, ad hoc synergies can only be achieved if the participants in the VAC are structured and comply with certain agreed standards set and approved by the community. Therefore, for greater agility in responding to market needs, it is necessary that VAC internally exhibits a cellular structure. These cellular structures share certain design characteristics that make the structure reusable, re-configurable and scalable. Rick Dove was the first to use these expressions in his remarkable book *Response Ability* in order to define an organisational structure of an enterprise with the name *agile enterprise* (Dove 2001). We borrow his expressions and definitions to define networks with flexible structures in order to respond to the post-mass mode of production based on personalisation needs in a society of open innovation.

Entities needing to cooperate and form a new VAC have to comply with certain organizational principles that make ad hoc communication possible with the least loss in time and energy. These principles form a certain framework, known as the collaboration framework, which is accepted by the participants in the VAC. The framework does not need to be negotiated and re-negotiated every time a new VAC or a network of VAC is to be formed. It is well known that cooperation and collaboration negotiations today consume a great deal of effort, time and energy for both sides in a bilateral relationship. Even more so in a multilateral relationship where time, energy and therefore cost grow exponentially. The VAC framework targets, on the other hand, alleviating this major constraint towards forming ad hoc structures because such structures have already agreed on the terms and conditions. These terms and conditions are actualized for every new collaborative project undertaken (Tsigkas 2005). A VAC or a network of VAC is the result of socionomation, and characterizes the non-mass based era. In a future volume we will hand over the interested reader to an in depth analysis of the principles concerned, as well as ways of implementing VAC based on the typology of mass customization of goods and services. Practical examples validate the theory.

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Mass Customization

4

Abstract

An integrated way of thinking as well as the necessary theory is presented for the development of design methods for lean production of mass customized *things*. Mass customization reunites mental with manual work and gives the means of production back to users. In a mass production factory, the capitalist separation of mental labour from manual labour is seamlessly connected to specific capitalist relations of production. These relations are characterized by the separation and alienation of the immediate producer from the means of production. In contrast, in the factory of mass customized products, the abolition of capitalist relations is a prerequisite and must be replaced by new meta-capitalist relations which will be supported by knowledge, free will and access of producers to the means of production. Knowledge is the result of a process during which through the activation of a specific mechanism leads to the creation of new consciousness. This takes place mainly through the interaction of the user and the *topos* which will implement the wish. The theory is illustrated via an example from the furniture industry.

4.1 Introduction

The concept of mass customization (MC) is attributed to Stan Davis in Future Perfect (Davis 1996) and was defined by Tseng and Jiao as *producing goods and services to meet individual customer's needs with near mass production efficiency* (Tseng and Jiao 2001).[1] Kaplan and Haenlein concurred, calling it *a strategy that*

[1] Page 685

The person and not the individual is the only topos of the community

(Giorgio Agamben)

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creates value by some form of company-customer interaction at the fabrication and assembly stage of the operations level to create customized products with production cost and monetary price similar to those of mass-produced products (Kaplan and Haenlein 2006).

This dream that has yet to come true, at least in industrial production, finds wide application in the production of services offered through the Internet. Mass customization reunites mental with manual work and the use of the means of production from users. In the mass production factory, the capitalist separation of mental labour from manual labour is seamlessly connected to specific capitalist relations of production. These relations are characterized by the separation and alienation of the immediate producer from the means of production. In contrast, in the factory of mass customized products, the abolition of the capitalist relations is a prerequisite and must be replaced by new meta-capitalist relations, which will be supported by knowledge, free will and the access of producers to the means of production. Knowledge is the result of a process during which, through the activation of a specific mechanism, leads to the creation of new consciousness. This takes place mainly through the interaction of the user and the *topos* which will implement the wish. The new relations of production are called meta-capitalist with mass customization, as the new mode of production should not be compared to mass production. Mass customization characterizes the meta-capitalist society and needs a revision of its definition, removing from the initial expression the phrase «...in the cost of mass production». In the international literature, a large proportion of research related to the development of flexible and agile equipment as well as algorithms is observed. But, the research framework assumes the capitalist factory, the division of labour and the corresponding relations which govern it. The research framework for mass customization should assume a non-capitalist factory. For this reason repositioning mass customization inside the economy of *one* is needed.

The discussion about mass customization nowadays and in recent years has been confined and limited to what we call *mass configuration*. In fact, this form of customization is compatible with the capitalist mode of production. The concept of a modular product design and assembly according to customer order is quite old. It could be considered as the beginning of mass customization. However, customer involvement in the process of design is quite superficial and limited to the choice of pre-designed and a priori decided modules on behalf of the user.

Mass customization is definitely not a technical task of mass configuring product or services to fit the needs of individual customers, and it is not a business strategy that many scholars and practitioners around the world prefer it labelled. Mass customization is the social system of production in the meta-capitalist society currently evolving. In this social system of production personal knowledge is the origin and originator of value. In modern capitalism, value is created through the mainstream economy based mainly on the labour theory of value founded by Karl Marx. In the meta-capitalist society, value will be mostly created through the *prosumer* economy and will be governed by a theory of value based on knowledge. This economy goes further and beyond the experience economy of Josef Pine (Pine and Gilmore 1999).

4.2 Theory of Mass Customization

Mass customization is lacking a theoretical background. This gap was bridged through the development of a theory that defines the characteristics of value creation in meta-capitalism. The theory developed and the method born from the theory is discussed in a future volume, supported by many examples of implementation. In this section there is brief description of its basic principles (Tsigkas and Papantoniou 2009).

Mass customization is rigidly connected to the active participation of the user to value creation, covering the whole spectrum of his or her potential involvement: from partial co-creation to total co-creation of a product. One of the most important researchers of customer co-creation, Frank Piller, has devoted a considerable portion of his research on the typology of methods for value co-creation (Piller et al. 2011). In this spectrum, the person is displaced from a topos with zero participation in value creation to a topos with total participation in value creation. The need for displacement constitutes the main cause for guiding enterprises to search for new ways of value co-creation and co-innovation outside their walls in society, through a continuous relocation from closed to open innovation and social innovation. The greater the need for this relocation, the greater the need of a gradual separation from the capitalist mode of operation. The importance of productivity diminishes and in its place the importance of the speed of innovation for a personalized society rises. The displacement creates the need for a complete replacement of the classical labour theory of value by a knowledge theory of value. In the future, knowledge as a global good will be acquired from everywhere and will be created everywhere. Enterprises wishing to develop new products will orient themselves towards the world and new forms and ways of collaboration, abandoning the usual source of internal know-how, seeking innovative ideas outside their four walls and offering knowledge they possess and do not need in return or even without return.. The open innovation of Henry Chesbrough (2003) is already a reality as the work of Eric von Hippel “democratizing innovation” (Von Hippel 2005) confirms. In crisis hit Greece, small and medium enterprises are helping each other, abandoning the dogma of *win-win* and moving to a new dogma of *all for one and one for all*, a basic characteristic of *socionomation*.

The new rising market of mass customization needs new economic theories which will support production and the incorporation of knowledge to new products and services, since theories that support the markets of mass production are no longer valid. The basic characteristic of this economy is that produced value is incorporated into the body of the product in the form of individuated knowledge. The higher the degree of individuation and personalization, the higher the value of incorporated knowledge. With respect to value, there are four possible flows originating from the interaction between the *creator* and the *thing* illustrated in Fig. 4.1. The four different value flows correspond to the respective knowledge characteristics: *praxis* (p), *entelehia* (e), *openness* (o) and *individuation* (i):

Praxis is the characteristic of knowledge required by its creator in order to enact the process of individuation. *Openness* is knowledge related to accessibility to new knowledge. *Individuation* is related to the degree of new knowledge incorporated in

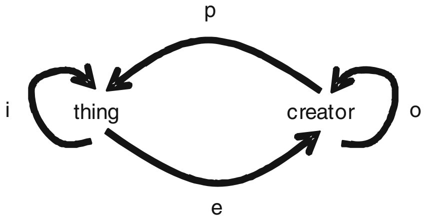

Fig. 4.1 Value flows in mass customization

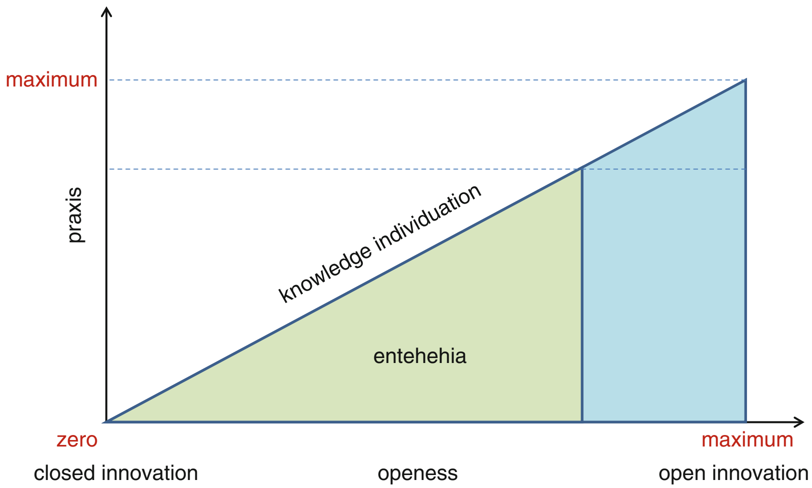

Fig. 4.2 Knowledge flow relations in mass customization

the *thing* in order to make it different. Finally *entelehia (realization of oneself)*, is the characteristic of the knowledge related to the potentiality of a *thing* to arrive at its conclusion, that is to satisfy the purpose for which the *thing* is created. In Fig. 4.2 the relation between the creator *praxis* and innovation *openness* with the *entelehia* of achieving *individuation* of knowledge is illustrated.

The value flows between the creator and the *thing* reflect knowledge incorporated in the *thing* through the process of individuation. Individuation is completed when the *thing* reaches its entelehia for which it is created. Individuation of entelehia is a function of praxis and openness of knowledge. This function constitutes the function of mass customization and describes the interaction *creator-thing* as an integral of a series of differential displacements until the *thing* reaches its end. Through the use of mathematical symbols this function can be expressed as follows:

$$i(e) = \int df(o, p) \quad o = [0, \max] \tag{4.1}$$

Based on the above relation for each desired level of *entelehia (e)*, a certain level of *individuation* (i) can be achieved which corresponds to the *praxis* (p) of the creator and the openness (o) of innovation. *Things* that exhibit equal level of individuation are called *homeoformic* constituting families of things belonging to a common topos. The phenomenon is called *homeoformism*. Homeoformic *things* have similar behaviour related to form, space and world when interacting with their environment. Every topos is distinct, refers to a specific class of homeoformic *things* and exhibits concrete qualities. Therefore through individuation, it is possible to design classes of *things* for which classes, lean production lines of mass customized *things* can be desiged, corresponding to one lean production line for every class. An integrated way of thinking as well as the necessary theory was presented for the development of design methods for lean production of mass customized *things*.

One of the causes that may lead to a person needing to relocate from a passive consumer to a co-creator of a *thing* is the wish for a particular user experience described by Josef Pine, one of the best known researchers of mass customization and the term he has defined about the experience economy (Pine and Gilmore 1999). This view of Josef Pine is based on the belief that users of products and services are mobilized by the wish of living particular experiences, which can be acquired through their interaction with individuated products and services. In our view, however, this is but a new form of consumerism and mass customization is used only as a motivation of attenuating consumption. The real motivation, we believe, is in the openness of society implementing the wish of the citizen to participate in value creation in the twenty-first century and the need for change of the social system of production as analysed in Chap. 2. The new social system of production is characterized by the end of salary-based work and therefore the end of the capitalist mode of production, the rise of free work performed through value adding communities and the recognition of the role of the individual in the process of mass customization via open innovation.

4.3 An Example from the Furniture Industry

The furniture industry is moving quickly towards mass customized products and therefore the displacement of enterprises from mass production to mass customization is a necessity. A way many factories deal with this need is through the opportunity given to their customers to configure their own order through choosing standard parts by means of a configurator. Standard parts are produced in a mass production way. Nevertheless, the interaction between the customer and the enterprise remains at the level of choice on the side of the customer and not of co-creation. In the meta-mass production era, due to the participation of the user in the design of the final product, enterprises should start planning their gradual displacement towards this direction. Gradual displacement will allow the enterprise to embark on a smooth course to the future topos. Below, there is a description of a way of approaching the future topos and the steps that need to be followed in each case. A necessary condition for this displacement is the recognition of the new operational framework companies are going to operate within, the basic characteristics of which are the following:

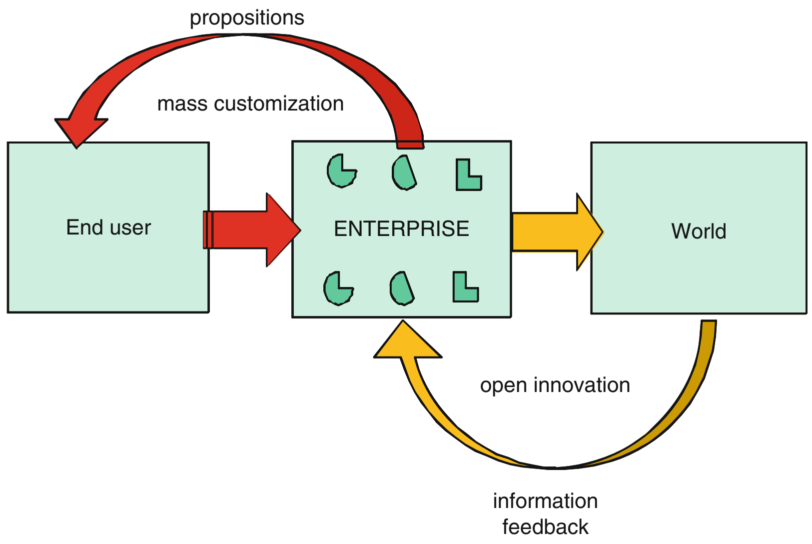

Fig. 4.3 Endless relations in the value co-creation cycle

- Gradual individuation of markets
- Quick access to information outside their four walls in order to produce new knowledge to offer to end users
- Facilitation of the interaction between the enterprise and end users
- Design of individuated products by end users
- Redesign and adaptation of the demand and supply chain to the new requirements of the meta-mass production markets

The new relations in the value co-creation cycle are illustrated in Fig. 4.3.

The characteristic of the new relations is the continuous, endless and two-way communication flows created between the stakeholders in the knowledge production loop, in this case, between the enterprise itself, the end users and the open knowledge society (world). Through information feedback, either in the loop of mass customization or in the loop of open innovation, there is gradual attenuation of the capability in the use and reuse of the knowledge created. The new knowledge is set at the disposition of all stakeholders at the same time and through a new feedback loop, which increases the density and the quality of the acquired knowledge. For the operation of such a network, a suitable infrastructure in information technology will be required as well as suitable software to facilitate interaction between the enterprise and the end user-producer of knowledge. Such a network of stakeholders can be organized in a form of one or more value adding communities (VAC).

How should the enterprise be organizing production and the supply chain in order to prepare itself for the era of mass customization? According to theory, the first step is the definition of the purpose (end) of the end use of the products the enterprise will offer in meta-mass production markets (Tsigkas and Chatzopoulos 2009). It follows a classification of products which cover the needs of:

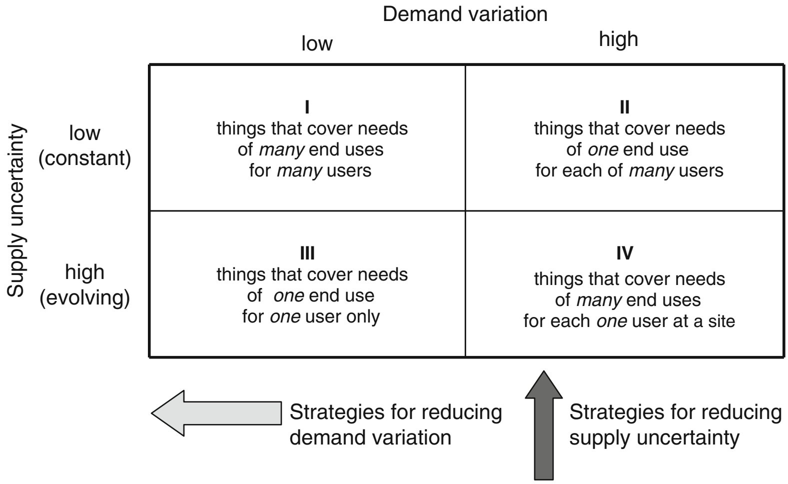

Fig. 4.4 Demand variation and supply uncertainty grid

(I) Of many end uses for many users – standardized products
(II) One end use for each of many users – individuated product
(III) One end use for the one user only – single and singular product
(IV) Many end uses for each user at a site – compound product

Theoretically, the four product categories constitute individual homeoformic classes that demand a different approach in organizing production and supply. In reality, not only in this particular case and in most enterprises, displacement from mass production to mass customization does not mean that all standardized products will be immediately abolished in favour of mass customized ones. There is, however, going to be an important difference: the standardized products will be a result of stakeholder interaction in the knowledge loops and not as a result of closed processes within the four walls of the company. The classic process in the design and production from closed becomes open. The transition takes place gradually and therefore all the categories must coexist for a while. Once the purpose and the basic categories of products have been defined, the second step is to position the four individual classes of products in the so-called demand variation and supply uncertainty grid. It is a usual phenomenon in many branches of industry that the needs and the characteristics of demand and supply to be different for the different product classes. Figure 4.4 exhibits the grid of the example given.

In the grid, the individual product classes are illustrated, according to the demand variation and supply uncertainty. The biggest enemies of production are the inability to define exactly the level of demand and supply. Every production company knows that it must develop and implement strategies to reduce demand variation and supply uncertainty. In a mass production factory these two challenges are usually met through producing and sustaining sufficient inventory quantity as excess inventory through a technique known as forecasting. In the meta-mass production factory, while the enterprise moves towards mass customization,

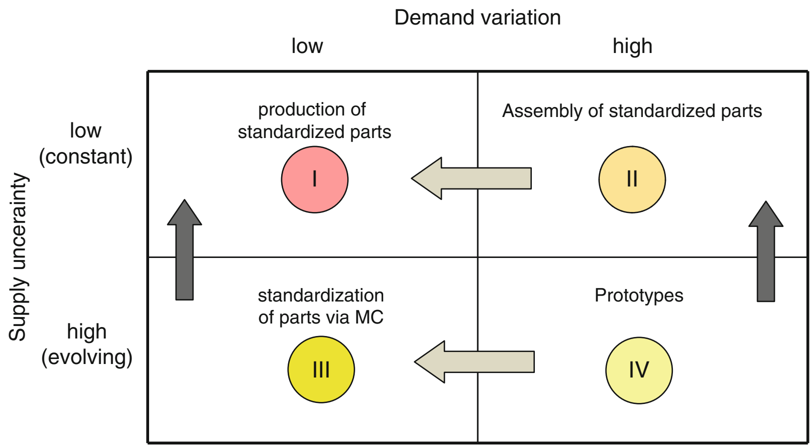

Fig. 4.5 Relocation to semi-mass production state

inventory existence based on forecast will increase the cost of production, since it makes no sense to maintain inventory in finished products, because the products are designed by customers and are not therefore known a priori. Elimination of inventory is, on the other hand, the dream of every company, but for the moment utopian. Full and total mass customization would mean elimination of inventory, not only of final products, but also semi-finished ones with the only aim the availability of sufficient quantity of raw material and parts in order to cover the needs of individuated markets. In the capitalist way of organizing work this is impossible. However, the transition to the meta-mass production topos will necessarily pass through a semi-mass production topos, where the existence of inventory in semi-finished form will be the intermediate solution on the way to full and total mass customization. The semi-finished form will depend on the ability of the participants in the knowledge circuit to develop standardized parts through interaction. These parts can then be produced in a mass production fashion and be assembled individually with the participation of the end user and not based on the forecast as shown in Fig. 4.3. In this way the necessary and sufficient conditions may occur for the gradual elimination of semi-finished products.

In the case under study, the path is clear. The aim is to reduce demand variation and supply uncertainty. The chosen strategy is signalled with a light and a dark arrow. The light arrow demonstrates the necessary displacement that needs to take place in categories II and IV towards categories I and III correspondingly in order to achieve a reduction in demand variation. The dark arrow shows the displacement required in categories III and IV towards categories I and II correspondingly so as to achieve a decrease in the supply uncertainty. The targeted result of the strategy is to pursue as much as possible the displacement of categories II, III and IV into products of category I, in the form of a standardized part and not of a finished product. The result of implementing the strategy is illustrated in Fig. 4.5.

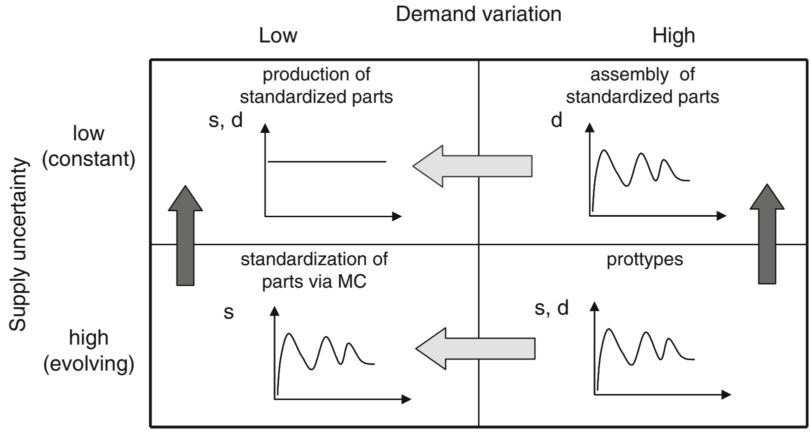

Fig. 4.6 Reduction of demand variation and supply uncertainty

Fig. 4.7 Measures by means of a scanner for individualized shoes (Helsinki World Congress for MC 2009)

In Fig. 4.5 it can be seen that relocation has been completed and a category of standardized parts developed with which the enterprise can produce all four categories of products referred to above. This capability is realized by activating the stakeholders knowledge circuit described above. In Fig. 4.6 demand variation and supply uncertainty are illustrated by the four categories of products which will be produced through standardized parts exhibiting very low supply uncertainty and very low demand variation.

The new operational environment which results after the implementation of the strategy favours the use of lean methods for the production of mass produced individuated final products. In Fig. 4.7 part of the process for the manufacture of shoes is shown based on exact customer measures.

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Part II

Lean Enterprise in Theory

Basic Principles of Lean Production 5

Abstract

Lean production as it appears in the literature and the various publications of consulting companies focuses on the avoidance of waste emphasizing that enterprises operate with inherent waste incorporated in their activities. This perception is not readily accepted among those with management responsibility in organizations that have seen growth, very good performance and remarkable profits for several consecutive years. So, why is there is so much noise about lean production and why should a successful company change their mode of operations in order to become lean? Is there perhaps a kind of fashion, a trend of the times that sometimes pushes enterprises without any real reason to follow that trend? This chapter addresses the issue.

5.1 Introduction

Lean production as it appears in the literature and the various publications of consulting companies focuses on the avoidance of waste stressing that enterprises operate with inherent waste incorporated in their activities. This perception is not readily accepted from those who have management responsibility, especially in organizations that for many consecutive years have seen growth, very good performance and remarkable profits. Therefore, why is there is so much noise about lean production and why should a successful company change their mode of operations in order to become lean? Is there perhaps a kind of fashion, a trend of the times that sometimes pushes enterprises without any real reason to follow that trend? If one looks closely at the issue, one will discover that this phenomenon has happened repeatedly in the course of the evolution of production management. Many of us sufficiently long in the business of manufacturing will remember various strategies, to name a few: Just In Time (JIT), Business Process Re-engineering (BPR), Zero

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Lean production is a one way street for the enterprises, especially today

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Defects (0-Defects), Total Productive Maintenance (TPM) and others which were widely implemented, quickly became fashionable with a lot of fanfare, while after a period of time this noise died out and the moment of absolute silence arrived. Should we anticipate something similar happening to lean production? This is superficial for the following reasons. Every era uncovers its own needs and expects responses to these needs. Especially in manufacturing, every era is characterized by a main differentiating element. In the 1970s, the main differentiating element was advances in technology. Enterprises promoted their advanced technology in order to differentiate themselves from competitors. In the 1980s, the new differentiating element became quality. Technology on its own was no longer the differentiating element because it had been introduced to the production process in a large number of enterprises. In the 1990s, speed to customer took the lead from quality to become the main element of differentiation in the market. Since both advanced technology and high quality were widespread in a large number of organizations, the next level of differentiation came in the arena of competition. In the decade of 2000, competition quits the level of the factory to move to the supply chain, with the trend that many enterprises relocated much of their activities to other companies. Outsourcing on a large scale took place worldwide. High technology and quality in combination with high response to customer service, was the main feature that differentiated companies from each other. In the new competition arena, the competing entities are not factories alone but whole supply chains. 2010 is the era with strong trends in markets seeking individualized products. The new competition will sustain the existing elements of differentiation and will look at new ways of cooperation and value creation far from those of mass production. We strongly believe that this decade will become the beginning of the era of mass customization, as the successor social system of production, distancing itself from the capitalist division of labour, a characteristic of mass production society. Since about the year 2000, implementation of lean production in the West, has helped many organizations achieve their targets towards quick customer response, reductions in the cost of production and zero working capital. It is therefore not a fashion, but especially in today's difficult economic conditions, lean production is a one-way street with no return, firstly for the survival and secondly for the preparation of the organization towards an open lean and mass customization era.

5.2 The Road of Toyota to the West

The Toyota production system (Ohno 1988) made its way to the West via the United States and Great Britain, mainly as daughter companies of multinational enterprises which had established themselves in Europe and had already implemented the system in the USA. The system combines behaviours, issues and special techniques into a socio-technical system of production. Taiichi Ohno, Shingeo Shingo and Eiji Toyoda initially developed the system between 1948 and 1975. As the Toyota production system (TPS) expanded throughout Japan and towards the West, it acquired different names and several variations emerged.

Toyota themselves had no specific name for their production strategy until 1970. The founders of Toyota paid a lot of attention to the work of Deming and the scripts of Ford. However, when they arrived in the USA to study the assembly line mass production technique that had made Ford rich, they were not impressed at all. Later, when visiting a super market, they observed the simple idea of a drinks dispenser, where whenever the customer wished a drink, he/she took one away and another replaced it. The idea of Kanban as a material pull mechanism was born. In 2001 Toyota put together their philosophy, values and ideals of production and gave it the name *The Toyota Way 2001*. The principles and the behaviours that underlie TPS are incorporated into the Toyota Way as the individual road of Toyota. It consists of two major pillars with two key areas: (1) continuous improvement and (2) respect for people described briefly hereunder:

5.2.1 Continuous Improvement

The principles for continuous improvement include the establishment of a long term vision with the aim of confronting challenges, continuous innovation and seeking the cause of the problem:

1. Challenges
   Form a long term vision with courage and creativity
2. Kaizen (continuous changes for improvements)
   Improve business activities continually with a perpetual target of innovation and evolution
3. Genchi Genbutsu (go and see)
   Go to the source and look for the real facts in order to make the right decisions, create consensus and achieve targets as quickly as possible.

5.2.2 Respect for People

The principles related to respect for people include ways of developing respect and group work.

1. Respect
   Respect others. To undertake every effort for mutual understanding, undertake responsibility and do everything possible in order to develop mutual trust.
2. Group work
   To encourage personal and professional development, share opportunities for development and maximize individual and group performance.

Toyota, through their established principles and behaviour, created a core philosophy for management and people. Many researchers, especially in the US, tried to offer the American companies ways of transferring the Toyota philosophy to the production shop floor. In 2004 Jerry Liker, an American professor from Michigan, wrote a book entitled *The Toyota Way* (Liker 2004). In this book Liker calls the path of Toyota a *system designed to provide the tools to the people so that* *to be able to improve their work*. The system can be summarized in 14 principles. According to Liker, the 14 principles of the Toyota Way are grouped into four areas:

1. Long-term philosophy
2. The right process will bring the right results
3. Add value to the company through the development of the people
4. Solving problems at the root creates a learning organization

The Toyota Way passed firstly to the USA and gradually to the rest of the Western world. However, American companies tried to imitate implementing the tools developed by Toyota without developing principles to fit their operations. This is the root of the problem. Principles based on a completely different life philosophy and culture regarding the personal, professional and social attitudes, are not easily transferable outside of Japan. If there is a set of principles to be transferred to a different country, then there is a major risk that these principles will adopt sooner or later a tooling character. That has happened with the Toyota Way in the majority of enterprises in the West. For example, implementation of the principle of continuous improvement, where applied, was sustainable only by using disproportionate effort. The reason is due to the fact that management forces it from above rather than coming intuitively from the people involved in the work as something natural, implicit and familiar. Not to forget that Toyota worked more than 30 years in developing the system.

5.3 Old and New Perception on Waste

We have referred extensively to value in the introductory chapter. Waste is defined as anything that does not add value. However, this definition should never satisfy us, because non-adding value does not necessarily mean wastage. For example, something that needs to happen in order to facilitate addition of value at a following stage should be excluded from the above statement. Moreover, if waste is eliminated it does not necessarily mean that value is added. Nevertheless, the medium-term task is the redesign of operations flow. The term waste traditionally refers to work, materials, space and time. The old perception of waste according to TPS includes the following causes:

1. Overproduction
2. Waiting for work
3. Conveyance
4. Extra or wrong work
5. Inventory
6. Motion
7. Correction of mistakes

Observing the seven causes of waste, one can easily deduce that overproduction is the independent cause of further six other dependent causes that are sources of waste by themselves. We should add more energy consumption in production than necessary as a form of waste to the list. We refer to the use of energy that is influenced by the implementation of lean production excluding energy for electricity and heating buildings. One of the effects of lean production is the reduction in energy requirements above and beyond energy savings for production operations. Savings achieved through energy conservation exclusively address the decrease in the cost of energy consumed. An environmentally sound production system contributes to the reduction in waste of energy resources, from whichever sources they come from, both renewable and non-renewable energy sources. In this way lean manufacturing is by definition green manufacturing, a trendy word nowadays. Furthermore, lean production contributes to the new perception of waste reduction and avoidance. Over-consumerism, promoted by marketing and long supported by the banks, has its roots in the *old* capitalist system. It is, however, a logical consequence of the twenty-first century that lean enterprise cannot be compared and must not correspond to the lean enterprise of the mass production era where Toyota emerged and grew up. Toyota as a car constructor and producer developed and refined its production system in an era (1945–1975) when mass production was at its peak, resulting in an immense reduction in the cost of labour and increase in speed throughout the factory. Today with the cash flow crisis in the market, Toyota faces similar problems, one of the reasons being that their factories have reached perfection in synchronizing everything, mainly through automation. Such perfection and automation abolishes flexibility and agility when demand reflects increased variety and individual needs something very common and frequent nowadays. A displacement of an enterprise to a lean topos on the one hand, while maintaining strategies of mass production on the other, will not have a huge impact just because of the elimination of internal waste. The reason is that, being in a lean topos, the company will be much quicker in piling up inventories and filling up store volume than before.

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Lean Enterprise: A Method

6

Abstract

The Toyota Way is based on a set of principles developed by the company for its own use, leaving open the path for developing methods to implement the principles. Implementation of TPS worldwide has followed multifarious methods depending on how enterprises believed and promoted solutions based on the principles. It is true that lack of implementation methodologies, in combination with the tooling nature that those principles acquired in the West, has led to the rise of two main schools of lean thinking. The first school was totally based on the principles and tools created by the Japanese of Toyota and their supporters who dogmatically adhered to their way of thinking and practice. The second school developed methods which incorporated the Toyota tools and demonstrated how they could be used to achieve a lean environment. The aim was to adapt both the principles and the tools to Western ways of thinking and practice. This chapter is devoted to the same aim.

6.1 Introduction

The Toyota Way is based on a set of principles developed by the company for its own use, leaving open the path for developing methods to implement the principles. Implementation of TPS worldwide has followed multifarious methods depending on how enterprises believed and promoted solutions based on the principles. It is true that lack of implementation methodologies, in combination with the tooling nature that those principles acquired in the West, has led to the rise of two main schools of lean thinking. The first school was based totally on the principles and tools created by the Japanese of Toyota and their supporters who dogmatically followed their way of thinking and practice. The second school developed methods which incorporated the Toyota tools and demonstrated how

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Lean thinking is a philosophy, lean flow is a method to implement the philosophy

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they could be used to achieve a lean environment. The aim was to adapt both the principles and the tools to Western ways of thinking and practice. To this school belongs John R. Constanza and the method he developed called Demand Flow® Technology (DFT). Constanza saw DFT as a business strategy (Constanza 1982). It has been implemented in the largest companies worldwide as well as in hundreds of medium-sized companies, both sides of the Atlantic. DFT has been improved on over the years (Gilliam et al. 2005).

We support the Western-oriented approach because it better fits the methodical way of work in which engineers create value. A production system is a system which needs, for design and implementation, a number of engineering disciplines or experts with an engineering mind. If a system needs modifications and changes, this should happen through the essential involvement of engineers, once the reason that causes the need for improvement or innovation has been confirmed. In all lean implementations, two objectives should be achieved. (1) creation of lean flow and (2) continuous improvement and innovation. The way those two objectives are implemented mainly depends on which school of lean thinking the know-how owners belong to.

Regarding the above, a method for achieving lean flow in the internal supply chain is presented in this chapter. It constitutes an extension of DFT for facilitating the displacement of an enterprise to the open lean topos. Lean flow is the major characteristic of a lean enterprise and thus it is necessary to outline its theoretical background, coined here as lean *flow typology*.

6.2 Lean Flow Typology

An important deficit in practical implementations of lean production and consequently of lean enterprise is the missing theoretical framework of characterizing flow systematically. The use of generally accepted principles (GAP), such as those defined by Liker on the basis of TPS, depends solely on the experience and knowledge of the individual consultants concerned and not on a generally accepted methodology (GAM) adapted to the particularities of each implementation case. As a result, reproduction of knowledge is held individually by each consultant so knowledge update does not exist, mainly knowledge transfer towards the companies which in turn reproduce what they already know. Actual needs will be fulfilled only through new knowledge, its use in practice and vice versa, that is, if from practice, theory can be born in order to restart the knowledge creation cycle. As a consequence, it is beneficial to introduce and systematically develop courses on lean flow in Universities since a theoretical background is thus necessary. It is therefore important to study the constituent parts of lean production, i.e. the flow and its various types which may exist under the general term lean *flow typology*. In the following, firstly the meaning of the word *flow* will be defined, secondly the meaning of the word typology will be explained and finally the typology of lean flow will be addressed.

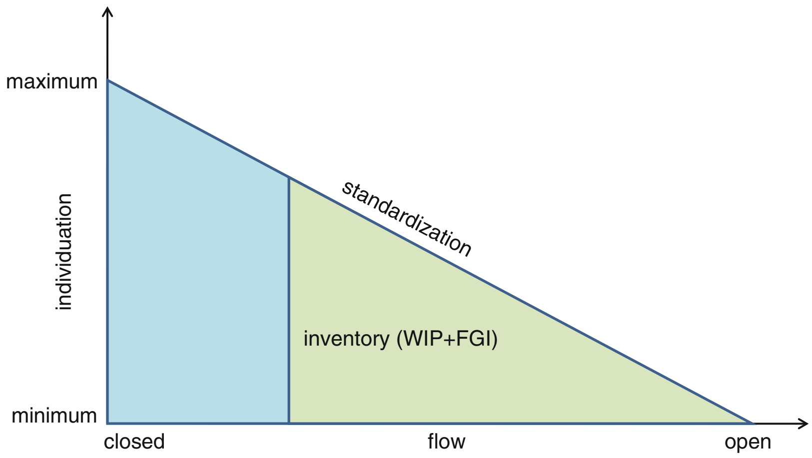


Fig. 6.1 Interaction flows

The word *flow* (signifier and signified) refers to the value stream of the material elements, work and information. The purpose of production is to produce goods that satisfy the customer, by exerting force on the material elements. During this process, work and information is used appropriately to fulfil customer end use value. Invested capital in modern enterprises incorporates human capital thus knowledge is treated as a means of production.

The word *type* (signifier) refers to the form a value stream may take based on particular criteria (Sect. 3.2) *praxis*, *entelehia*, *openness* and *individuation*. Form refers to the degree of individuation contained in the thing for a certain level of entelehia. Flows with similar form belong to a common topos classified as *homeoformism* (Sect. 3.2). It is suggested that interaction flows should be transferred for realization inside the enterprise, through design of the appropriate value stream by means of the method of lean flow (Sect. 6.4). In this case, the schema of interaction flows is mapped as a schema of inventory flows in the process (Fig. 6.1).

In Fig. 6.1, the spectrum of flows is distinguished as a result of its interaction with the end user, which varies from completely closed i.e. zero end user participation in product creation to completely open i.e. full end user participation in its creation. All the intermediate flows are possible and rely on the strategy chosen by the enterprise. Each option corresponds to a value stream as a framework for the economic review for evaluating the changes towards improvements and displacements of the enterprise to a different topos. As seen from Fig. 6.1, the more standardized a product in conjunction with closed flow (zero interaction), the higher the inventory level in production. In contrast, the more individuated the product in conjunction with open flow (full interaction), the less the inventory leading to the minimum level. In a future volume, the choice criteria in conjunction with displacement strategies for achieving differentiation in the spectrum of interaction flows will be analysed in detail. The chosen strategy will result in a particular

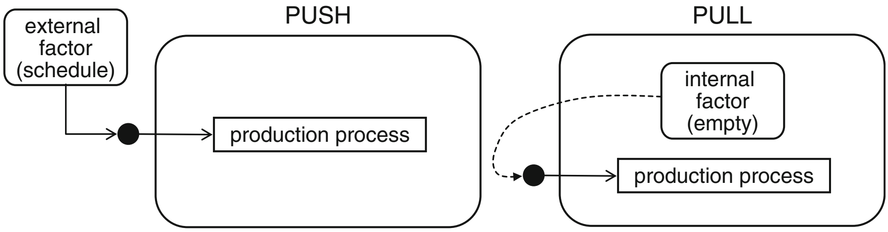


Fig. 6.2 Mechanisms of push and pull (Adaptation from Hopp and Spearman 2001)

value stream which will support the enterprise in evaluating their desired level of mass customization.

Based on the definition of *type*, *typology* refers to the study of all kinds of inventory flows, their allocation into categories and the corresponding value stream. According to the category of inventory flow type, the appropriate means for the displacement of value stream will be determined.

Since needs fulfilment in a lean enterprise results exclusively from the interaction of the enterprise with the customer-user, it is self-explanatory that the generated value stream must have the characteristics of *pull* and not of *push* which characterizes mass production. To uncover the essential differences between *pull* and *push*, we observe that the basic characteristic of each flow type is the mechanism which causes the movement of a material, work and information. For example, a Materials Requirements Planning (MRP) system based on the *push* mechanism schedules work according to real or projected demand, while the *pull* mechanism Kanban authorizes the start of work according to the state at the moment (i.e. lack of inventory is signalled by means of a card or a visual signal). The word Kanban is Japanese and means card or sign. The difference between push and pull is illustrated in Fig. 6.2. Push practices schedule the start of work from information initiated from outside the production environment, while pull practices authorize the start of work due to information initiated from inside the production environment. Certainly, in order to cause motion through Kanban, there must be a real end user order. Such an order sets in motion the internal processes which initiate work without the intervention of any other production planning factor. A pull system creates an environment with a regulated and constant work in process (WIP), while in theory, in a push system WIP has restricted regulation capabilities therefore is susceptible to running out of control. In practice, the lead-time through push manufacturing is variable, which varies customer response time influencing on time delivery.

How is the logic and practice of pull incorporated into lean flow? Based on the definition of flow given above and the degree of interaction with a customer, the value stream must reflect the specific flow type. In a closed innovation enterprise the following flow types are frequently met (Table 6.1).

Customer participation in the case of closed innovation is very small and occurs, if at all, only through the modification of existing standard products which the enterprise allows to a certain degree.

Table 6.1 Flow types – closed innovation

	Products	Customer participation
1	Fully standardized	none
2	Partly standardized with customization capability	through specifications
3	Configurable	through choice
4	New products	through specifications

6.3 Basic Pillars of Lean Flow

There are three pillars influenced by the way the enterprise operates: working capital, production cost and quality. A description of the role of these three pillars in lean production follows hereunder.

6.3.1 Working Capital

Working capital is of primordial importance for the viability and sustainability of an enterprise. Contrary to the concept of the times, the target of each enterprise at business level is to reduce its needs for working capital so as to gradually reduce its dependence from the banks. Since full independence may not be feasible, a practical rule to follow is that working capital borrowing should not surpass 20–30% of turnover. The goal is to achieve zero or almost zero working capital. Many enterprises, in an attempt to reduce their working capital needs, slow down payments to their suppliers and, at the same time, try to collect any outstanding amounts from customers. This way is inappropriate in the medium-term since it is only a matter of time before the supplier stops supplying such customers, the supply chain breaks down and cash flow gets interrupted.

The most appropriate way is to seek solutions in reorganizing production resources by reducing the working capital needs inside the enterprise. The implementation of lean flow leads the enterprise to the desired result. One of the main reasons why many enterprises need working capital is due to having a high finished goods inventory and a large amount of WIP. This happens because, typically, the customer waiting times are shorter than the time needed to produce the particular product. Therefore, the only way customer orders can be fulfilled is through carrying finished goods inventory. Presumably, the enterprise does not produce only one type of product, but many and possibly variants. Hence, it will be necessary to produce and make available all those variants they believe or hope to sell in the next period as an inventory. However, in the age of finite market opportunities, the danger that products remain in storage as *non-useful* inventory is high. Forecasting software systems, no matter how sophisticated and modern, are not able to forecast quantities with accuracy. In this case, we should really talk about the degree of inaccuracy rather than accuracy. Even in the best case, the forecasting accuracy of useful inventory varies in the range of 50–60% and falls even more in cases where the enterprise produces several and different products.

In many cases, the total working capital tied up in producing useful and non-useful inventory may be released when the existing finished products inventory is sold due to promotions or discounts encouraged by Marketing, several months later. In any case, the enterprise must possess working capital for as long as inventory is sustained in a non-useful state in order to be able to support production. The overwhelming majority of enterprises belonging to this category have already approached the banks in order to borrow working capital for their operations. However, the dependence as well as the cost is high, particularly if the amount of credit relative to sales turnover exceeds normal limits as referred to above. Let us see how working capital is calculated and how needs can be reduced via lean flow.

If

1	Raw materials and purchased parts inventory	RMI
2	Work in process	WIP
3	Finished products inventory	FGI
4	Accounts receivable	AR
5	Accounts payable	AP
6	Working capital	WC

$$\text{Then WC} = [\text{RMI} + \text{WIP} + \text{FGI}] + [\text{AR} - \text{AP}] \tag{6.1}$$

If WC = 0 then relation (6.1) can be written as:

$$[\text{WIP} + \text{FGI}] + [\text{RMI} - \text{AP}] + \text{AR} = 0 \tag{6.2}$$

Because the value of raw materials and purchased parts (RMI) constitute the accounts payable (AP) regarding suppliers of materials, (6.2) can be simplified as follows:

$$\text{WIP} + \text{FGI} + \text{AR} = 0 \tag{6.3}$$

Equation (6.3) shows that in order to realize the target of zero working capital, production should occur as close as possible to the moment of product delivery to achieve the minimum level of work in process (WIP) and finished products (FGI). Lot production, on the contrary, favours long lead times due to the high WIP inventory levels inherent in the way production is scheduled (Fig. 6.3).

The implementation of lean flow will facilitate the achievement of zero working capital. Due to physical synchronization of the processes combined with the implementation of the pull mechanism for replenishing materials and components, the minimum quantity of WIP can be achieved. This leads to a very short lead time in production and a short customer response time, eliminating the need to keep a finished goods inventory (Fig. 6.4).

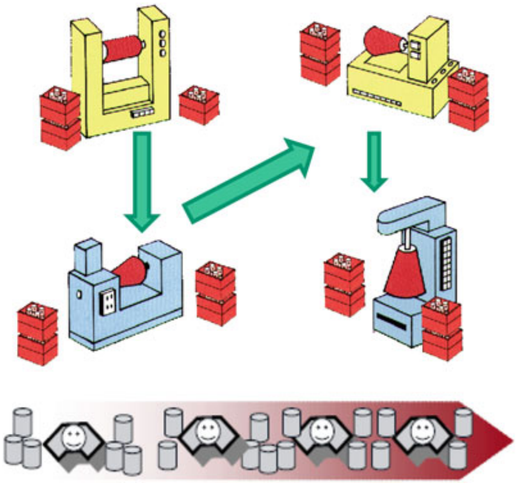


Fig. 6.3 Lot production (WIP>> >0) (Domange)

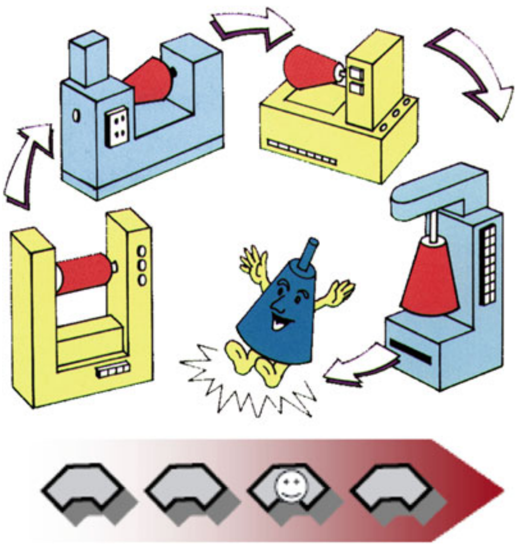


Fig. 6.4 One piece flow (WIP ~ 0) (Domange)

6.3.2 Cost of Production

Many companies, when referring to the *cost of production*, think of the cost of work. Unfortunately, this is only partly true. The cost of production is calculated on the basis of a simple formula.

$$
\begin{array}{lcll}
\text{Cost of production} & = & \text{Cost of materials} & \text{CM} \\
 & + & \text{Cost of work} & \text{CW} \\
 & + & \text{Cost of overhead} & \text{OH}
\end{array}
\quad (6.4)
$$

In the above equation, the smallest percentage rate concerns the cost of work, which in many branches does not exceed 5–10%. The highest rate is the cost of materials at about 55–60% and the rest belongs to the cost of overhead at approximately 25–30% depending on the particular case. What is the reason therefore why enterprises, in their attempt to reduce production costs, often choose to reduce personnel and direct personnel in particular as a solution? The reason which pushes companies to this choice is mainly due to the measurement of productivity. If, for example, sales are reduced, then sooner or later, production will slow down and *non-useful productivity*, i.e. the ratio of cost of goods sold (COGS) to the cost of work (CW) (COGS/CW), is therefore reduced relative to the previous state, and so in order to improve this ratio the company reduces personnel. This solution is heading in the wrong direction because it affects the cost of production unilaterally and in particular the cost of work which constitutes the smallest part. Instead, the enterprise should look at ways to reduce overhead costs and the cost of transporting materials, the percentage of which exceeds 80–90% of the total cost of production. The useful productivity, in our opinion, must refer to the ability of the company to steadily increase the ratio of the material part of cost of goods sold (MCOGS) to the sum of Cost of materials and the cost of general overhead (GOH). This ratio we call *lean flow index* (LFI). The cost of work constitutes a fix and not a variable cost and is therefore part of the general cost of overheads. The target in a lean enterprise is a steadily increasing lean flow index (LFI). The equation for calculating the cost of production becomes:

$$\text{General Overhead} = \text{OH} + \text{CW} \quad (6.5)$$

$$\text{Cost of production} = \text{CM} + \text{GOH} \quad (6.6)$$

$$\text{Lean Flow Index} = \text{MCOGS} / (\text{CM} + \text{GOH}) \quad (6.7)$$

Where,

$$\text{CM} = \text{cost of inventory } (\text{RMI} + \text{WIP} + \text{FGI}) \quad (6.8)$$

A successful implementation of lean flow drastically reduces inventories (WIP, FGI) and therefore their cost as well as general overhead costs primarily due to process synchronization in production and the drastic reduction in activities that do not add value to all company departments. As enterprises expand lean activities to the external supply chain, the cost of acquisition and storage of raw materials (RMI) will be reduced so that the lean flow index continuously increases. The higher the index, the lower the level of inventory and the lower the cost of materials needed to be available in the factory to produce certain product quantity.

The calculation of the cost of production in a lean environment is based on the new value stream created after the displacement of the current value stream to the lean topos. The basis for the absorption of the cost of production is the Total product cycle time (TPct), which is the longest time path through manufacturing. The way of accounting for the cost in a lean flow environment is described in Sect. (6.11).

6.3.3 Quality

Quality in lean flow is assured at the level of task execution in each line operation. An important improvement in the degree and the cost of quality is achieved, because, on the one hand activities are relieved from the burden of non-adding value and on the other hand, the task execution of each operation is based on the principle of "validate the work of the one upstream, execute the work at the operation and verify the work executed". In this way statistically high process capability is achieved, i.e. high work repeatability is achieved because, particularly in critical work, each task has essentially undergone two verifications each time. The first verification refers to the verification of the work itself and the second refers to the validation of the work of the upstream worker. Hence, errors can be practically avoided. Moreover, workers must be able to perform at least three operations for line operation flexibility. The novelty of this method is due to the fact that quality is tested at the source by the people responsible for product value fulfilment and not by intermediate personnel usually belonging to the quality assurance department. Immediacy abolishes the need for inspection, thus resulting in the reduction in the cost of quality. A detailed description of the way process quality is assured is given in Sect. 6.5.1.

6.4 Lean Flow in Production

When Constanza arrived in Japan to study its production process, he observed that enterprises did not use MRP systems for scheduling production and materials requirements at all. While in the West production needed complex and strong information systems for the synchronization of work processes and logistics, in Japan synchronization was created through the physical closeness of the work and the use of the pull mechanism for materials necessary for product completion. The result of physical process synchronization was high speed work flow through manufacturing and the lead time was almost equal to the time necessary to build the product. In contrast, in MRP systems, mainly because of the need to adjust necessary waiting times for process synchronization in production, dead times are artificially declared thus prolonging lead times without reason. Dead times as information *installed* in the systems, in practice, correspond to WIP between processes necessary for process synchronization.

When Constanza returned to the USA he developed the method of DFT (Demand Flow® Technology) and presented it as a business strategy. The method can be used for the design of business strategies carried out by Marketing. He insisted that every marketing strategy should start its realization from production, once the enterprise has decided to create value through manufacturing. For this reason, the method has flow creation in production as a starting point. His primary concern was to connect the closest point of the enterprise to the customer, which is Marketing. The name chosen for this method was directly connected to its purpose. That is, he wanted to show how flow creation in production is based on real demand and not forecast. In order to make this happen, he suggested that observation of the production process should start from the point closest to the customer and move upstream, i.e. against the work flow. Namely, if the final product is completed in one line of final assembly, then observation and the recording of the value stream should start from the assembly point and continue upstream towards the beginning of the production process, walking the physical work flow, as he characteristically advised. This suggestion is due to two reasons. First, when somebody visits a factory for the first time, not knowing well the final product, it is easier to follow the path of dis-assembly rather than the one of assembly. This way can be compared to the path of an explorer of a river, who always starts from the estuary and moves upstream towards the springs. Scientific research is similar. The second reason is that the point closest to the customer is the point of product completion, which the customer pays for and therefore implementation of lean flow must start from that point and continue towards the springs. In this way, a lean value stream is achieved through the pull mechanism. From the point from which the product is differentiated due to customer order, implementation of lean flow starts. This point we call *interaction point (IP)*, which in a closed loop order, is the point where the order for the final product acquires the individual characteristics of an individual order for a specific customer (see typology of lean flow, Sect. 6.2). Upstream of the interaction point, production is executed anonymously and its purpose is to sustain inventory within a range of several days in an intermediate store location in production through the pull mechanism. From that point onwards, production is executed according to customer orders for finished products.

The ultimate aim of lean flow is the achievement of a value stream in which the customer interaction point is as close as possible to the springs i.e. to the beginning of the production process, so as to achieve production made to order and not to stock. The goal is achieved as long as the value stream allows for one piece flow, or very close to it, but never though lot production. The lean flow method permits the formation of value streams for one piece flow and not lot production. The benefit for the enterprise in working capital is significant. Many enterprises today, although there is market demand for their product, go bankrupt or are close to it because the needs for working capital are high, the available capital is not enough and the banks either do not lend capital or the interest rates are unbearable for their survival. In the present climate, it will be increasingly difficult for enterprises to borrow. Next, and in parallel to working capital, operations cost is reduced mainly as a result of the significant decreases in dead times, waiting times, transfer times and generally of

Table 6.2 The steps of the method

Part	n/n	Step
I		***Lean work flow***
	1	Product flow synchronization
	2	Sequence of events
	3	Process map
	4	Definition of daily demand at capacity (Dc) and TAKT calculation
	5	Calculation of resources
	6	Line balancing
II		***Lean material flow***
	1	Definition of pull sequences
	2	Sizing of pull sequences
	3	Implementation of pull sequences

all activities that do not add value. Another gain is the acceleration of production because of physical synchronization of processes.

The method of lean flow is the embodiment of theory in the form of practice and is therefore suitable for immediate implementation, avoiding the usual way of conducting a study and later implementing it. Constanza used the term technology in its name since it is based on simple mathematics and implementation is led by specific rules. All questions that could be asked during implementation can be reduced and answered using the rules and the corresponding mathematical formulas that govern the method. It includes two parts: the first (1) refers to the steps for the design and realization of lean work flow and the second (2) refers to the design and the realization of lean material flow. Briefly, the steps are presented in Table 6.2.

A detailed description of each separate step is presented hereafter.

6.5 Lean Work Flow

The target of lean flow is the displacement of the value stream of a factory to a lean topos. The word factory is used here in a broad sense to refer to both production of goods and production of services. The introduction of lean flow to the factory causes direct communication of processes due to geographic proximity. The result is a significant reduction in WIP and the parallel execution of work as much as possible. In such an environment where the work steps are simplified and, at the same time, there is close geographic proximity, the planning needs of production are reduced primarily as a result of the drastic reduction in WIP. Synchronization of production starts to get autonomated without the involvement of an external factor. Planning will largely address the long term availability of the resources capacity of the enterprise through the use of ERP (Enterprise Resource Planning) systems.

The process of lean work flow design incorporates two parts: the first part refers to investigation of the type of flow and the value stream that corresponds to the particular type. The second part refers to the use of the method of lean flow for the displacement of the value stream to a lean topos. This consists of the synchronization of product or service flow and the organisation of the processes based on the calculation of resources, and the design of production resources layout.

Constanza defined six basic steps, the execution of which lead to a lean topos. It begins with the new state without any reference to the actual state and how this should be changed. The usual practice of analysing the current state in order to uncover activities needing improvement, is not followed in lean flow mainly because it is not about improving the actual state, but about a radical change in the way production operations are organized and executed. In their famous book *Learning to see* (Rother and Shook 1999), a graphical means of representing the value stream was introduced, called *value stream mapping* (VSM), to make visible the work flow and information flow of the production process. As clarified by John Shook, the VSM diagram was devised in order to make visible activities in production or the supply chain that do not add value and generally create problems and not as an analysis technique or modelling tool for material and work flow (Shook 2010). This clarification comes from the developers themselves after overuse of the VSM technique for the analysis in many cases of complex VSM, something that created *operational rigidity* among lean production specialists, as to how a value stream should or should not be mapped. It is a fact that, although the VSM may represent the actual topos of flow and the obstacles posed to it, it does not essentially help displacement towards a lean topos. The time consumed in discussions about whether the current value stream is mapped with accuracy or not is time that does not add value to the continuation of the implementation. As a consequence, the challenge is the new topos that will result after implementing lean flow. The in depth analysis of the current topos of the value stream does not add value since it is known that it must be changed.

I do not know if my teacher John Constanza has studied the ancient Greek philosophers. I am referring to Socrates and the different way he perceived research, contrary to the Sophists. The Sophists claimed that history, i.e. the past is the source and the starting point of all information. According to this belief, the cause of the birth of the origin of the things (where something comes from) is sought in the past or at the most in the present. Socrates claimed that the origin of the existence of the thing is sought in the future, by means of the question *what is it* (τι εστί). Seeking what is the goal (for what reason) of a thing, we seek the origin of its creation. Classical scientific knowledge and research methods are based on the Sophists way of thought, innovation and creation on Socratic ways of thinking. In the words of Johannes Antoniou, a Greek professor of Mathematics at the Aristotle University of Thessaloniki, ‘From science we expect to explain phenomena in a better way than witchcraft’. The findings of science can be used for the realization of innovation. The conception of innovation, however, cannot be supported by the research methods of classical science and for their conception and their realization a particular knowledge branch of research methods especially for innovation must be created, which I call *socratic*. Transferring these principles to the lean production practice, VSM is created according to the Sophists position, while Constanza’s

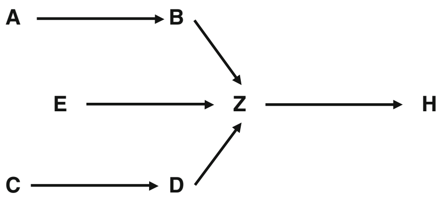


Fig. 6.5 Product synchronization flow

method has socratic roots. Personally, I support the socratic way of thinking and its way of arriving at the origin of things. Nevertheless, knowledge of the flow typology is necessary and useful, i.e. at the point of interaction with the end user in order to have an appropriate regulation of the pull mechanism. As far as VSM is concerned, we have decided to exclude its theory and its development here because we view it as known. In the implementations we discuss in Chap. 7, VSM is used to portray the graphical flow before and after production displacement in order to make visible the displacement from the old topos to the new. The steps described in the following pages are implemented in the same way and in the same sequence regardless of whether it concerns assembly lines, manufacturing lines, or even administrative and service processes.

6.5.1 The Steps of the Method

Step 1: Product synchronization flow. This refers to the diagram which presents the synchronization of all the processes needed for the production of a product. A process is a series of sequential steps of work executed by a person or a machine at a certain product volume. The processes relate to activities, are named using a verb and are connected by means of an arrow in order to declare work flow, flowing from one process to the next. The method can be compared to the way that electricity flows in an electrical circuit. Figure 6.5 shows an example of product synchronization flow.

In product synchronization flow, seven processes participate (A,B,C,D,E,Z,H) in product completion. Each product is described by a synchronization flow. It is usual that a synchronization flow is common for many different products. In practice, the Paretto rule of 20% of the products which correspond to 80% of the sales turnover is chosen to study the flow. In Fig. 6.6 an example of a product synchronization flow originating from the manufacture of truck-lifts is given.

The aim is to develop mixed model synchronization flows (MMSF). To each MMSF corresponds one lean production line. The first step is the backbone of the method. With the completion of this first step, an early indication of the final layout of the resources in production is given.

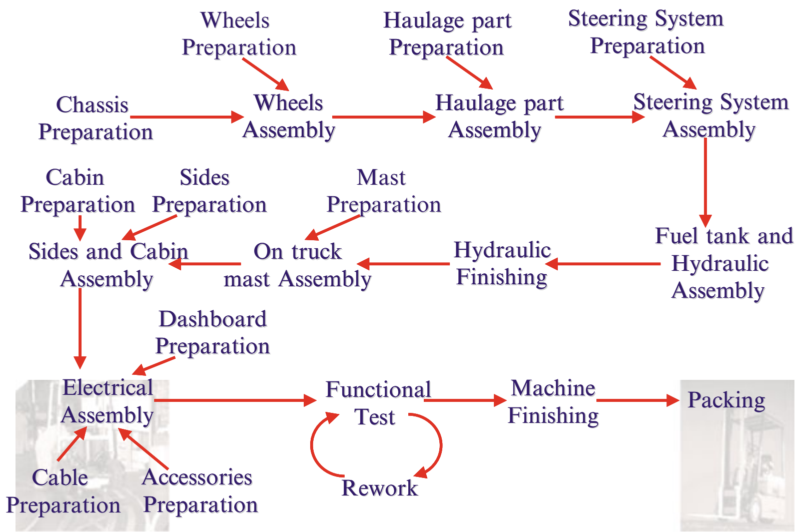


Fig. 6.6 Truck lift product synchronization flow

Step 2: Sequence of Events(SOE). This refers to the detailed recording of all events needed to be executed for the completion of each process as well as the time duration for each event. The SOE follows a certain standard shown in Fig. 6.7.

Three types of work are referred to: firstly work related to preparation, secondly work needed for the production of the product and thirdly work related to transportation. Every event that does not add value must be signalled appropriately. The reason is simple: for events that do not add value a way must be found in order for it to be eliminated. The SOE has a dual reason of existence. The first is related to the need of knowing the sum of the time duration of all events for each process. The second is related to the need that results from the production line be a graphical representation of the work in motion in order to lead the workers to a complete and exact execution of the sequence of events per process. Furthermore, there is a third reason, which is related to balancing work on production lines, described in detail in step 6. Each event may be certified related to the correct way of executing the work wherever necessary (in process control – IPC). This way is supported by the use of the following colour coding (Fig. 6.8). yellow (square) declares the work content that must be executed by the worker for adding value, blue (circle) declares test work that must be done by the worker after he has completed his work and red (triangle) is used to certify the right execution of the work by the next worker before he starts his own task. Consequently, each worker executes three kinds of tasks in his workplace: firstly he checks the work executed by his colleague, secondly he executes his own work and thirdly he checks his own work. The three particular colours facilitate the workers who are colour blind because in this case there a differentiation in the grey scale for each colour.

Product P/N 973-000-01 Control PCBA	Sequence of events						Assembly Station #
SEQ #	TASK DESCRIPTION	Work Type(sec) V.A	Set-Up	LABOUR	Duty Cycle (%)	QUALITY INFO. DESCRIPTION	TOOLS (Pneumatic tools, Special Holders,Gigs,Etz.)
10	Solder the Crystal	+		20	80	To check the solderability performance	Solder Gun, solder wire
20	Solder the IR Diode and Thermistor	+		20		To check the IR orientation and the solderability performance	Solder Gun, solder wire
30	Cut the component IR Diode and Thermistor lead	+		20		To ensure the length of the component lead meet IPC requriement.	Cutter
40	Solder the Battery Wire into the PCBA	+		20		To check the wire polarity and the solderability perfomance	Solder Gun, solder wire
50	PCBA Touch up	+		20		Touch up the poor solder joint	Solder Gun, solder wire
60	Clean the PCBA	+		20		Cleaning the flux residue, soldering residue	Cleaning solvent, cleaning brush
70	Apply the Hot Melt Glue to fix the Battery Wire and apply the yellow glue to fix the Crystal	+		20		The application of the glue should be controlled to prevent the assembly problem	Hot Melt Glue, Hot Gun, Yellow glue

Fig. 6.7 Sequence of events (SOE)

MODEL # **FlowCraft 2**		OPERATION **OP 110**	
PROCESS ID **FINAL ASSEMBLY**		PAGE **1 of 3**	
▲	**TQC**		
■	**WORK CONTENT**		
●	**VERIFY**		
FIND	PART #	DESCRIPTION	QTY
1	**370501**	**perforated strip, 9 holes**	**2**
2	**370503**	**perforated strip, 3 holes**	**2**
3	**370511**	**Screw, 5.8mm**	**4**
4	**370510**	**Square nut**	**4**
5	**370511**	**Screw, 5.8mm**	**4**
6	**370531**	**Trunnion flanged**	**2**
7		**Engine support**	**1**
8		**Engine assembly**	**1**
9	**370510**	**Square nut**	**4**
P.C.O **AGS 110A6** **Rev. C**	DATE **25/7/2000**		
FlowPRaXis®		*Copyright 2000 FlexCOM. AT&P*	

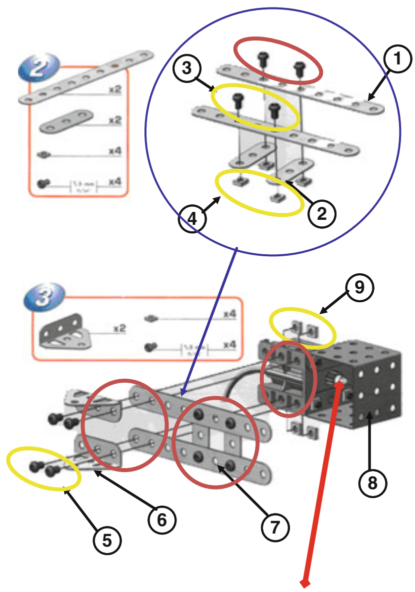


Fig. 6.8 Example of a graphical method sheet (training material with Mecano elements)

		Process A	Process B	Process C	Process D	Process E	Process F
Product 1		20	15	35	10		40
Product 2		25		20	15	35	40
Product 3			3	20	15	20	60
Product 4		5			5		50
Product 5		15	3	15	10	10	30

Fig. 6.9 Process map

Step 3: Process map. The process map is a systematic way of combining information of the mixed product synchronization flow with the sequence of events (SOE). It is the heart of the method since it is used for the calculation of resources and line balancing. The process map shows products that belong to the synchronization flow of the mix in the first column and the processes on the product synchronization flow on the first line. Processes can be referred in the map in any order. For every product, the process time is inserted from the corresponding SOE for every process that appears on the product synchronization flow. In this way the map is completed. An example of a process map is given (Fig. 6.9).

Step 4: Demand definition and TAKT. TAKT refers to the frequency or rhythm that a product unit must be produced. It is indissolubly connected with market demand. It relates to the maximum daily demand per product. The maximum daily rate demand at capacity (Dc) in lean flow is not calculated from a mathematical formula resulting from the theory of forecasting, but is the result of internal concessions in the company and it is defined taking many factors into account. One of the factors that influence the determination of Dc, is the estimation from the sales and marketing department with respect to what will be sold in the next 1–2 years, if feasible. In the current economic climate, it is not easy to perform such an estimate, because of the uncertainty resulting from demand variations in many products. Information concerning the quantities and types of products produced in the previous year in combination with production management's opinion regarding the future situation, is another factor. The challenge is to converge the various internal opinions, with the final decision taken by the general manager. However, the rule for the final setting of Dc is that this should be established so lines operate daily at 75–80% of capacity and not at 100%. The reason being that, lean flow lines are purposely designed to have greater capacity than usually required so as to absorb daily demand variation of up to 20–25%, to produce only to order and avoid holding inventory of finished products. Based on this practical rule, this variation is absorbed by the line designed to provide this level of agility. Once Dc per product is established, the calculation of TAKT can be performed if the time interval within which Dc should be fulfilled is fixed. Usually, this time corresponds to the time available for production during the day (H). The formula used to calculate TAKT is therefore:

$$\mathrm{TAKT} = \mathrm{H}\,(\mathrm{s})/\Sigma\mathrm{Dc} \qquad (6.9)$$

	Mechanical treatment	Drilling	Plating	Paint	Cabling	Power supply	Power supply test	Power conversion		Final assembly	Burn-in test	Packaging	Repair
13007-01	100,0%	100,0%	Y 87%	Y 75%	O 55%	-	-	100,0%	Y 60%	100,0%	Y 95%	100,0%	3,0%
13008-00	100,0%	100,0%	Y 87%	-	O 90%	-	-	100,0%	Y 90%	100,0%	Y 85%	100,0%	3,5%
13009-02	100,0%	100,0%	Y 87%	-	O 80%	-	-	100,0%	Y 50%	100,0%	Y 85%	100,0%	4,0%
13005-08	100,0%	100,0%	Y 87%	-		100,0%	Y 70%	-	-	100,0%	Y 98%	100,0%	6,0%
13006-05	100,0%	100,0%	Y 87%	-	O 10%	100,0%	Y 43%	O 15%	Y 85%	100,0%	Y 65%	100,0%	2,5%
13002-06	100,0%	100,0%	Y 87%	Y 75%	O 50%	-	-	100,0%	Y 60%	100,0%	Y 85%	100,0%	1,5%
13007-07	100,0%	100,0%	Y 87%	Y 75%	-	O 50%	Y 60%	100,0%	Y 95%	100,0%	Y 95%	100,0%	3,0%
130010-08	100,0%	100,0%	Y 87%	-	O 45%	100,0%	Y 50%	-	-	100,0%	100,0%	100,0%	1,5%
2245607-09	100,0%	100,0%	Y 87%	-	O 85%	100,0%	Y 85%	-	-	100,0%	100,0%	100,0%	1,0%

Fig. 6.10 Process map

Where s is number of shifts and ΣDc is the sum of Dc of all finished products
The time available for production (H) is the time that refers to a shift time of 8 h minus the time intervals the enterprise has defined as work breaks, which vary from country to country and also from company to company. TAKT characterizes a process and every process has a TAKT related to the volume passing through it (ΣDc). This finding is significant because it helps to distinguish whether or not a sequence of activities constitutes one or more processes. Hence, if the quantity passing through the sequence of activities does not change then the process is one and the same. A classic example is an assembly process where the quantity of products passing through does not change from the beginning of the process to the end. Furthermore, we should not confuse a machine with a process. In one process, more than one machine may be incorporated because a process may need one or more machines (similar but not the same) in order to fulfil demand. At this point, we need to comment on the difference between a process and a procedure. A process is characterized as a sequence of activities executed on a quantity of products, while a procedure is characterized as a sequence of activities unrelated to the quantity of products. A product synchronization flow depicts a procedure of processes.

In cases of product synchronization flow where rework processes are incorporated (Rwk), the demand for these processes is estimated as a percentage of demand that passes though the process calculated on the basis of statistical data available during a certain period of time. The same is valid for options processes per product (designated with O in the process map). In this case, demand is estimated as a percentage of the demand that passes through the process calculated on the basis of statistical data per option. If a process has a yield lower than 100%, then the percentage of the yield per process is illustrated. In Fig. 6.10 an example of a process map is given, which includes the cases of rework, options and yield.

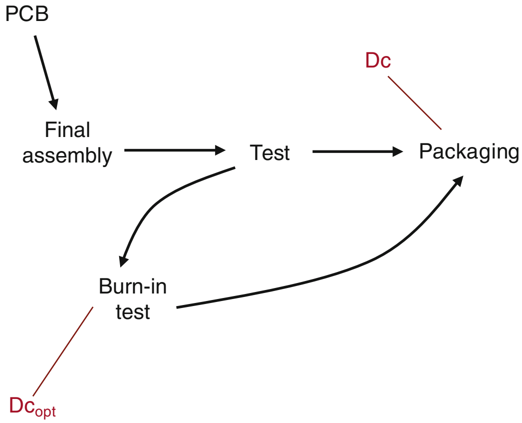


Fig. 6.11 Product synchronization flow

	PCB	Final assembly	Test	Burn-in Test	Padkaging	Dc
Product 1	x	x	x	*	x	80
Product 2	x	x	x	*	x	30
Product 3	x	x	x	-	x	50

Fig. 6.12 Process map – options

(a) Demand calculation for options processes (Option- O)

Given the following product synchronization flow (Fig. 6.11) and the corresponding process map (Fig. 6.12).

As shown in the process map two products (product 1, product 2) need the process of burn-in test. What percentage of products go through this test? The information is given on the process map presented in Fig. 6.13.

The above table shows that 50% of product 1 and 10% of product 2 go through the process of burn-in test. Furthermore, for every product 1 there is a need for one electronic board, for every product 2 the need is four electronic boards, while for product 3 two electronic boards are necessary. In order to calculate the demand

	PCB	Final assembly	Test	Burn-in Test	Packaging
Product 1	100%	100%	100%	50%	100%
Product 2	400%	100%	100%	10%	100%
Product 3	200%	100%	100%	-	100%

Fig. 6.13 Process map – options

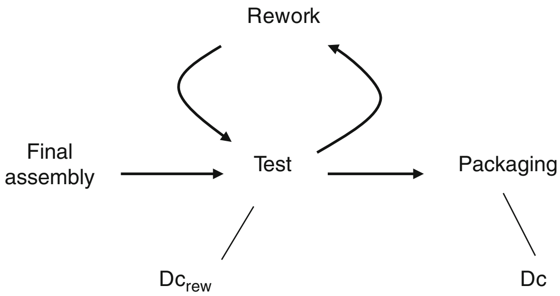


Fig. 6.14 Product synchronization flow

(Dc_{opt}) for the option process of burn-in test, the following formula is used (option is the percentage of the total product demand that require the burn-in test process):

$$Dc_{out} = Dc \times option \tag{6.10}$$

(b) Demand calculation for rework processes (Rework-Rwk)

Given the following product synchronization flow (Fig. 6.14) and the corresponding process map (Fig. 6.15).

As shown from the process map, two products (product 1, product 3) go through the rework process. What percentage of products go through rework? The information is given in the process map presented in Fig. 6.16.

The process map shows that 5% of the quantity for product 1 and 10% of the quantity for product 3 need rework. In order to calculate the demand (Dc_{rew}) for the rework process, the following formula is used (Rwk is the percentage of the total product demand that require the rework process):

	Final assembly	Test	Rework	Packaging	Dc
Product 1	x	x	*	x	80
Product 2	x	x	-	x	30
Product 3	x	x	*	x	50

Fig. 6.15 Process map – rework

	Final assembly	Test	Rework	Packaging
Product 1	0	0	5%	0
Product 2	0	0	0%	0
Product 3	0	0	10%	0

Fig. 6.16 Process map – rework

$$\mathrm{Dc_{rew}} = \mathrm{Dc}\ (1 + \mathrm{Rwk}) \tag{6.11}$$

The formula is valid for one rework loop. In cases where the product rework process is needed more than once then the following sequence must be used:

$$Dc_{rew} = Dc\left[(1 + Rwk) + (Rwk)^2\right] \textit{ for 2 times} \tag{6.12}$$

$$Dc_{rew} = Dc\left[(1 + Rwk) + (Rwk)^2\right] + \ldots + (Rwk)^N] \textit{ for ``N'' times} \tag{6.13}$$

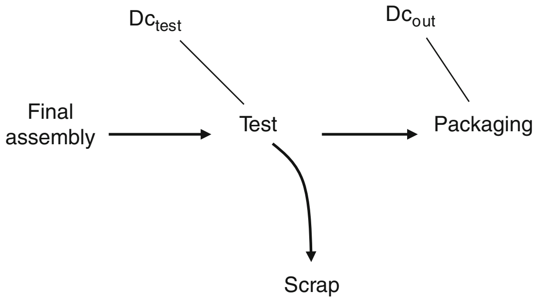


Fig. 6.17 Product synchronization flow

	Final assembly	Test	Packaging
Product 1	0	5.0	0
Product 2	0	0	0
Product 3	0	3.0	0

Fig. 6.18 Process map – scrap

(c) Demand calculation for processes with scrap

Given the following product synchronization flow (Fig. 6.17) and the corresponding process map (Fig. 6.18).

The process map shows that 5% of the quantity of product 1 and 3% for product 3 is lost as scrap. In order to calculate (Dc_{test}) the process of test the following formula is used (scrap or yield is the percentage of the total product demand that require the rework process):

$$Dc_{test} = Dc\ /(1 - \ scrap) \qquad or \tag{6.14}$$

$$Dc_{test} = Dc\ /yield \tag{6.15}$$

Step 5: Calculation of resources per process. For the calculation of resources per process it is necessary to know the work content time per process as well as the TAKT per process. The ratio of work content time to TAKT gives the number of

420	Dc	Process A	Process B	Process C	Process D	Process E	Process F
Product 1	12	20	15	35	10		40
Product 2	16	25		20	15	35	40
Product 3	37		3	20	15	20	60
Product 4	55	5			5		50
Product 5	8	15	3	15	10	10	30
Σdc		91	57			61	128
TAKT		4,62	7,37	5,75	3,28	6,89	3,28
Atw		11,37	5,53	21,92	9,92	22,62	49,45
RES		2,46	0,75	3,81	3,02	3,29	15,07

Fig. 6.19 Resources calculation

resources. Work content times are known from the process map (step 4). Nevertheless, a question arises with respect to which work content time should be considered. The process map includes different products that may have different work content times. The time to be considered is the weighted average with respect to the demand for each product per process. Mathematically the above is expressed as follows:

Let:

The weighted average time	$A\tau_w$
Number of resources for the mixed model	RES_w

$$RES_w = \text{Atw} \,/\, \text{TAKT} \qquad \text{where} \tag{6.16}$$

$$At_w = \Sigma(AT_i \times Dc_i)/\Sigma Dc_i \;\; (i = 1, 2 \ldots n) \tag{6.17}$$

The result is significant because the sum of all calculated resources equals the number of operations for the new mixed model line. An example of resources calculation per process is shown on Fig. 6.19.

The product mix constitutes the basis for the determination of product families leading to an equivalent number of mixed model lines (i.e. one mixed model line per product family). The number of lines is defined by the similarities of processes and commonality of materials for the products. Process similarity refers to similar work steps and content times, while material commonality refers to the materials and components common for the products.

A wrong product mix is likely to provoke imbalances in the production time manifested through the inability of keeping to the designed TAKT. Consequently, it is necessary to have a method of defining families of products, which can be produced in the same flow line keeping to a specific TAKT for the mix and volume. The procedure leading to the determination of families of products is called *time indexing* and is realized by means of a successive classification of products in the total process map based on the criteria of the number of resources RES (=AT/TAKT) per process and product in relation to the number of resources that result from a mix of products RES_w (=AT_w/TAKT). Specifically, the validity of the following condition of homeoformism is examined, expressed as follows:

$$0,7 \times \ RES_i < RES_w < 1,1 \times \ RES_i \ i \ = 1, 2 \ldots n \tag{6.18}$$

Given the above condition, the range of similarity of the work content time translated into resources for products that belong to the same family is defined. If the number of product mix resources lies between 70% and 110% of the number of product resources, then this product belongs to the same family (a practical condition of homeoformism). The products which do not fulfil the above relation are removed from the initial process map and are put in a new one, where a new cycle of time indexing starts from the resulting product mix. The classification procedure is completed when all products are classified into a family. To each resulting product family corresponds one flow line.

Step 6: Line balancing. The sixth and final step refers to line balancing, where the target is to group work together in each SOE per product and process so each resource on a production line executes the allocated tasks as close as possible to TAKT, but not surpassing it. This target is non negotiable. If the goal is not feasible an imbalance may result which should be resolved by means of specific balancing tools discussed hereafter. The closer to TAKT the tasks are allocated per resource the better line balancing is achieved and as a consequence better line efficiency can be achieved. In a lean enterprise, productivity is sought through the capability of increasing LFI (lean flow index), defined as the ratio of MCOGS (material cost of goods sold) to the sum of cost of inventory (raw materials, semi-finished and finished products) and the cost of general overhead (Sect. 6.3.2). Success in high production lines efficiency is the precondition for the assurance and the improvement of productivity of the enterprise.

(a) Balancing lean flow lines

The following example is used to help understand line balancing in the environment of lean flow versus the one implemented in a non lean production flow. Let TAKT be 30 min and the process time be 100 min. The necessary resources are calculated by (step 5):

$$RES \ = AT/TAKT = 100/30 = 3,33 \tag{6.19}$$

The calculation shows that there is a need of 3.33 resources which correspond to 4 operations. While each resource must undertake work as close as possible to TAKT and given that perfect balancing can be achieved, then the time for each operation is distributed as follows:

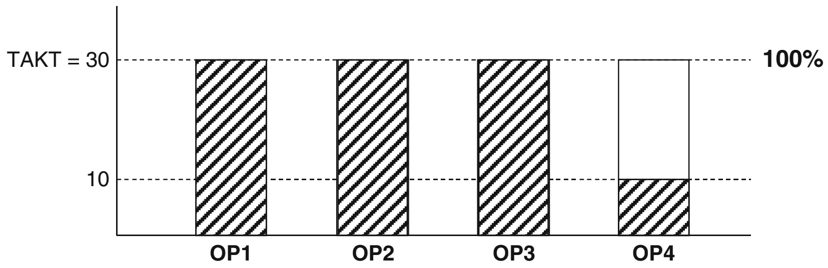


Fig. 6.20 Line balancing in lean flow

$$\text{OP1} + \text{OP2} + \text{OP3} + \text{OP4} = 30 + 30 + 30 + 10 = 100 \tag{6.20}$$

The result of balancing is shown in Fig. 6.20.

The figure above illustrates that three resources are 100% occupied and produce exactly to TAKT, while the fourth is occupied at 33%. This means that the operator at operation 4 has 20 min available to execute other activities inside the TAKT. This balancing (pull) supports the natural synchronization of processes on the shop floor, while the resources in this way can participate at 100% availability, taking better advantage of their capacity. Higher efficiency in production in comparison to a non lean flow line is achieved.

(b) Balancing non lean flow lines

For this purpose we will use the same example. Execution of work in operations is usually determined on the basis of production activities grouped into tasks following a logic of technical feasibility set by the department of industrial engineering through work studies as opposed to achieving the TAKT target. The basis of production is the creation of lots or batches. Line balancing in a non lean flow has the purpose of allocating work in equal time parts to each resource (push). Allocation of the 100 min to four operations would give the following distribution.

$$\text{OP1} + \text{OP2} + \text{OP3} + \text{OP4} = 25 + 25 + 25 + 25 = 100 \tag{6.21}$$

The result of line balancing is shown in Fig. 6.21.

The figure above shows that the operators are equally occupied at 83% (=25*100/30) of available capacity in all four consecutive operations. For the remaining 17%, the operators work on product units waiting in front of their operations. In order for work to always exist the line is pushed to saturation so that product units will exist to receive work. However, in this way products are delayed on the production line as they are grouped into lots in front of the operation. In this example, there is a waiting time of 5 min per product unit per operation. Consequently, the production lead time is 120 min (=4 × 25 + 4 × 5) instead of 100 min (=30 × 3 + 10) for lean flow. Therefore, in a non lean flow, lead time is at least 20% longer that in lean flow and the resource usage is at least 20% greater for the same production quantity corresponding to a TAKT = 30 min. The situation

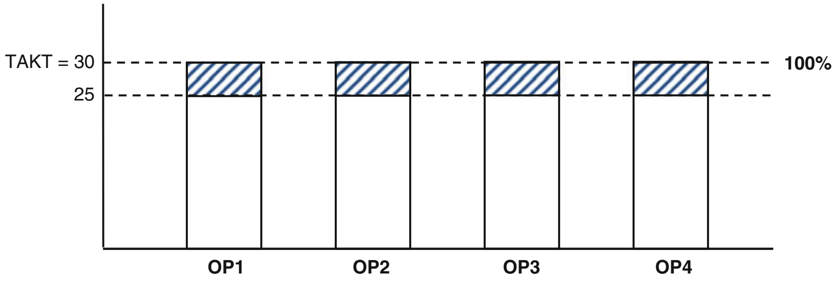


Fig. 6.21 Line balancing in a non lean flow

gets worse when the line operates to produce less than capacity because, in this case, lead-time increases and productivity decreases. This is the main reason why supervisors and production managers do not want to set up and staff lines with the appropriate personnel to satisfy daily demand less than the demand at capacity.

(c) Balancing work for a product mix

In the case of a product mix, balancing must be performed for every member of the mix separately, based on the TAKT of the mix per process. Thus, the number of resources can be calculated as follows:

$$RES_w = AT_w / TAKT \tag{6.22}$$

The work content time for each product at every operation is called the operational cycle time and is calculated as follows:

$$OP(ct) = AT / RES_w \tag{6.23}$$

From the above equation, it is likely that the time required for every operation varies from product to product and this is illustrated in the following figure (Fig. 6.22).

d) Operation of a flow line

After calculation of resources and the determination of the number of operations for each mixed model line, the mode of operation is described below. The basic characteristic of a flow line is the IPK (In Process Kanban). On the downstream side of every operation one IPK is placed as a rule. In Fig. 6.23 a balanced line exhibiting seven operations and the corresponding IPK per operation is illustrated. Prior to the execution of production, each operation will be filled with the related product in the appropriate semi-finished state.

It is quite acceptable that every IPK carries one semi-finished unit similar to the one carried by the corresponding operation. The IPK functions as a signal for the start and continuation of the work. An empty IPK is the signal to filling it. Every upstream operation continues work only if the corresponding IPK of the adjacent downstream operation is empty. The line starts producing when there is a customer pulling a finished product from the IPK at OP7 (Fig. 6.24).

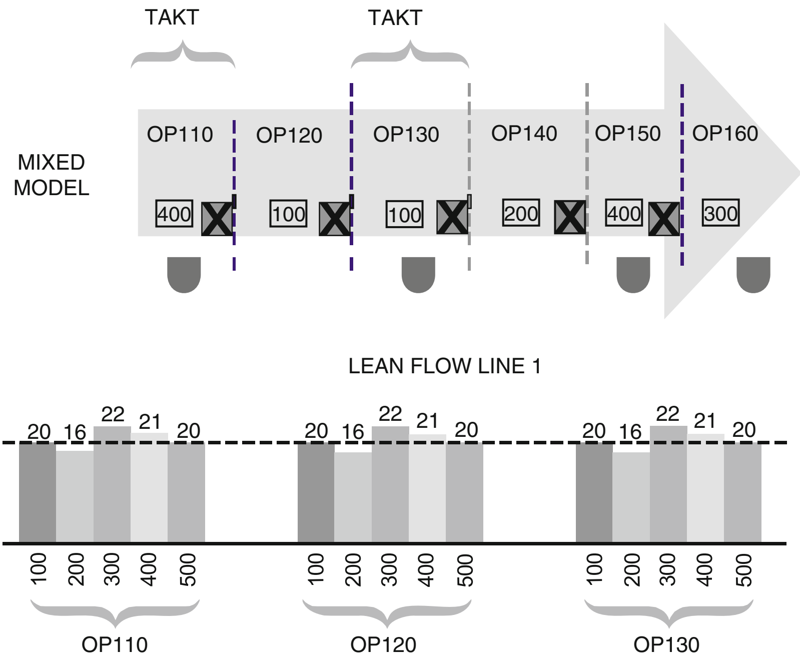


Fig. 6.22 Mixed model flow line

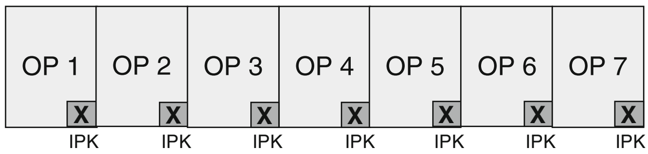


Fig. 6.23 Lean flow line after balancing

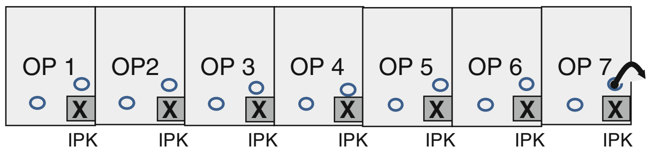


Fig. 6.24 Lean flow line prepared for production

Any withdrawal of a product unit from the IPK of OP 7 releases a series of consecutive cascaded signals towards the beginning of the line, resulting in the production of the product moving units from operation to operation in response to signals from the empty IPK. The movement concerned is illustrated in Fig. 6.25.

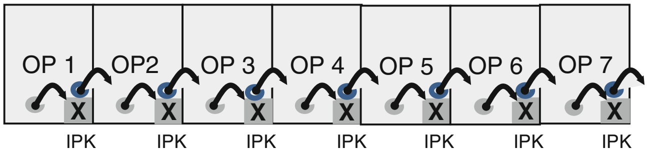


Fig. 6.25 Lean flow line during production

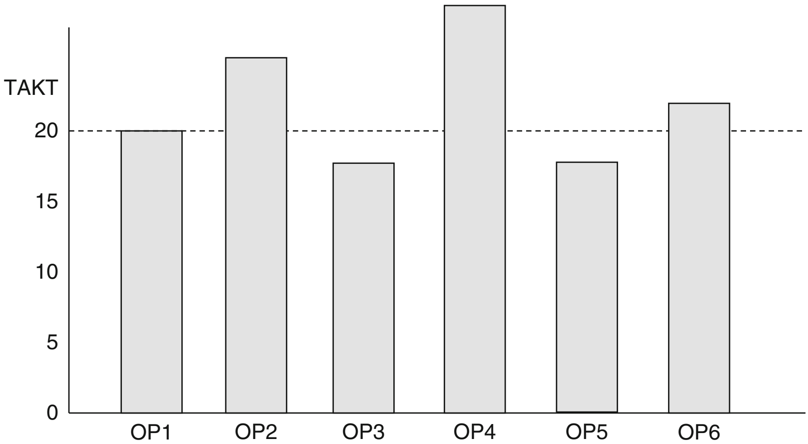


Fig. 6.26 Operations work content times

e) Balancing tools

In practice, it is true that perfection in balancing is an exception and not a rule. The availability of balancing tools is necessary, because the attainment of TAKT is, as mentioned above, a non-negotiable target. Let us suppose that after the first balancing activity the result exhibited in Fig. 6.26 has been achieved.

As shown in Fig. 6.26, it is clear that the line still exhibits imbalances. In order to support the activity of line balancing in a lean environment, the following tools are suggested, with the recommendation of applying them in the order presented:

1. Eliminate activities that do not add value
2. Relocate work to an adjacent operation
3. Add resources (operators or machines)
4. Add inventory and time for building the inventory

The above tools intervene directly on the line for balancing work. As well as these direct tools, there is another tool which intervenes indirectly on the production line in order to address product sequencing in a lean flow line. The basic thought is that one line can be balanced through an appropriate sequence of products with different work content from the same family, if these products are interchanged, as for example ABCςBCABC. The valid sequencing rule depends on the calculation of the mixed model lines defining the mix and volume of products for each line. This tool is described in detail in demand and production planning (Sect. 6.9.3). In the following there is a description of direct balancing tools.

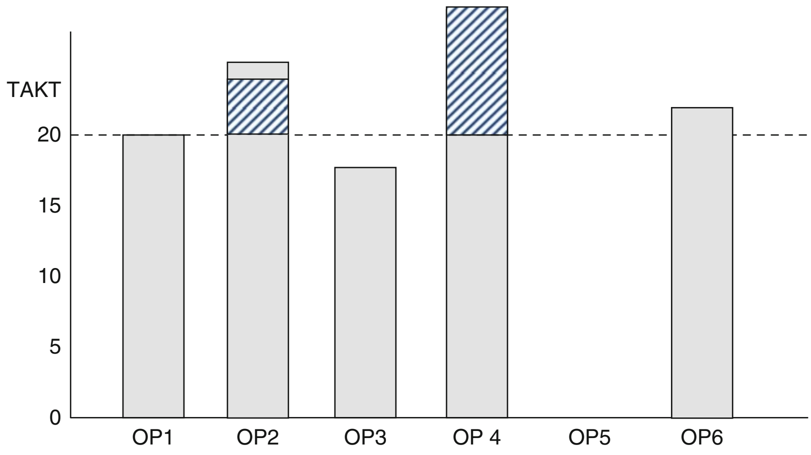


Fig. 6.27 Elimination of activities that do not add value

Eliminate activities that do not add value

Reduction and eventual elimination of all activities that do not add value to the SOE of the various products in each process is the target. Such activities concern transportation, preparation and setups. The tool should be used firstly in the implementation sequence to balance the line. The implementation of the tool is usually of low cost. In Fig. 6.27 the balancing situation after implementing the tool is illustrated.

Relocate work to an adjacent operation

This refers to the relocation of work from one operation to an adjacent upstream or downstream operation. In processes concerning manual work, the implementation of the tool is relatively simple as far as product design allows for it. In many cases, it is appropriate to modify the product in order to achieve better balancing. In processes concerning machine operations, relocation of work is almost impossible, mainly because machines execute specific work and such level of agility is not built-in by the manufacturer. In Figs. 6.28 and 6.29 respectively the balancing situation before and after work relocation is illustrated.

Add resources (operators or machines)

In cases where the implementation of the first two tools does not achieve the desired line balancing level then adding more resources, i.e. operators or machines is needed. In the example of Fig. 6.30 three production cases with different production processes are illustrated. TAKT in all cases is 10 min.

In case 1, the work content time in the bottleneck resource is 20 min, consequently, it will be necessary to add one more resource for the attainment of TAKT (20/10 = 2). The additional resource is added in parallel to the existing one and the work is also executed in parallel.

In case 2, the work concerns a machine process, where the average weighted time is ATw = 30 min. Consequently, the result of the division ATw/TAKT =3,

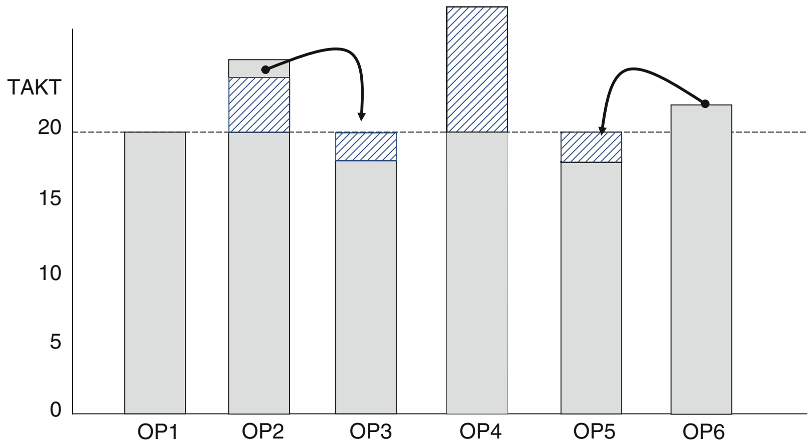


Fig. 6.28 Before work relocation

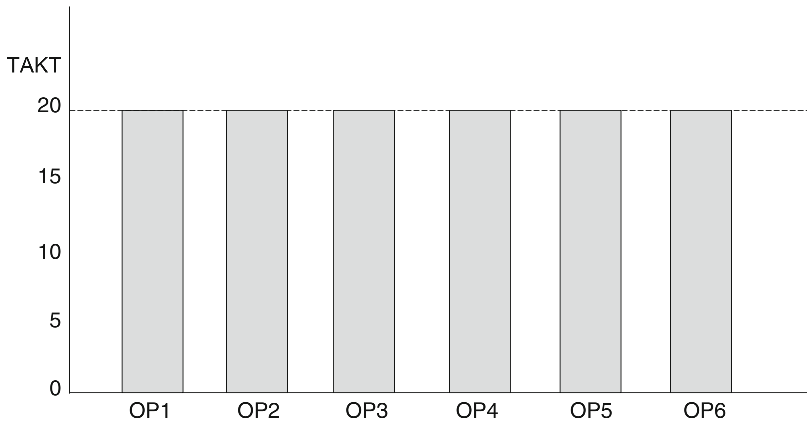


Fig. 6.29 After work relocation

and leads to the conclusion that three (3) machines will be needed for the attainment of TAKT (where setup time plus production time is smaller than TAKT). The work is executed as follows. During the first TAKT, the first machine starts production and needs 30 min to complete the task. In the second TAKT, the second machine starts and it also needs 30 min to finish the task. In the third TAKT, the third machine starts and needs 30 min as well for task completion. Therefore, after the first 30 min (10 + 10 + 10), the rhythm of production is 10 min. In this way, the attainment of TAKT is achieved, with three machines operating in parallel not in series and with an operation phase difference of 10 min each time.

In case 3, the work concerns a process with one machine, the average weighted time of which is ATw = 240 min. Therefore, the result of the ratio ATw/TAKT = 240/10 leads us to the conclusion that in this case there is a need for twenty four

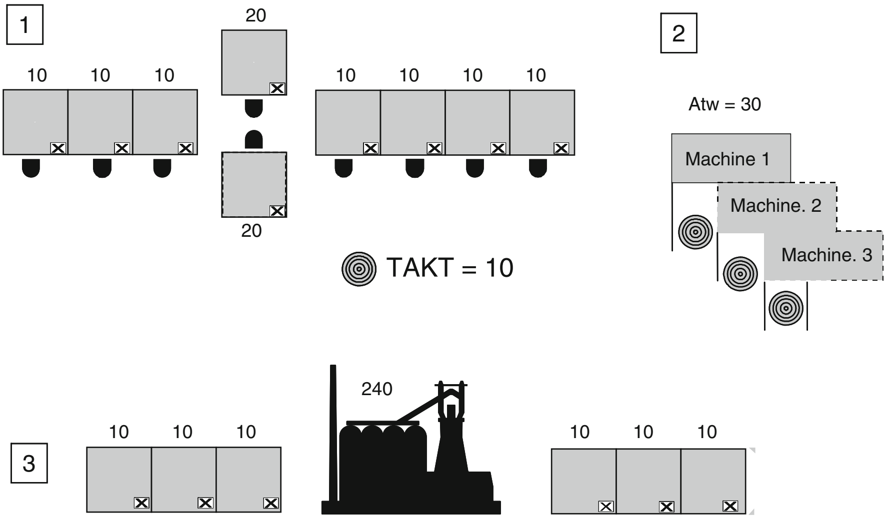


Fig. 6.30 Calculation of additional resources

(24) product units for the attainment of TAKT. The work is executed as follows: If the machine is static, in other words if during production the work is executed simultaneously on a number of pieces, then there must be at least 24 pieces in production and an equal number of pieces upstream and downstream so that the flow is not interrupted while the process is in progress. A typical example of such a process is the oven. The oven is a machine which usually operates on a number of product units, in this case 24, at the same time. For this reason, such machines are called static batch machines. In the case of a dynamic batch machine the work is executed simultaneously on a number of units where there will be one piece coming out of the process and at the same time there is a new one going in. The number of units inside the machine is still 24 at any time. Thus, the flow will not be interrupted while the process is in progress. A typical example of such a process is in the flow painting booth. This type of machine is based on one piece flow and for this reason it is called a dynamic batch machine.

Since the use of more resources will require investment, it must be evaluated as an alternative to building inventory, described underneath. The alternative solutions have advantages and disadvantages and must be used according to the needs of each enterprise.

Add inventory and time for building the inventory

Let a line have seven operations, one of which (OP4) is a machine operation. The work content time in every operation is 20 min, while in operation OP4 it is 28 min. It is obvious that in OP4 there is an imbalance. How can this problem be faced (Fig. 6.31)?

It is given that in every OP and the corresponding IPK there is one piece of semi-finished unit of a product. As long as there is a customer pulling a final product from OP7, then there will be a signal to start production, and after 20 min there will be a

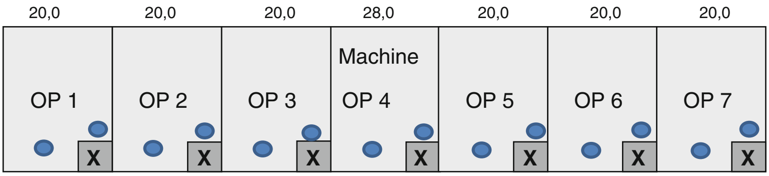


Fig. 6.31 Add inventory and time

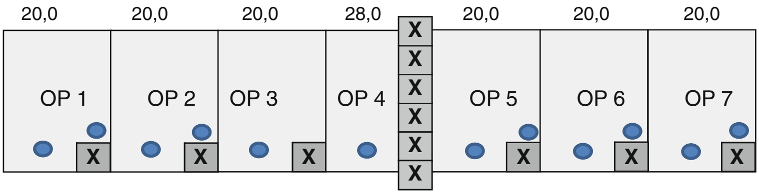


Fig. 6.32 Add inventory and time – start of shift

new semi-finished unit at all operations except OP5, where one unit will appear after another 8 min because the operational cycle time at OP4 is 28 min. In this case, there is flow interruption which must be repaired otherwise there is a danger of violating TAKT. The proposed way to face this imbalance is to add an inventory in front of OP4 so that every 20 min there will be one piece flow to OP5. The minimum number of units (number of IPK) that should be built and be available as an inventory in front of OP4 is calculated as follows:

$$\text{Number of IPK} = \text{I} \times \text{C} / \text{TAKT} \tag{6.24}$$

where

I (imbalance) = AT – TAKT

C (number of imbalances during the shift) = H/AT

In the case of a mixed model line there is by definition no imbalance and therefore C = 1. Through simple substitution of the data (H = 420, TAKT = 20) in (6.24) it gives

$$\text{Number of IPK} = [(28 - 20) \times (420/28)]/20 = 8 \times 15/28 = 6$$

Thus, the minimum number of pieces that must exist as inventory at the start of the shift in front of OP5 is six (6). The following figure illustrates the situation at the beginning of the shift before production starts with 6 IPK filled with semi-finished units at the downstream side of OP4 (Fig. 6.32).

With one piece flow assured in the line, what will be observed at the end of the shift is the accumulation of six (6) pieces of semi-finished units at the downstream side of the machine at OP3. Therefore, there is a need for placing six (6) IPK on the downstream side of OP3 (Fig. 6.33).

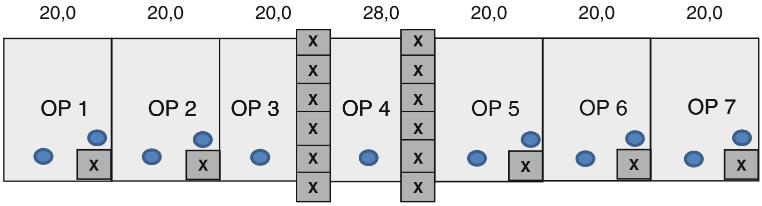


Fig. 6.33 Add inventory and time – end of shift

Before production continues in the next shift, the necessary inventory must be prepared on the downstream side of machine operation OP4 as described above. For this reason, and before the start of the next shift, there will be a need to operate the machine at OP4 for the production of 6 pieces of semi-finished units. This work will require a time equal to 168 min (= 6 × 28). The time of 168 min needed can be credited to an operator who would come 168 min before the start of the shift and leave 168 min before the end of the shift. Thus, the extra time for building inventory is not overtime.

f) Fulfilment of daily demand

The calculation of resources needed for the design of lean flow in production is made on the basis of designed daily rate (Dc). If however, the daily demand rate (Dr) is different from Dc, how many resources must be placed on the production line? The formula used for resources calculation based on the daily demand rate Dr is the same for calculating resources for the line design based on Dc, substituting Dc for Dr (for one shift and one product) in (6.9).

$$\mathrm{TAKT} = \mathrm{H}/\mathrm{Dr} \tag{6.25}$$

$$\mathrm{RES} = \mathrm{AT}/\mathrm{TAKT} = \mathrm{AT} \times \mathrm{Dr}/\mathrm{H} \tag{6.26}$$

Let us suppose that one line is calculated to have five (5) operations for a Dc = 100 pieces. If one day the need is to produce 80 pieces then the question is how many operators will be required to work on the line? The implementation of the simple method of case three will result in one operator less compared to the case of the production of 100 pieces [(1−0.8) × 5 = 1]. With four (4) operators, how would they be placed on the line? In non lean flow production, the answer is given through the redistribution of work so that the work can be allocated to four (4) operators and not to five (5) as originally designed. However, doing this leads to extra work each time the daily production rate is different from the Dc, which is not only time consuming, but does not add value. In an environment of lean flow, the four operators are placed, without any conditions or rules attached as to their initial placement, at four operations. Despite there being four operators on the line, all five operations have to be accomplished so there must be movement of the operators at specific points in time, each time towards an empty operation (hole). In Fig. 6.34 one initial situation is illustrated.

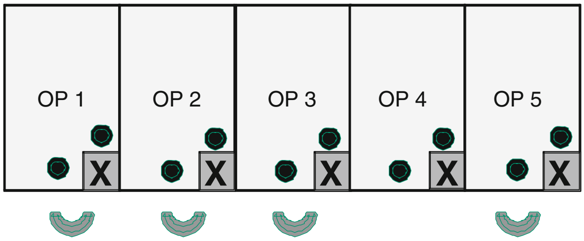


Fig. 6.34 Lean flow line with a hole in OP 4 and flexing

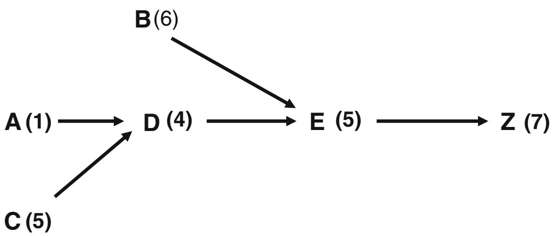


Fig. 6.35 Product synchronization flow

The movement is regulated by an empty IPK and is always in the direction of the customer (downstream) aiming to fill the empty IPK. The precondition for the movement of the operator is work completion at the current operation. If the downstream operation IPK is full, then the operator should move to the upstream operation only if the IPK is empty. If neither IPK is empty then this is a sign that the line has stopped producing. This technique is called flexing. Flexing poses the requirement that each operator knows how to perform work of a minimum of three operations: the main operation, one upstream and one downstream. For reasons of quality assurance, the quantity that may be required to be produced daily cannot be equal or less than half (1/2) of Dc. The reason is that in this case every operator would both test and validate his (her) own work without a second pair of eyes to validate the work. Process capability, expressed in quality level and line efficiency, is endangered in this case.

g) Total product cycle time

In lean flow, the product lead time is called total product cycle time – TPct. To each product corresponds one TPct and it is defined as the longest time path through manufacturing. Its calculation is based on the product synchronization flow. For the calculation of TPct, the procedure always starts from the point closest to the customer and examines all possible times paths until its arrival at the origin of the path. The diagram illustrated in Fig. 6.35 depicts a product synchronization flow made of six processes and the corresponding work content times.

The work content time of all processes is AT = 28 (A + B + C + D + E + Z), while the TPct = 21 (Z + E + D + C) corresponding to the longest time path of

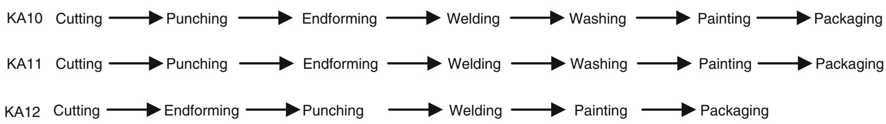


Fig. 6.36 Product synchronization flow

	Cutting	Punching	Endforming	Welding	Washing	Painting	Packaging	Dc
KA10	2,0	3,5	1,5	2,2	4,0	3,2	2,5	10,0
KA11	2,5	3,0	2,0	2,5	3,5	3,0	2,5	100,0
KA12	2,8	3,6	1,8	2,3		3,2	2,5	50,0

Fig. 6.37 Process map

the product synchronization flow. TPct is also the basis for accumulating production cost. The aim is the continuous reduction of TPct through the reduction of work content times of processes that are part of the TPct path. A continuous reduction in TPct also means a reduction in production costs. Therefore, activities relating to improvements in production must be performed on the TPct path. TPct should be necessarily updated each time there is an improvement, because it may be that another time path has become the longest time path through manufacturing. On the basis of the above diagram, an improvement in the currently valid TPct is possible in order to establish another path e.g. Z → E → B as the new TPct = 18. In Sect. (6.11) a method of cost accounting and its implementation in a lean environment, particularly in production, is presented.

6.5.2 Lean Flow in Machines Environment

The same six-step procedure is also followed in the manufacturing of parts in a machines environment. The method finds its full implementation in such environments. Doubts are frequently expressed concerning whether manufacturing processes can be implemented using the logic of lean flow. The reasons why questions arise are related to the restricted flexibility and different production times and with the existing setup times of the machines that process materials. Specifically, the ability of machines producing inside the TAKT is placed in doubt. In the following example, the method of lean flow is followed step by step for the design of lean machine cells. Let us design a lean flow cell for a mix of products with the following part numbers, KA10, KA11 and KA12. The following data are given:

1. Product synchronization flow (Fig. 6.36)
2. The process map with the corresponding times and the Dc for every product (Fig. 6.37)

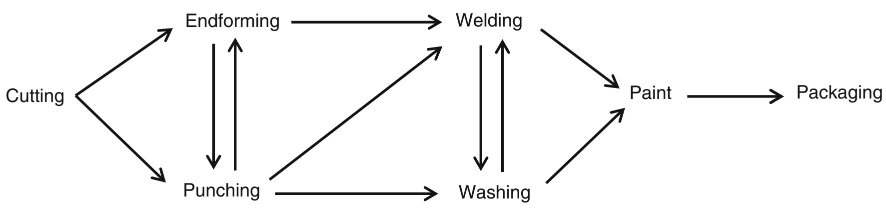


Fig. 6.38 Mixed model product synchronization flow

	Cutting	Punching	Endforming	Welding	Washing	Painting	Packaging
KA10	2,0	3,5	1,5	2,2	4,0	3,2	2,5
KA11	2,5	3,0	2,0	2,5	3,5	3,0	2,5
KA12	2,8	3,6	1,8	2,3		3,2	2,5

Fig. 6.39 Process map

	Cutting	Punching	Endforming	Welding	Washing	Painting	Packaging	Dc
KA10	2,0	3,5	1,5	2,2	4,0	3,2	2,5	10,0
KA11	2,5	3,0	2,0	2,5	3,5	3,0	2,5	100,0
KA12	2,8	3,6	1,8	2,3		3,2	2,5	50,0
H	450,0	450,0	450,0	450,0	450,0	450,0	450,0	
SHIFTS	1,0	1,0	1,0	1,0	1,0	1,0	1,0	
Σdc	160,0	160,0	160,0	160,0	110,0	160,0	160,0	
TAKT	2,8	2,8	2,8	2,8	4,1	2,8	2,8	

Fig. 6.40 Takt calculation

What is required is the number of machines needed for balancing the cell and the design of a possible conceptual flow diagram. The method of lean flow is implemented.

Step 1: Mixed model product synchronization flow (Fig. 6.38).
Step 2: Sequence of events (SOE). In the case of machines, the SOE does not apply the balancing act, i.e. grouping work to TAKT, because it is practically not feasible to move work from one machine to the next.
Step 3: Process map. The work content times per process and product are given in minutes (Fig. 6.39).
Step 4: Determination of Dc and TAKT calculation. The designed daily rate per product is given. Furthermore, it is known that the shift duration is H = 450 min. Hence, the process map is completed with the TAKT calculation (Fig. 6.40).
Step 5: Resources calculation per process. Based on the theory, the process map is completed with the resources calculation (Fig. 6.41).

	Cutting	Punching	Endforming	Welding	Washing	Painting	Packaging	Dc
KA10	2,0	3,5	1,5	2,2	4,0	3,2	2,5	10,0
KA11	2,5	3,0	2,0	2,5	3,5	3,0	2,5	100,0
KA12	2,8	3,6	1,8	2,3		3,2	2,5	50,0
H	450,0	450,0	450,0	450,0	450,0	450,0	450,0	
SHIFTS	1,0	1,0	1,0	1,0	1,0	1,0	1,0	
Σdc	160,0	160,0	160,0	160,0	110,0	160,0	160,0	
TAKT	2,8	2,8	2,8	2,8	4,1	2,8	2,8	
Atw	2,6	3,2	1,9	2,4	3,5	3,1	2,5	
RES	0,9	1,1	0,7	0,9	0,9	1,1	0,9	

Fig. 6.41 Calculation of resources

Step 6: Cell balancing. From the process map in step 5 it is obvious that there are enough resources (all values are <1) apart from the punching press where the calculation shows that more resources are required (1.1). That means that with this product mix a TAKT of 2.8 min cannot be achieved. Therefore, we must use the balancing tools described above. From the tools discussed there are three candidates: the elimination of activities which do not add value, adding resources and the use of inventory and time. We consider that the first tool has already been used. Adding a punching press to cover an imbalance of 10% is not financially justified. Therefore, what remains as a suitable solution is the third tool, the one of adding inventory in combination to the time needed for the creation of this inventory. The use of the formula 6.24 in order to calculate the extra IPK needed, gives the following results:

$$\text{Number of IPK} = \text{I} \times \text{C} / \text{TAKT}$$

IPK = $(AT_w - TAKT) / TAKT$ (C=1, product mix)
IRK = (3.2 – 2.8) / 2.8
IPK = 0,14 → 1 (IPK < 1 cannot exist)
Therefore extra time = 1 × 3.2 = 3.2 min

The result of the formula expresses the number of extra IPK that need to be added before and after the press for balancing the line.

Step 7:Conceptual lean flow layout (Fig. 6.42).

In the lean flow layout the result of balancing with two IPK placed before and after the punching press process has been taken into account.

6.5.3 Lean Flow in Spare Parts

Concerning production of spare parts, these are products with their own demand, bill of materials (BOM) and turnover which must be considered. The production of spare parts takes place at the same flow lines as the main stream products of the

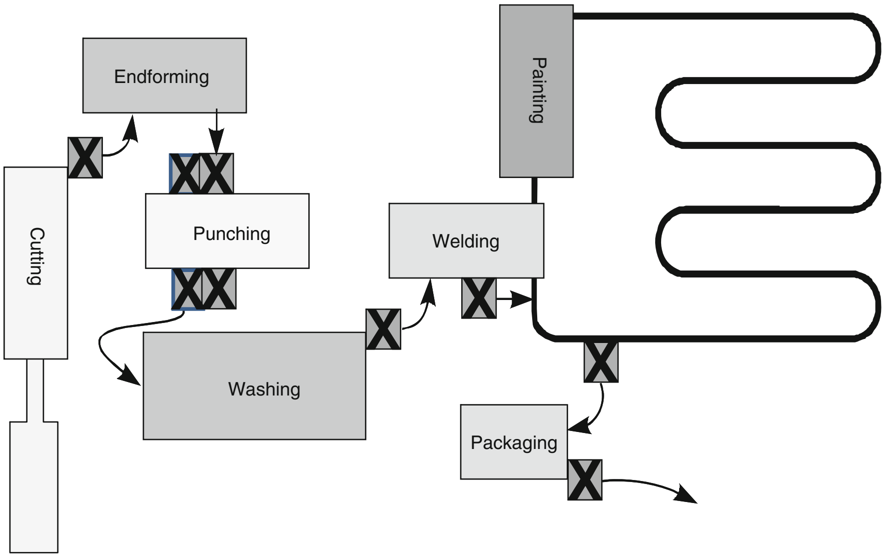


Fig. 6.42 Conceptual lean flow layout in a machines environment

company. In the case where spare parts are produced, the Dc must be adjusted for every product to account for the additional demand unless there is a separate forecast exclusively for the spare parts. The rest of the procedure is exactly the same as described above.

6.6 Lean Material Flow

The lean material flow exploits the physical synchronization of work with the aim of achieving high inventory turns (IT) in production needed for order fulfilment without breaks. The result is the realization of the order at the time needed with a high lean flow index (LFI) and therefore a reduction in the cost of production, once a high useful productivity is achieved (Sect. 6.3.2). Hence, it is necessary, on the one hand to design production with high and sustainable IT, on the other hand this production environment will exhibit an increasing useful productivity which will gradually be extended to the whole supply chain. The beginning takes place at the point closest to the customer i.e. production, continues towards the raw materials warehouse and finally towards the suppliers. The lean supply chain presupposes collaborative behaviour from all the stakeholders in the value added network. The internal logistics will be studied at this point, which is the core for the realization and extension of the strategy in the supply chain.

For the achievement of a high IT in the production process, the pull mechanism based on Kanban is used. The use of the Kanban method makes the involvement of any other materials requirements planning system redundant. There are two types of

Table 6.3 Cases of Kanban pull sequences

From → to	Stores	Supermarket	Flow line	Machine or machine cell
Stores	F	F	P	P
Supermarket	F	F	P	P
Flow line	F	F	P	P
Machine or machine cell	F	F	P	P

Table 6.4 Example of a Kanban pull sequence

½	Flow line	F	Supermarket	P	Machine or machine cell
½	Flow line	←	Supermarket	←	Machine or machine cell

requests: the request for fetching materials (F) and the request for the production of more materials (P). The request for fetching materials is called fetch-Kanban, while the request for producing more is called production-Kanban. One Kanban request is half of the pull mechanism procedure. The other half belongs to the fulfilment of the request by receiving the quantity of the material or the product at the point where the need for replenishment was created.

After line design, the concern is the design of the replenishment system for providing materials to the lines from one or more points of storage. This point of storage is called a supermarket that, together with the supported lines, creates a physical and logistical site for the use of inventory that includes materials in raw and in-process form and is called RIP (raw and in-process). Table 6.3 presents the possible Kanban requests in production. In a lean flow environment the objective is to create pull sequences which start from the point of use closest to the customer and finish at the point of reception for suppliers.

A pull sequence may consist of a Kanban mix for fetching and producing materials as shown in Table 6.4. This particular pull sequence starts from a flow line that needs a part for the production of the final product and is replenished by means of a Kanban request from a supermarket. The supermarket is replenished by the machine or machine cell producing the part. The flow constitutes half (1/2) of the replenishment procedure. The request is satisfied through the return of materials from the supermarket and constitutes the other half (1/2) of the pull sequence. In the following section, the procedure and the economic aspect of the lean materials flow design is described.

6.6.1 Design of the Pull Mechanism

This relates to the replenishment of the flow lines with materials and components, either from those which come from suppliers or those produced through their own resources. The following figure illustrates the possible pull sequences in production (Fig. 6.43).

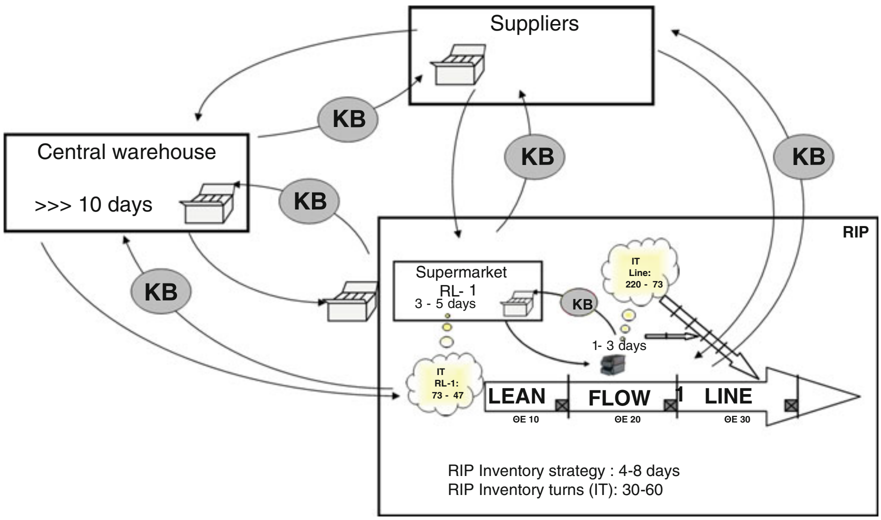


Fig. 6.43 Pull sequences

Inside the RIP, production evolves and whatever is consumed must be replenished. The achievement of a high IT inside the RIP leads to reductions in bounded working capital, production costs and improvements in assured quality, as described underneath:

Reduction in working capital needs

This is achieved through the replenishment time of the supermarket and the flow lines. An inventory policy which satisfies a high IT ranges from 4 to 8 days. In this case, if the number of working days is 240, then IT = 240/8 = 30 in the case of a replenishment time of 8 days, and IT = 240/4 = 60 in the case of 4 days of replenishment time. If IT = 30 then the necessary working capital is regained 30 times per year (2.5 times per month), if IT = 60, then it is regained 60 times per year (5 times per month).

Reduction in production cost

This is achieved due to the reduction of the active inventory (RAW + WIP) in RIP. Furthermore, it is due to the reductions in overhead achieved through the use of the principle of double container (Kanban) and the use of the quick count methodology. The Kanban method does not demand the allocation of material to production orders, which is free to be used for the production of any product. Moreover, because of the high IT, a physical inventory counting is not required, which results in overhead costs being lowered even further.

Quality improvement

One piece flow and the low active inventory ensure the capability of immediate localization of mistakes and of its correction at the source before its detection at an advanced phase of production. Given the aim to create RIP sites sustaining high IT, the quality of the attainment of the target depends on the flow typology and specifically from interaction flows with the end-user.

The central role in target realization is undertaken by the supermarket. In a lean enterprise, ultimate reduction is in the gradual decrease in the need sustaining the role of a central warehouse. The future storage place is called a supermarket. The difference is neither verbal nor spatial; it is essential, and concerns the transformation of the central warehouse into a supermarket. What essentially is a supermarket? A supermarket is a store characterized by the following inventory policy: 80% of the value of inventory is sufficient for about 10 days, corresponding to an IT = 240/10 = 24. The remaining 20% of the inventory value belongs to the central warehouse for longer than 10 days. This target shows the strategic direction in which every enterprise should be oriented.

The continuous and gradual approach of the target will occur with the involvement of all the stakeholders in the venture. However, it will be mainly up to the department of purchasing and production on the side of the enterprise, and the contracted suppliers on the other, to realize the target. This concept naturally presupposes suppliers resupplying the lean enterprise within 10 days, at all times. It is often true that suppliers are a long way from the production site. In a globalized market for materials and components where purchasing cost plays a significant role, it is logical that enterprises have been oriented towards suppliers with low materials cost, but they do not usually account for the cost of working capital, the cost of production and the cost of quality, which may be caused by the one-dimensional view of looking only at the cost of materials. The strategy that an enterprise will choose to implement regarding materials must consider all the parameters in the extended value stream for the calculation of all types of cost influenced by these parameters (total cost of ownership). One more phenomenon arising from the current economic climate, and one which will possibly be amplified in the future is ocean piracy (Burnson 2011), which puts the supply chains in danger.

In the lean enterprise, the cost is reduced as the time during which a piece of material or component waits without a specific mission in a factory is reduced. An inventory without a specific mission is called inactive inventory. The inventory which fulfils the preconditions of its existence in the supermarket and generally in the RIP, is called active inventory. In the following there are two examples of RIP corresponding to two different flow types: production of standardized products (Fig. 6.44) and configured products (Fig. 6.45).

It is obvious that in the case of a standardized product the active inventory in the RIP will be higher than the active inventory of the configured product, because the customer interaction point is early on in the production process. The difference is mainly due to the different type of active materials inventory existing in the supermarket.

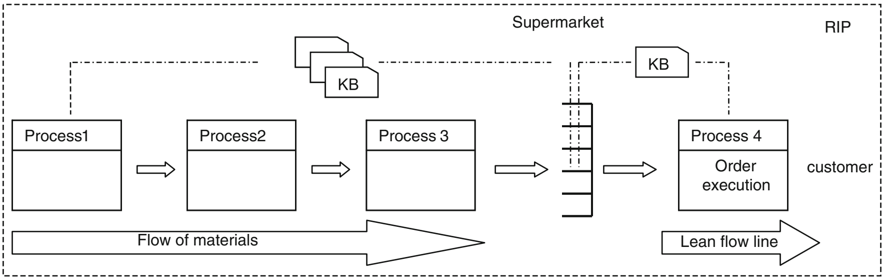


Fig. 6.44 Standardized products

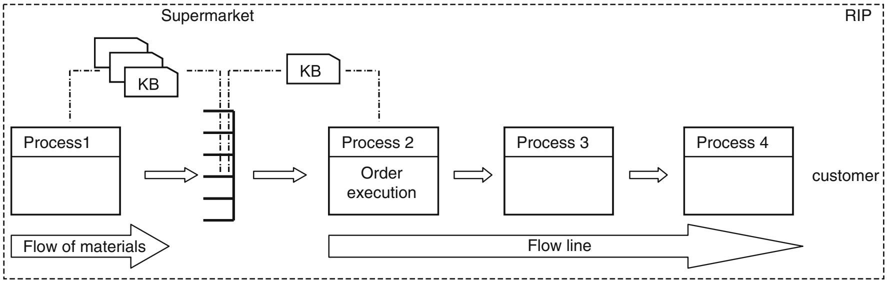


Fig. 6.45 Configured products

6.6.1.1 Calculation of Material Kanban Quantity

The material Kanban quantity (Kq) is calculated by using the following formula:

$$Kq = \frac{R}{TAKT} \tag{6.27}$$

The Kanban quantity Kq covers with material the time within which components must be available for production needs, R refers to the replenishment time of a component belonging to a final product with a certain TAKT and a quantity Q used per product. Substituting TAKT = H / (Dc × Q) accounting for components consumption and supplier packaging size P, the above formula (6.27) can be written as

$$Kq = \frac{Dc \times Q \times R}{H \times P} \tag{6.28}$$

Dc	=	Product designed daily rate at capacity
Q	=	Quantity used per component for product (BOM)
R	=	Replenishment time for the component
H	=	Time available for component replenishment
P	=	Component package size

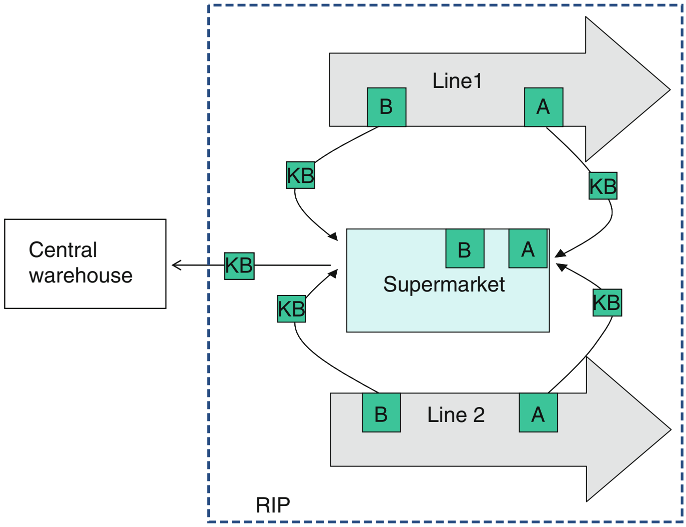


Fig. 6.46 Kanban sizing

The formula (6.28) calculates the minimum Kanban quantity concerning pull sequences of type (F) for materials. In the formula concerned, the most important parameter is the replenishment time – (R) of the point of use and it is directly connected to the time of material resupply from a supplier (internal or external). For external suppliers, R is a negotiable issue. Regarding internal suppliers, R depends on the inventory policy selected for the point of resupply. Practically, it refers to the time interval for which a point of resupply must have a certain amount of inventory available for the support of the points of use defined by the pull sequences.

Material inflows in the RIP increase the amount of inventory, while outflows decrease it. As regards RIP inflows, the update is done via a related transaction in the production information system. For RIP outflows, the update is performed automatically (back-flush transaction) at the moment of the final product completion based on the BOM. Inside the RIP there is no need for precise information related to materials movement because of the high IT. For the exact inventory balance inside the RIP what is still missing is the exact amount of scrap that must be declared separately.

The procedure for designing lean material flow based on the example above is described hereafter.

Step 1. concerns the calculation of the Kanban quantities for two components (A, B) which are used in two lines (1, 2). The components are resupplied by a supermarket. Line 1 produces final product X and line 2 produces final product Y (Fig. 6.46).

The data are shown in the Table 6.5.

The requested Kanban quantities are shown in the Table 6.6.

Table 6.5 The data

	Line 1 X(A,B)	Line 2 ϒ(A,B)	Supermarket
Dc	150	100	–
Q	(2,1)	(5,3)	–
R	2 days	1 day	5 days
H	1 day	1 day	1 day
P	(5,10)	(5,10)	–

Table 6.6 The requested Kanban quantities

	Line 1 (packs)	Line 2 (packs)	Supermarket (packs)
KB_A	+	+	+
KB_B	+	+	+

Implementing the formula (6.28) successively for each component and line the following results are accrued

Line1

$$KB_A = 150 \times 2 \times 2/(1 \times 5) = 120 \text{ packs}$$

$$KB_B = 150 \times 1 \times 2/(1 \times 10) = 30 \text{ packs}$$

Line2

$$KB_A = 100 \times 5 \times 1/1 \times 5 = 100 \text{ packs}$$

$$KB_B = 100 \times 3 \times 1/1 \times 10 = 30 \text{ packs}$$

Supermarket

The supermarket supplies both lines with components A and B, therefore formula (6.28) can be written as follows:

$$KB_i = \Sigma(Dc_j \times Q_{ij}) \times R/(H \times P_i)(I = \text{component}, j = \text{line}) \tag{6.29}$$

Expanding the above formula for component A and B respectively gives the following results

$$KB_A = \left[\left(Dc_1 \times Q_A{}^1\right) \times R\right]/(H \times P_A) + \left[\left(Dc_2 \times Q_A{}^2\right) \times R\right]/(H \times P_A)$$
$$KB_B = \left[\left(Dc_1 \times Q_B{}^1\right) \times R\right]/(H \times P_B) + \left[\left(Dc_2 \times Q_B{}^2\right) \times R\right]/(H \times P_B)$$

Arithmetic substitution gives:

$$KB_A = [(150 \times 2) \times 5]/(1 \times 5) + [(100 \times 5) \times 5]/(1 \times 5) = 800 \text{ packs}$$
$$KB_B = [(150 \times 1) \times 5]/(1 \times 10) + [(100 \times 3) \times 5]/(1 \times 10) = 225 \text{ packs}$$

Fig. 6.47 Two bin Kanban system at the production line

The results are summarized below

	Line 1	Line 2	Supermarket
KB_A	120	100	800
KB_B	30	30	225

Step 2. concerns the implementation of the pull mechanism on the shop floor. For implementation, it is necessary to explain how the results will be used. For each calculated Kanban quantity per component for each line, two containers should become available, each of which must be able to accommodate the calculated quantity. The line is resupplied with components from the supermarket, using the principle of two bins as follows: one bin is filled with the calculated Kanban quantity, while the second bin is empty. The empty bin is a signal for replenishment that takes place at the supermarket. In Fig. 6.47 an example of such a system is presented.

The time interval inside which this may happen is equal to R selected for every line. Each Kanban container carries the following five elements: the description of the part, its code number, the point of use, the point of resupply and the Kanban quantity. Above, an example of a Kanban card with the five elements is given (Fig. 6.48).

For transportation inside the RIP, e.g. production lines resupplied from the supermarket, the Kanban card can, instead of the exact quantity, use a quick count method, as for example two containers, one box, three palettes, one sack etc. The reason is that transfers and movements of materials in the RIP do not need to be recorded due to high IT, as already mentioned above. The two-bin, single card system, as it is called, is only used for resupplying the lines with materials and constitutes the fetch-Kanban unlike the product Kanban described below. The system concerned helps to keep a low inventory at the lines, thus achieving resupply just in time. A similar system is used for the replenishment of materials outside of

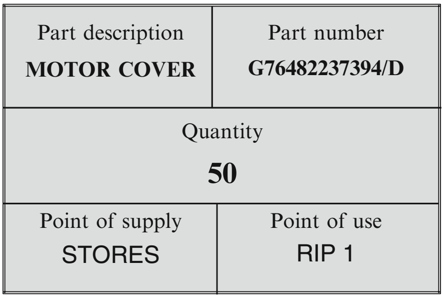


Fig. 6.48 Kanban card

Table 6.7 Results of Kanban sizing

	Line 1 (packs/cards)	Line 2 (packs/cards)	Supermarket (cards)
KB_{ς}	120/1	100/1	800:100 = 8/8
KB_B	30/1	30/1	225:30 = 7.5/8

RIP, e.g. between the stores and supermarket or the suppliers and the supermarket. All inflows or outflows from RIP require full and exact identification. In any other case the accuracy of the inventory is reduced. Therefore, it is obvious that the use of two bins contributing to the conservation of lean replenishment of materials in the RIP is an essential tool of lean production.

Regarding the operation of the pull sequence between the supermarket and central warehouse, the calculated quantity per part must be placed in a number of bins similar to those used for the Kanban operation at the production lines. To calculate the number of bins (Kanban cards), the minimum Kanban quantity per part and line is taken into account and this quantity is divided by the total Kanban quantity that resulted from the calculation of Kanban quantity for the supermarket. The result is rounded up to the next integer number of cards. Underneath, the results of Kanban sizing are exhibited in Table 6.7.

The supermarket which will be created must contain a minimum quantity for both parts. For part A, 8 bins with the respective Kanban cards, where each bin will contain 100 packs and for part B, 8 bins with the respective Kanban cards, where each bin will contain 30 packs. At production lines 1 and 2, for part A, 2 bins (1 full and 1 empty) with a capacity of 120 packs for line 1 and 100 packs for line 2. For part B, 2 bins (1 full and 1 empty) with a capacity of 30 packs with the respective Kanban cards for both lines. The number of Kanban cards is the minimum needed to be introduced to the resupply circuit. In practice, for reasons of better regulation of the material flow in the pull sequence, the use of more cards for absorption of possible demand variations is desirable. Furthermore, through the technique of inserting or withdrawing Kanban cards, demand adjustments can be achieved without the need to reprogramme production or redesign the Kanban system.

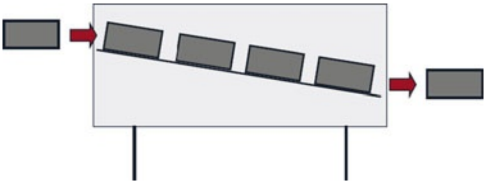


Fig. 6.49 Operating principle – FIFO

Fig. 6.50 Part of a supermarket

However, how does replenishment between the lines and the supermarket and the supermarket and stores operate? Let us suppose that at line 1 a bin containing part A becomes empty. The material handler takes the empty bin and goes to the supermarket. At the supermarket, he finds a bin filled with part A, removes the line Kanban card from the empty bin and places it inside the full bin. In the empty bin, he places the card removed from the full bin located at the supermarket. Using this procedure, it is guaranteed that the Kanban cards are kept within the replenishment circuits for which they were created to regulate. The empty bins in the supermarket are collected and transferred for replenishment by the corresponding materials handler to the point of their resupply based on the respective pull sequence, where the same procedure is followed as described above. Finally, full bins are stored by the materials handler in the supermarket and the lines following the FIFO principle (first in-first out). Figure 6.49 illustrates the FIFO operating principle. Figure 6.50 presents part of a supermarket.

Fig. 6.51 Supermarket Kanban board

There are three possible suppliers of a supermarket: another supermarket or stores, a production line (automated or manual) and an external supplier. In all three cases, there is a need for managing material replenishment. There are many ways to collect and organise the Kanban cards at the supermarket. One method frequently used is the following. Each time a bin is removed from the supermarket for transfer to the production line, the respective Kanban card is posted on a board (called a Kanban board) placed for that reason very close to the supermarket. Once per day usually after the end of the shift for practical and security reasons, the responsible materials handler collects and transfers the cards and the empty bins for replenishment and resupply of the supermarket. An example of a Kanban board is shown in Fig. 6.51.

There are cases where the recording of materials consumption before the completion of the finished product to achieve high inventory accuracy inside the RIP is not only desired but also obligatory. Such cases regularly show up in production where there are processes which have a completion time of several days (e.g. the oven) and therefore the final recording of materials consumption through the back-flush transaction is not enough for guaranteeing high inventory level accuracy. In these cases, an intermediate recording of the consumption of all materials concerning the corresponding semi-finished state is suggested. The final consumption is registered at the completion of the finished product (Fig. 6.19. Intermediate material consumption). Typically the intermediate consumption concerns 95% of the final product BOM, with the other 5% included in final consumption. The point where the back-flush takes place is called the intermediate back-flush location (Constanza 1982) (Fig. 6.52).

6.6.1.2 Calculation of Production Kanban Quantity

Two cases of production-Kanban can be distinguished:

1. The producing resource is a machine cell
2. The producing resource is a single machine

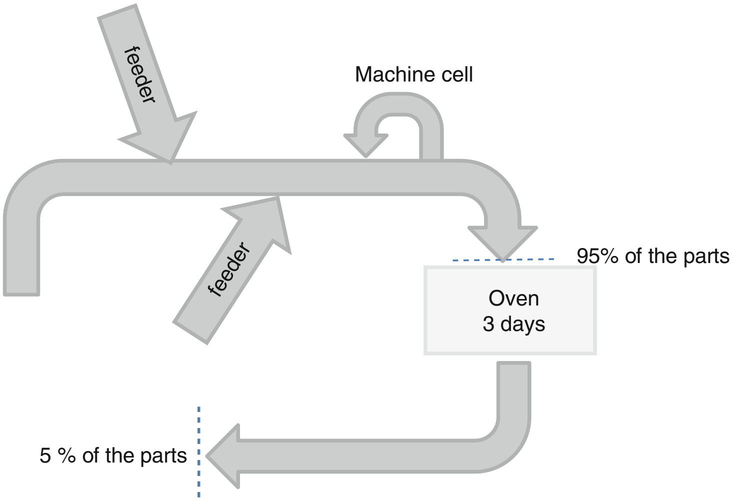


Fig. 6.52 Intermediate material consumption location (Constanza 1982)

If the producing resource can produce products within the TAKT of the lean flow line, then one piece flow can be achieved and there is no need for activation of any pull mechanism. In this case it holds that: production time per unit of product (te) plus setup time (tr) of the producing resource is lower or equal to the TAKT of the lean flow line:

$$\text{te} + \text{tr} <= \text{TAKT} \tag{6.30}$$

The producing resource can at any time supply the point of use at the line with whatever part is needed to complete the order within its TAKT. However if

$$\text{te} + \text{tr} > \text{TAKT} \tag{6.31}$$

then the producing resource cannot produce in one piece flow for the line and therefore must be decoupled from the flow by means of a supermarket and the use of a pull mechanism implementing a Kanban system. The two cases are examined below by means of two examples.

Case 1: Machine cell A machine cell consists of a series of dissimilar machines connected for the production of a family of products. The example scenario refers to the following pull sequence for a family of products:

Lean flow line	→	Supermarket	→	Machine cell

The pull sequence is described as follows: the point of use at the flow line is supplied with the needed products by means of a fetch Kanban from the supermarket which in turn is resupplied by a machine cell. The calculation of the production

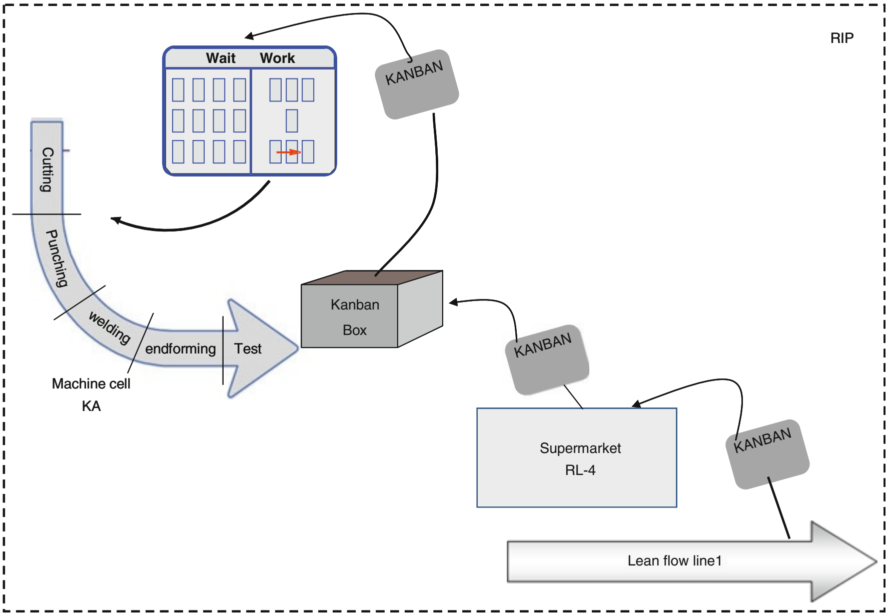


Fig. 6.53 Pull sequence for production Kanban

Kanban quantity for fulfilling the line demand is requested. Concerning the fetch Kanban quantity the parameter R is determined, on the basis of the desired inventory policy at the flow line. For the calculation of the production Kanban quantity the parameter R can be negotiated with those responsible in production. However, this way of determining the parameter R is based on practical experience without any theoretical base. Underneath, a way is described so that the theoretical approach may give new data to be considered for the final decision. The following diagram illustrates the pull sequence of the example (Fig. 6.53).

The lean flow line, the supermarket and the machine cell are all inside the same RIP. Product KA10 is used on the line and is replenished by supermarket (RL-4). The supermarket is resupplied by the machine cell (KA), by means of production Kanban. The production Kanban cards are collected into a Kanban box and then transported to the machine cell for production planning. Moreover, the machine also produces other products, which for practical reasons are taken into account here only for calculating the TAKT of the cell. Underneath, the procedure for the calculation of the Kanban quantities is described.

The following are requested:

1. Calculation of the fetch-Kanban quantity for the product KA10, from the supermarket to the line
2. Calculation of the production Kanban quantity for the product KA10 from the machine cell (KA) to the supermarket

Table 6.8 Data for the calculation of fetch-Kanban quantity

Dc	Demand at capacity	150
Q	Quantity used	1
H	Available time for production	8 h
Rl	Line replenishment time	4 h
P	Packaging size	1

Table 6.9 Data for the calculation of TAKT of the cell

ΣDc	Total demand at capacity	960
H	Available time for production	8 h

Table 6.10 Data for the calculation of cell Kanban quantity

	tr (min)	te (min)	tr + te (min)
Cutting	30	0.1	30.1
Drilling	15	0.1	15.1
Welding	15	0.2	15.2
End forming	0	0.3	0.3
Testing	12	0.3	12.3
	72	**1**	**73**

For the calculation of the fetch-Kanban quantity the following data are given (Tables 6.8, 6.9 and 6.10).

The procedure is as follows:

Step 1. the fetch-Kanban quantity for product KA10 at the lean flow line will be calculated (6.28):

$$K_1 = \frac{Dc \times Q \times Rl}{H \times P}$$

Through simple data substitution in the above formula:

$$K_1 = \frac{150 \times 1 \times 4}{8 \times 1} = 75 \text{ pieces}$$

Since the total number of production Kanban cards for product KA10 should be calculated, it is obligatory that the calculated quantities should be a multiple of the line Kanban quantity of 75 pieces.

Step 2. Calculation of the Kanban quantity Kc of a product that must be produced from the machines cell for covering the time lost due to setup time of the machines (tr). Because machine cells production times (te) of a unit of product are usually different, there will always be a machine which will be the slowest, also called a pacemaker, and thus set the production pace of the cell (tep). For the production of the Kanban quantity Kc the following relation is valid:

$$\mathrm{Kc} \times \mathrm{TAKT} = \mathrm{Kc} \times \mathrm{tep} + \Sigma(\mathrm{tr_i} + \mathrm{te_i})\ \mathrm{i} = 1, 2, ..., \mathrm{n} \tag{6.32}$$

From 6.32 follows that Kc can be expressed as

$$\mathrm{Kc} = \frac{\Sigma(\mathrm{tr_i} + \mathrm{te_i})}{\mathrm{TAKT} - \mathrm{tep}} \tag{6.33}$$

Through simple data substitution to the above formula:

$$\mathrm{TAKT} = \frac{H}{\Sigma Dc} = \frac{480}{960} = 0,5$$

$$\mathrm{Kc} = \frac{73}{0,5 - 0,3} = 365$$

From step 1 it is known that Kc should be a multiple of the Kanban quantity of 75 pieces, therefore:

$$Kc = \left[roundup\left(\frac{365}{75}\right)\right] \times 75 = 375\, pieces$$

And the number of cards is calculated as follows:

$$N(cards) = \frac{375}{75} = 5\ cards$$

Step 3. Calculation of the production time for the Kanban quantity Kc from the machine cell (R). This time is calculated as follows:

R = production time of the first piece + production time for the remaining pieces

For the production of the first piece it is sufficient to set up each machine and to process the piece in every machine successively. For the production of the rest it is sufficient to calculate the time tep for the quantity Kc-1. This can be mathematically expressed as:

$$\mathrm{R} = \Sigma(\mathrm{tr_i} + \mathrm{te_i}) + [\mathrm{tep} \times (\mathrm{Kc} - 1)]\mathrm{i} = 1, \ldots, \mathrm{n} \tag{6.34}$$

Simple arithmetic substitution in the above formula gives:

$$\mathrm{R} = (72 + 1) + [0,3 \times (375 - 1)] = 73 + 112,2$$
$$\mathrm{R} = 185,2\ \mathrm{minutes}$$

Therefore, the time required to produce 375 pieces from the machines cell is R = 185.2 min.

Step 4. Calculation of the minimum Kanban quantity that must exist in the supermarket for a replenishment time R = 185.2 min with products from the machine cell. In any other case there is a danger of the flow line remaining short of material. The minimum Kanban quantity is calculated as already determined by means of the formula (6.28):

$$K_{RL} = \frac{Dc \times Q \times R}{H \times P}$$

Simple arithmetic substitution in the above formula gives:

$$K_{RL} = \frac{150 \times 1 \times 185,2}{8 \times 60 \times 1} = 57,9$$

From step 1 it is known that the Kanban quantities must be a multiple of the line Kanban quantity of 75 pieces, therefore K_{RL} must be increased to 75 pieces which corresponds to one card. Therefore, there are 5 (see step 2) plus 1 card in total 6 cards in the resupply pull sequence circuit, starting from the line through the supermarket towards the cell and back to the line. The total number of cards (6), corresponds to the minimum Kanban quantity. What happens, however, in the case where the producing resource is an single machine?

Case 2: Single machine In this case, the products are produced by single independent machines instead of dependent machines organized in cells and this environment is frequently met in fabrication shops. All processes in a product synchronization flow are executed by machines with individual setup times (tr) and run times (te). In such an environment, synchronizing and self-regulating production is performed by means of an intermediate supermarket placed between the machines exhibiting the following typical pull sequence.

Lean flow line	→	Supermarket	→	Single machine

The following diagram illustrates the pull sequence of the case (Fig. 6.54).

A lean flow line, the supermarket and the machine are all inside the same RIP. The products KA10 and KA20 are used in the line and are resupplied by the supermarket (RL-4). The supermarket is resupplied by the machine KA by means of a production Kanban for product KA10 and KA20 respectively. The production-Kanban cards are collected into a Kanban box and transferred to the machine for production planning of both products KA10 and KA20. The machine must be set up for the production of these two products. Moreover, the machine also produces other products, which for practical reasons are taken into account here only for calculating the TAKT of the process executed by the machine. Underneath, the procedure for the calculation of the Kanban quantities is described.

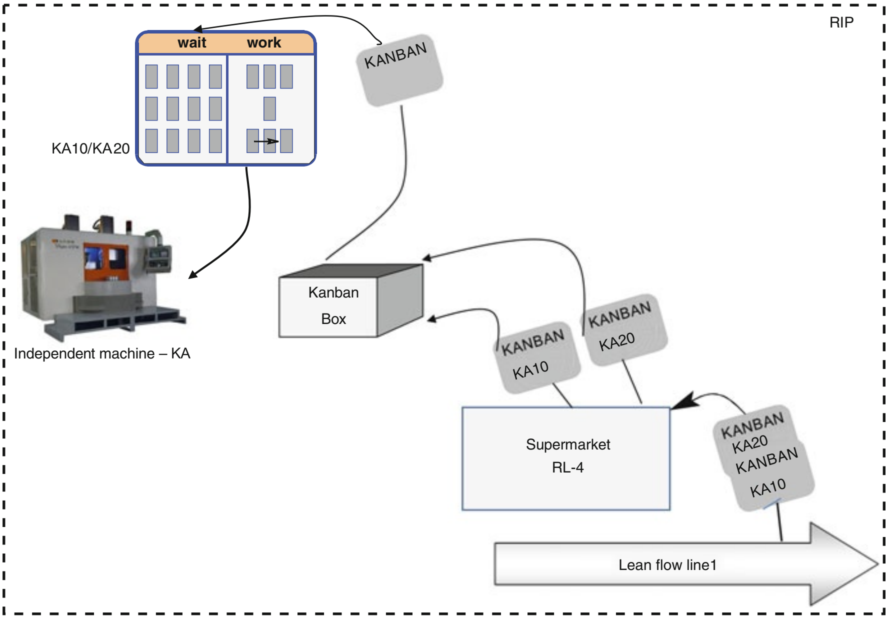


Fig. 6.54 Pull sequence for production Kanban

Table 6.11 Data for the fetch-Kanban quantities

Dc – KA10	Demand at capacity for the product	150
Dc – KA20	Demand at capacity for the product	250
H	Time available for production	8 h
Rl	Replenishment time for the products	4 h
P	Packaging size for both products	1

Table 6.12 Data for the production-Kanban quantities

ΣDc	Total demand at capacity of all products	960
H	Time available for production	8 h
	tr (min)	te (min)
Welding KA10	15	0,2
Welding KA20	15	0,4

The following calculations are requested:

1. Calculation of the fetch Kanban quantities for products KA10 and KA20 from the supermarket
2. Calculation of production Kanban quantities for products KA10 and KA20 from the independent machine KA

   For the fetch Kanban quantities the above data are given (Table 6.11).

   For the production Kanban quantities the above data are given (Table 6.12).

Step 1. Initially, the transportation Kanban quantities for product KA10 and product KA20 respectively at the flow line will be calculated implementing the formula (6.28):

$$\mathrm{K}_1 = \frac{Dc \times Q \times Rl}{H \times P}$$

Simple arithmetic substitution in the above formula for each product gives:

$$K\ (KA\,10) = \frac{150 \times 1 \times 4}{8 \times 1} = 75\,pieces$$
$$K\ (KA\,10) = \frac{250 \times 1 \times 4}{8 \times 1} = 125\,pieces$$

Because the number of production-Kanban cards for products KA10 and KA20 must be calculated, it is obligatory to be a multiple of the Kanban quantity of 75 pieces for KA10 and Kanban quantity of 125 pieces for KA20 respectively.

Step 2. Calculation of the Kanban quantity Kc of a product that must be produced from the machine for covering the time lost due to setup time of the machine (tr). For the production of the Kanban quantity Kc the following equation is valid:

$$\mathrm{Kc} \times \mathrm{TAKT} = \mathrm{Kc} \times \mathrm{te} + \mathrm{tr} \tag{6.35}$$

From 6.35 follows that Kc can be expressed as

$$Kc = \frac{tr}{TAKT - te}$$

The TAKT of the process is calculated as follows

$$TAKT = \frac{H}{\Sigma Dc} = \frac{6 \times 80}{960} = 0,5\,\mathrm{min}$$

$$Kc(KA10) = \frac{tr}{TAKT - te} = \frac{15}{0,5 - 0,2} = \frac{15}{0,3} = 50\ pieces$$

$$Kc(KA10) = \frac{tr}{TAKT - te} = \frac{15}{0,5 - 0,4} = \frac{15}{0,1} = 150\ pieces$$

From step 1 it is known that Kc (KA10) must be a multiple of the quantity of 75 pieces and Kc (KA20) of the quantity of 125 pieces respectively

$$Kc\ (KA10) = \left[round\,up\left(\frac{50}{75}\right)\right] \times 75 = 75\ pieces$$

$$Kc\ (KA20) = \left[round\,up\left(\frac{150}{125}\right)\right] \times 125 = 250\ pieces$$

$$N\,cards\,(KA10) = \frac{75}{75} = 1\ \ card\ \ and$$

$$N\,cards\,(KA10) = \frac{250}{125} = 2\ \ cards$$

Consequently, for the quantity Kc (KA10) = 75 pieces, one Kanban (1) card will be needed for a quantity of 75 pieces, while for the respective Kanban quantity Kc (KA20) = 250, two (2) cards will be needed representing a Kanban quantity of 125 pieces for each one.

Step 3. Calculation of the production time for the quantity Kc for each product from a machine (R). This time is calculated as follows:

$$\text{R} = \text{machine setup time} + \text{ production time for all pieces per product}$$

The above relationship is described mathematically as follows:

$$R = tr + te \times Kc \tag{6.36}$$

Simple arithmetic substitution in the above formula for each product gives:

$$R\ \ (KA\,10) = 15 + 0,2 \times 75 = 16,5\ min$$

$$R\ \ (KA20) = 15 + 0,4 \times 250 = 115\ min$$

Consequently, the time needed for the production of 75 pieces of product KA10 by the machine is R = 16.5 min and for 250 pieces of product KA20 is R = 115 min.

Step 4. Calculation of the minimum quantity Kanban which must exist at the supermarket for replenishment time R of the supermarket with products from the independent machine. In every other case there is a danger that the flow line will be short of material.

$$KRL = \frac{Dc \times Q \times R}{H \times P}$$

Simple arithmetic substitution in the above formula for each product gives:

$$KRL(KA10) = \frac{150 \times 16{,}5}{8 \times 60 \times 1} = 5{,}16\,pieces\; KRL(KA20) = \frac{250 \times 1 \times 115}{8 \times 60 \times 1} = 59{,}9\,pieces$$

From step 1, it is known that the Kanban quantities must be a multiple of 75 pieces for KA10 and 125 pieces for KA20. Consequently, the number of cards for each product is:

1. KA10 – 2 cards (1 in production + 1 in supermarket)
2. KA20 – 3 cards (2 in production + 1 in supermarket)

The number of cards corresponds to the minimum Kanban quantity per product.

6.6.1.3 Planning of Production-Kanban

A basic element for an effective resupply of the supermarket from machines cells or single independent machines, is the way of planning and executing the production Kanban. Planning and executing of the production Kanban while the time dimension is inherent into it, is not based on scheduling in the sense of a point in time, but on the principle of a change in state.[1] The appearance of a Kanban card declares a change in state from non-existence to existence of the need for the fulfilment of a pull sequence, it does not however signify when exactly something must be produced, as is the case of scheduling. The obligation of the fulfilment is signified through the card and not when the fulfilment must or can happen. Based on this explanation, it is significant the way and the procedure through which the signals declaring the state change and the need fulfilment are signalled. The way is based on the principle of servicing the pull sequences in the order they arrive, or better, in the order they satisfy the quantity requested through the production-Kanban (just in sequence). The procedure for implementing is illustrated in the following Fig. 6.55.

The diagram presents the pull sequence for replenishing a line with part A. The fetch Kanban regulates the line with part A from supermarket RL, which is resupplied by a production-Kanban from the press machine. From the example, three Kanban cards, each with a quantity of 20 pieces for part A, are requested to complete the quantity needed for starting production of part A. Therefore, a total of 60 pieces must be produced from the press machine each time the machine is set up for producing the part. Collection of the cards takes place on a board placed near to the machine called the *wait-work board* and is split into two parts. The left part is for the collection of production-Kanban cards waiting to be processed. When all three cards are collected, one card with a total quantity of 60 pieces is placed on the right hand side of the board for production. Specifically, the card is placed on the right hand side of the most recent Kanban card that has been placed in the production order. The order with which production needs are satisfied, follow the

[1] Just-in-time should be understood as *within-a-time interval*, and not *exactly-on-time*. In the sence of *within a time interval* the pull mechanism Kanban satisfies the principles of the philosophy just-in-time.

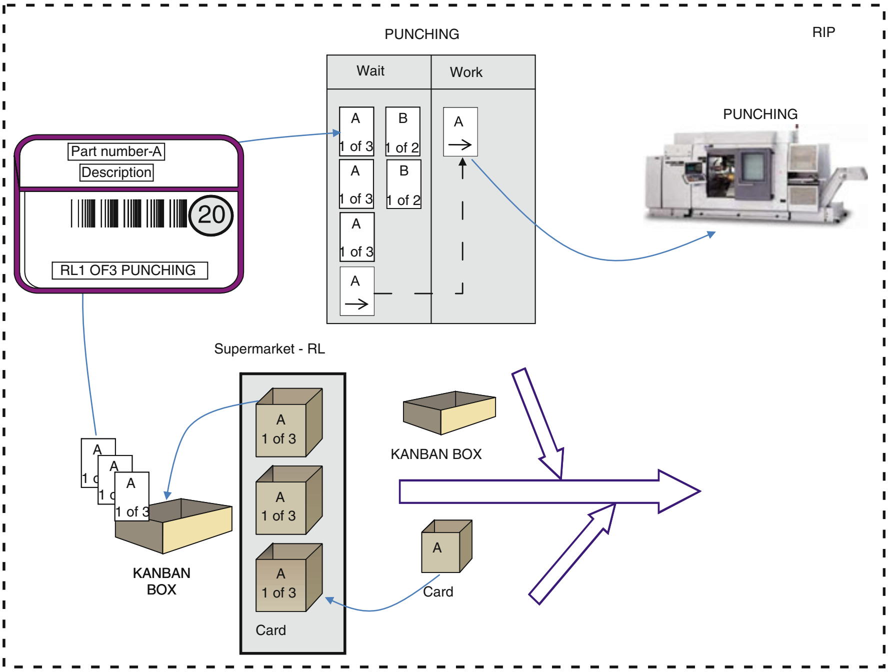


Fig. 6.55 Pull sequence for lean flow line replenishment

following rule: the cards that are positioned on the right hand side of the board declare a WIP quantity and follow a basic rule of lean production – that of FIFO, i.e. whichever card is placed first for production must be the first that goes for production. The rule is non-negotiable, because otherwise a fundamental principle of lean flow is violated. Therefore, the production-Kanban cards are taken to production starting from left to right and from top to bottom of the board. The execution of the production of the Kanban cards in a FIFO sequence substitutes fully the need for time scheduling which is typically used in a push environment. In that case, it is necessary to allocate all lots to the logic of the moment in time, when these must be executed in order to achieve production synchronization. In lean flow however, synchronization is given through the TAKT, and the exploitation of the synchronization achieved by means of FIFO. Production-Kanban is characterized by dual card and multiple containers. Two cards because there is the fetch card and the produce card.

As well as the way described above based on the FIFO principle, there is another one, similar to the principle which characterizes scheduling, described underneath because it is used in practice, although we do not advise its use as a first choice. The method is based on the principle of traffic lights and is illustrated in Fig. 6.56.

The procedure is the following: production-Kanban cards are placed on a board characterized by three zones in the order they arrive at the machine. The first zone is

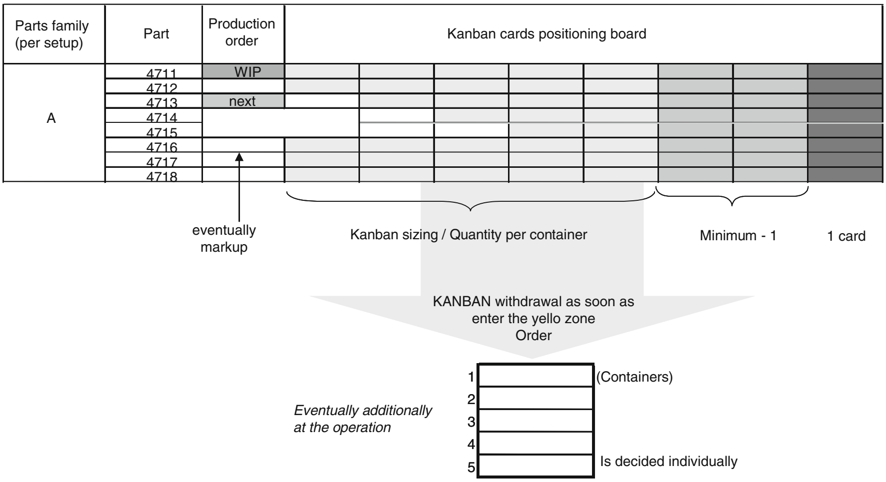


Fig. 6.56 Production-Kanban planning (Ehlers)

in green colour (light grey), the second zone in yellow colour (medium grey) and a third zone in red (dark grey). The first card for the production of a part is placed at the beginning of the green zone, here from left to right. As long as the addition of a new card remains in the green zone there is no signal for production. The first card to be placed in the yellow zone signifies that the calculated Kanban quantity for this particular part has been completed and production may start. If this does not happen then when the first card reaches the red zone, production of the Kanban quantity should start immediately, otherwise there is a danger that the requesting process will be short of materials. A further variation concerning the order, the colours and the operation of the Kanban planning board is shown in Fig. 6.57.

In this case where three zones are observed, the order for placing the cards is bottom up. The first zone is painted rose (light grey), the second zone in green (medium grey) and the third in red (dark grey). The operation of the board is the following: as long as the cards remain in the first zone, they can be produced as long as there is enough capacity. In the green zone, they can be produced unlimitedly. In the red zone, they must be produced otherwise there is a danger of the pulling process remaining short of materials.

It is clear that in both cases the factor time is the one that constitutes the base for the decision of whether to produce the Kanban quantity or not and each time it is taken with the personal responsibility of those responsible for production, with the danger of violating the FIFO rule basic to lean production. Violation of the order may lead to imbalances in the production system, which is sensed practically through difficulties in production capacity. Differences in the individual level in the order of production can disturb the production smoothing achieved on the basis of the production mix by design.

All these problems exist because, we believe, there is a basic misunderstanding in the operation of just-in-time in the production environment. The term is used in

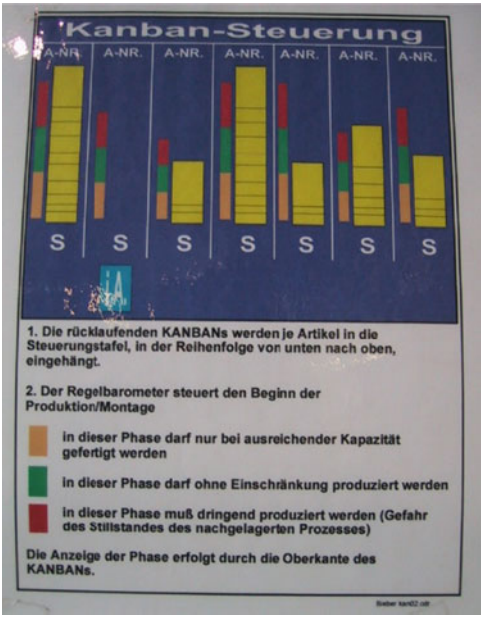


Fig. 6.57 Production-Kanban planning board (Leonardo Group)

push as well as in pull environments and therefore it is not an exclusive factor in the lean philosophy of production. However, the transfer of the concept from a push to a pull environment sustained the time dedication it had in the push environment, while in our opinion it should serve the purpose of use in a pull environment. It constitutes the support base which fits lean flow, that is, the creation of sequencing characterized by the FIFO logic. The orientation of lean flow differs in one basic way from the corresponding push environment: while it contains inherently the meaning of time, nevertheless it is not based on it for the synchronization of production activities. Unlike scheduling in a push environment where time planning is necessary for synchronizing activities in order to achieve just in time, in a pull environment it is necessary to sequence orders for executing a flow of orders and not for synchronizing activities in order to achieve just in time in production. Therefore in lean flow, a more accurate term which represents reality to just-in-time is the term just-in-sequence.

6.6.1.4 The Need of RIP Areas

A question frequently asked in seminars and during implementations concerns the number of RIP that need to be designed, which is translated to how many supermarkets will be needed and if there is a rule to follow. There is not a single answer to this question. However, let us see what is valid and what our suggestion is, on the basis of existing information so far. Old lean philosophy favours one supermarket for each level appearing on the Bill of Materials (BOM). We will agree with this view on the precondition that an attempt has already been undertaken to reduce the BOM levels. The result of this effort is the reduction in the numbers of parts, because that is how the work synchronization and one piece flow is achieved. Our own answer is that a supermarket is needed only at the point or the points of interaction with the customer and at those points where one piece flow is interrupted mainly because of the missing agility of the supply process.

The ultimate aim of lean flow is to host production under a single RIP establishing an environment with a high level of inventory turns. Once this is realized, one piece flow and synchronization of supply and consumption of materials can be achieved. In such an environment a significant simplification of costing the product is attained.

6.6.2 Material Fitness for Pull Mechanism

In the previous sections we have described in detail the fetch-Kanban, the production-Kanban and its way of planning and execution. The questions that remain to be answered though are: are all parts suitable for the pull mechanism? One way to investigate the suitability is the categorization of parts based on the analysis ABC/XYZ. The method categorizes the parts based on their value (ABC) and the consumption variation (XYZ). Below, there are two proposals for the analysis of categories ABC (Werner 2002) and (Wild 2002) (Tables 6.13 and 6.14).

We recommend the use of the first table for analysis ABC as most commonly used. Analysis XYZ is based on the consumption per part for a period of 12 months or time periods. Concretely ≪X≫ refers to parts which present a profile of more or less constant consumption, ≪Y≫ refers to parts that display a profile of variable consumption and ≪Z≫ refers to sporadic or erratic consumption. A proposal for analysis XYZ is given in Table 6.15.

Two dimensional analysis based on the value and consumption leads to nine categories resulting from the possible combinations of six letters (Fig. 6.58).

In this table, the size of ≪X≫ declares the degree of suitability of the parts belonging to the category concerned to assign them to the pull mechanism Kanban. Parts that belong to category AZ are not usually suitable for the pull mechanism and must be planned for production only when there is a specific customer order. The green (light grey) surface declares the Pareto distribution of 80/20, which means that 80% of parts can be assigned to the pull mechanism, while for the 20% of the parts different ways must be used for their production planning and execution. The analysis ABC/XYZ is suitable, not only for supplies and semi-finished products, but also for finished products. How can the matrix be used to calculate Kanban quantities? For each of the nine categories, management rules and the replenishment time of the points of use must be determined. The rules concern the replenishment of the supermarket initially and central stores. For the categories of components which will not be evaluated as suitable for utilising the Kanban mechanism, specific planning and management rules, must be defined. The

Table 6.13 Categorization criteria ABC (Werner 2002)

Parts	A	B	C
Value of parts	80%	15%	5%
Number of parts	20%	30%	50%

Table 6.14 Categorization criteria ABC (Wild 2002)

Parts	A	B	C
Value of parts	66.6%	23.3%	10.1%
Number of parts	10%	20%	70%

Table 6.15 Categorization criteria XYZ

X	Y	Z
Vc < 33%	33% < Vc < 67%	Vc > 67%

Variability factor = >Vc
Standard deviation/mean value per period

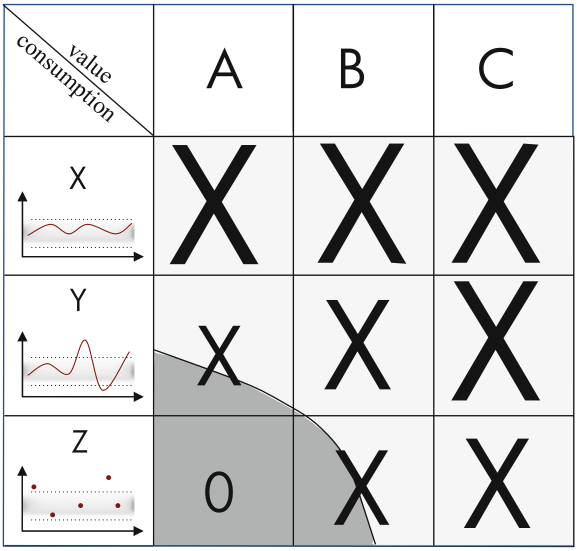


Fig. 6.58 Categories ABC/XYZ (Leonardo Group)

following matrix contains typical pull sequences for the nine categories. Every application must take into account the real data which are valid in each case (Table 6.16).

For reasons of completion the inventory policy in the supermarket and the stores is summarized (Table 6.17).

Table 6.16 Typical pull sequences

Category	Line	R_I	Supermarket	R	Stores
AX	Yes	2	Yes	8	No
BX	Yes	2	Yes	8	Yes
CX	Yes	2	Yes	0	Yes
AY	yes	2	Yes	8	Yes
BY	Yes	2	Yes	8	Yes
CY	Yes	2	Yes	0	Yes
AZ	No	0	No	0	No
BZ	No	2	yes	0	Yes
CZ	Yes	0	Yes	0	Yes

Table 6.17 Inventory policy

Supermarket		Stores	
Value	Days	Value	Days
80%	10	20%	>>10
IT = 240/10 = 24		IT < 24	

A supermarket is characterized by the following inventory policy: 80% of the inventory value with a replenishment time of up to 10 days. Stores are characterized by the following inventory policy: 20% of the inventory value with a replenishment time much higher than 10 days.

6.7 Lean Logistics

The term *logistics* used here relates to the activities of ordering the material components from suppliers i.e. the reception, storage, unpacking, repacking and transportation towards the point of use and points of resupply in production. It pertains to what is known by the term *internal logistics*. The term *lean logistics* refers to the use of a lean flow method in the internal supply chain. The purpose is the reduction and the elimination of all activities which do not add value to the value stream of the internal logistics through formalizing the logistics activities. Outbound logistics can be treated in the same way, however, this lies outside the scope of this book. Features which may help to formalize logistics activities without disturbing differentiation in the market are:

1. Codification of the part (one and single for internal and external logistics) – e.g. UNSPSC
2. Codification of a logistics unit (Serial ship container code – SSCC). A logistics unit may contain a quantity of the parts
3. Standardization of the process for packing and unpacking on the supplier side
4. Outsourcing activities of internal logistics to a third party (third party for internal logistics)

In the following, the use of lean flow in managing internal logistics is discussed.

6.7.1 Lean Flow in Internal Logistics

Internal logistics constitutes a value stream which contains the activities of ordering, receiving, storing, unpacking and repacking parts and materials to relocate them to the points of use and resupply in production. In the value stream, stores undertake the role of a lake, because by nature stores are a topos of dynamic concentration due to incoming and out-coming materials. In ecology, a parallel phenomenon is the dynamic water buffer where artificial lakes are created interrupting the river flow and outflows are regulated by means of a dam. In ecology, this phenomenon is desirable, because in this manner biotopes are created with beneficial effects on the environment. However, the existence of stores in production is a necessary evil. In the ideal case, what is desirable is the income of materials into the factory and finally in production is in a synchronized flow with the flow of incoming customer orders. Is that a utopia or a real possibility? It is certainly a utopia in reality but, knowing the path towards utopia, dystopia is avoided, determining displacements in the path towards the target. From this example, it is obvious that the target in a lean enterprise is the reduction in supplier order response time as much as possible. The main benefits in this case are the significant reductions in working capital, the financing cost, the cost of obsolescence, the surface for storage and finally the cost for managing inventory known as inventory carrying cost (ICC). The more the supplier response time is reduced the more the inventory policy, as described in the previous section, can be applied. Immediate implementation capability of the inventory policy displaces the topos of stores from a topos of a lake declaring an inventory pooling to a topos of flow, declaring movement of inventory aiming at a stepwise reduction in the duration the inventory remains in a storage location. The topos of stores becomes a topos for transferring materials from the packages of the supplier to the packages of the producer. The concept is the same as what is called *cross docking* in logistics. Cross docking is defined as an activity whose purpose is to reduce the cost and the total lead time with respect to the parts on the unloading platform and assigning them to shipment needs, instead of storing them at defined locations for order picking at a later point in time. If cross docking can replace storage, a series of benefits follows which typically include reductions in working space, storage needs, management cost and ordering cycle time as well as higher inventory turns and cash flow acceleration. The benefits of cross docking are therefore immediately aligned to the targets of lean management of the supply chain, namely small order quantities of inventory moving quicker and more frequently.

Implementation of lean cross docking will take place using the lean flow method (process and material) for the design and realization of the function, targeting the maximization of the benefits referred to above. Operation of lean cross-docks will have a significant impact, not only on the deficiency, but also on the effectiveness of logistics. In lean cross-dock, stores are viewed as a *production* topos and as such it

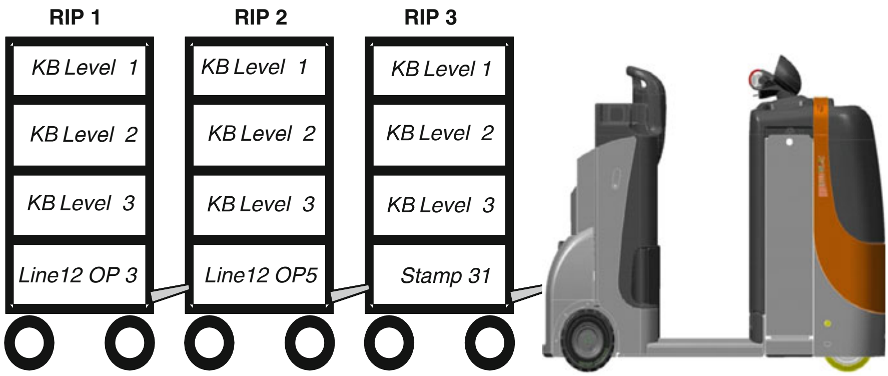


Fig. 6.59 Material replenishment by means of milk-runs (Domange)

must be organized. Therefore, stores alone can become an independent RIP (raw and in process), where “R” (raw)refers to storing material from suppliers and “IP” (in process) refers to the process flow necessary for the fulfilment or replenishment of the supply orders. The process flow refers to the preparation of the parts for replenishing production RIPs with quantities required by the points of use. For the articles replenished through Kanban, the work concerns the filling of the empty containers with the Kanban quantity, while for the remaining articles, work refers to the preparation of the quantity declared each time separately based on the order. The line design for work execution is based on the principles of lean flow. The cross docking line to be designed receives empty and delivers full Kanban containers ready to be transported to the points of use and replenishment in production RIPs. The commuting of materials among the points of use and the points of resupply is implemented through the use of *milk runs*[2] by special vehicles in the form of a small train. The vehicles follow predetermined paths at a defined frequency for the collection of empty Kanban containers from the existing production RIPs and their transportation to the cross-dock lines. After the Kanban containers are filled with the material, the vehicles undertake their delivery to the production RIPs keeping the same frequency and following the same route as for the collection of empty containers. In Fig. 6.28. a schema of a small train is illustrated carrying three small wagons loaded with Kanban containers laid out per level exactly in the same way as these are laid out in the supermarket or the points of use in production lines, and with the materials on order. The route followed during delivery of the full containers is the following: RIP 1 → RIP 2 → RIP 3, while the collection of the empty Kanban containers is exactly the opposite: RIP 3 → RIP 2 → RIP 1 (Fig. 6.59).

[2] This method takes its name from a practice in the production of milk products where a tank vehicle collects milk every day from various milk in order to deliver them to a milk producer.

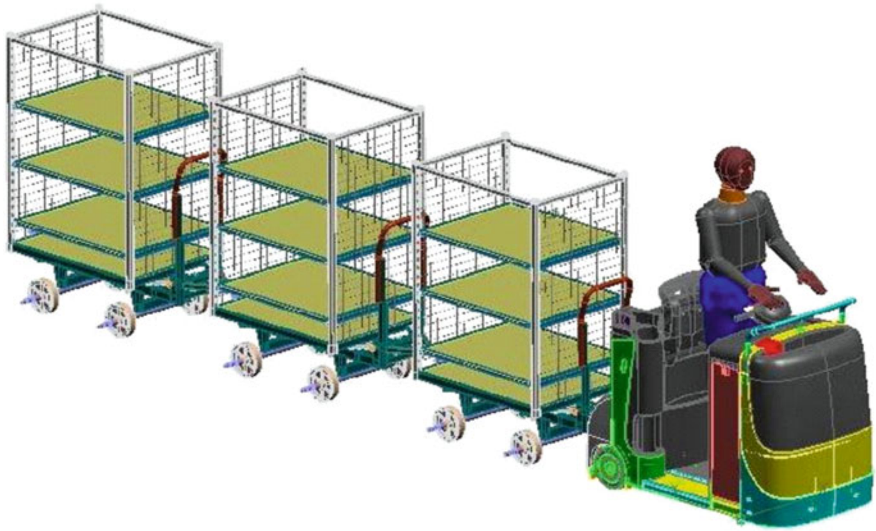


Fig. 6.60 Perspective illustration of a small train (Domange)

A perspective illustration of a vehicle for material transportation is given in Fig. 6.60.

6.7.2 Lean Flow in External Logistics

Lean logistics is completed with the extension of the Kanban mechanism towards suppliers. The aim is the stepwise reduction in materials inventory which must be stored at any time and the acceleration of inventory turns (IT). To such an environment, material quantities regulated via Kanban are calculated on the basis of supplier response time for each article (R) taking into account the necessity of extra material quantity as safety stock for covering uncertainties originating from possible demand variation during replenishment. Typically, the type and the size of supplier materials packaging is different from the type and the size of the Kanban containers used in internal logistics. However, the more the supplier response time can be reduced (R), the more the supplied quantity and the packaging size for materials will be reduced (given that the consumption rate stays constant) leading to the gradual harmonization of the Kanban containers for internal logistics with the means of packaging coming from the suppliers. The use of common Kanban containers between the company and suppliers makes displacement of the company central stores to stores of suppliers a practical possibility which can be further reorganized through lean flow methods in a supplier supermarket. Lean logistics becomes in this way a reality. The creation of a lean supply demands systematic collaboration of the stakeholders involved, but mainly discipline is required in the selection criteria of the members. It is clear that generally logistics operations do not add value to the product itself and are considered waste from the lean perspective. The result of this view is the attempt on behalf of the enterprise to reduce waste, that is, to reduce the operational cost of activities assigned to logistics. However, in a globalized market, added value does not originate from reducing waste, but is a result of several factors such as the speed with which enterprises displace themselves, the flexibility during displacement and the agility at each point on the displacement path in order to reach the target. The target is the total result achieved by an operating supply chain in speed, quality and cost and not the individual (at the enterprise level) benefit of each member of the chain. This is what the customer honours by paying for individual services. Interaction between internal and external logistics is described in the following section. It is the fundamental element for the structure of a lean individuated supply chain or network. All start from the point closest to the source of demand (immediate and intermediate). The point of interaction in supply is the site of stores. Demand and supply are met in stores for both immediate demand from an end customer or intermediate demand from a supplier caused by an end customer order.

A customer order for a product is followed by the need for its withdrawal after its use life cycle. Environmental protection led to recycling technology in order to renew raw materials, mainly those which can be reintroduced to the production cycle of other products. Management of the necessary withdrawal activities for renewing raw materials or reconstructing and renovating products is called *reverse logistics* in the literature (Fasoula 2005). This term, in our opinion, is not accurate. The inaccuracy is due to the fact that in the majority of cases the reverse chain does not end at the initial point where the product has been manufactured, but in recycling areas which have no relation to the initial producer. Consequently, the term must be used only in the case of a closed-loop supply chain that is the product at the end of its life cycle returns to the initial point, the point of its origin. In any other case, it must be named open-loop supply chain, because it concerns all activities and processes for replenishing useful materials and parts for their use in future products. A tendency recently observed is called *up-cycling* and concerns the creation of new objects from objects which have fallen into disuse and not into obsolescence. It concerns a new international tendency which combines creativity with the economic and ecological precepts of the times and exhibits similarities to the movement of open innovation.

In all types of supply chains, one is the principal question: what type of logistics will be needed and how can it be organized? The organization relies on the form of interaction between internal and external logistics. The study and design of this interaction requires the study and redesign of the current value stream. The point of interaction in supply is the topos of stores as mentioned above. Speed, flexibility and agility in the supply chain will be judged by the characteristics of the building element, stores and how these are subsumed within the lean strategy of the supply chain stakeholders. This subject is discussed in the following section.

6.7.3 Lean Logistics and Lean Value Stream

One of the basic causes of delay in the supply chain originates from the need for storage. Stores operate as a topos for receiving and securing articles and materials for subsequent displacement to production. International practice shows that from the moment an article enters stores until it exits the factory as part of a final product, it receives work for about 5–10% of the total time that it occupies space in the company accounting books. The longest waiting time of all is observed in stores, therefore stores can be compared to a pool, the water of which may seem stationary, because its flow has a low power stream flowing towards production. The goal in lean logistics is metaphorically for the pool to be displaced and to acquire flow, as for example the stream of a river. In this case, the factory may be assimilated to a hydroelectric plant situated in the river stream. The pressure of its waters sets the turbines in rotation, which moves the turbines to produce the electric stream for which the central utility of the region and its network have the order to transmit electricity. In the section of these sequenced interrelations for ordering electrical energy, the stream of the river appears as something ordered (Heidegger 2007). Respectively our factories lie in the stream of materials moved by customer orders.

Something analogous holds in a lean factory. Only what is necessary for the execution of a particular order contributes positively to the value stream of a lean supply chain, reducing its total operations cost. Everything else influences negatively the value stream increasing its total operations cost. To this belong, not only articles, but resources for storage, production, transportation and distribution to the final recipient of a product. The supply chain value stream is caused by the demand and is exactly what the river stream is i.e. the supplier of the water pressure, known from the science of power generation. The demand in the supply chain is calculated on the basis of projected and actual orders. In this sense the value stream is the supplier of material and non-material articles as a stream passes through the factory. The factory in turn uncovers, through the use of technology and its production resources, the value of the supply stream of material and non-material articles through the production of a product. In this way, ordered articles have their own *position*, each one for itself, as *positioned* in the value stream topos, which we call *position topos* and as such the article that belongs to a value stream position topos we call *depot*. The word depot is at the same time both a signifier and signified, as it enlarges the term stock known in the science of logistics. The article is deposited, in other words, lies into position for ordering, its internally stored value manifested in the product. The word depot (stock) manifests nothing less than the way everything is revealed, influenced by the cause of the revelation (Heidegger 2007). The cause of the revelation, in the case of the supply chain, is demand and is especially the reason of its existence. The reason of demand existence is the usefulness of the particular product for an end-user. The greater the usefulness of a product for an end user the greater its value according to Aristotle (Younkins 2005). In lean logistics, the only stock that reduces operational cost of the value stream, as already mentioned above, concerns material and non-material articles which are ordered because of real demand, i.e. have usefulness as the cause of the revelation. Every other form of stock or inventory increases operational cost of the value stream and alters the quality of a lean supply chain. Whatever incurs as stock does not exist as a thing opposite to us and as such it should not be part of a lean supply chain. Consequently, whatever exists without expressed order constitutes part of a value diminishing stream (VDS) which operates against a value adding stream (VAS). Stock with VAS is called *lean stock*, while the opposite *non lean stock* is the part of stock that exceeds the limits of real demand, i.e. it is part of a VDS. Surely a thing is in reality a thing. But, if we imagine the article in this way then it covers itself inside itself, i.e. what and how it is. Uncovered, it has a position as stock in the value stream as long as it is authorized to ensure the capability of continuing the production of a product on order. From the perspective of stock, the article is unmistakeably not autonomous, because it has its position in the value stream exclusively due to an end user order.

Based on what has been referred to above for the sake of lean logistics, the significance and the role of the stock must be revised. The target is the significant reduction in waiting time in stores before starting the incorporation process into a product. By means of *the topos theory* founded for the better understanding of the interactive relations in any one space, the logistics value stream will be approached. According to this theory, topos is characterized by four properties: *consciousness, openness, praxis and entelehia* (Tsigkas 2009). The supply and the value stream as topos where the interaction between external and internal logistics takes place is characterized by these relations. Therefore, it remains to be detected, what benefit the four respective properties can offer with respect to the supply chain. Finally, how these relations support the individuation of the value stream so that its operation can be adjusted to the individual requirements of a lean supply chain. It is certain that a professional in the subject would take a different approach. It is also certain that a Toyota practitioner would start on the basis of TPS principles. We will use *topos theory* because it produces an innovative way of thinking towards the new and open lean enterprise. From the theory, a mathematical relation for the determination of a value stream topos for lean and non lean inventory is developed.

Based upon the topos theory the value stream of the supply chain has the following properties (Fig. 6.61). *consciousness* for the cause of its provocation (forecast, maximum designed daily demand, real demand), *openness* with respect to the relations of the articles among themselves based upon the space (in-stock), the time (in-time) and the space-time (in-flow), organization with *praxis* for the supply, the resupply and the production with the goal the speed in resupplying the articles to the points of use, flexibility in the choice of distribution paths and the agility in demand variations. The properties of the value stream refer to three displacement stages for the stepwise achievement of lean logistics. The three stages refer to the stores, the supermarket and the cross-dock.

The case of a pure lean supply chain is in practice less probable. What is probable is that the value stream of a lean supply chain will be mixed. This means that one part will consist of inventory based on the designed demand daily rate at capacity (Dc) and the real demand daily rate (Dr) and another part will consist of inventory based on forecast (F) which should be priced separately. The

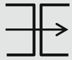
SYMBOL	1 	2 	3 
DISPLACEMENT STAGES	STORES	SUPERMARKET	CROSS-DOCK
Topos qualities	object	hypostasis	subject
consciousness	inventory	replenishment	production
openess	in-stock	JIT	in-flow
praxis	one sigma	three sigma	six sigma
entelehia *IT*	speed (6)	+ agility (12)	++agility (24)

Fig. 6.61 Properties of value stream topos

purpose on behalf of the enterprise is to continuously and permanently reduce the value relation of non lean inventory to lean inventory (with constant volume of sales). The prerequisite is the definition of the value stream topos of the articles supply chain. This topos will reach its minimum when all articles make up lean inventory and its maximum when these make up non lean inventory. It is assumed that the transition from one topos to another is linear. Consequently, the topos of value streams are straight lines which connect the minimum with the maximum for each article and can be expressed as follows:

$$Y_{gj} = \sum_{i} (D_i \times Q_i) - X_{bj}$$

Where D_i is the independent demand of the final products for each j article which is common to final products, y_g the quantity of non lean inventory and x_b is the quantity of lean inventory (Fig. 6.62).

If the above formula is implemented to each topos stage of the value stream, then the above table is completed as follows, taking into account that F is the forecast, Dc is the designed daily rate demand at capacity and Dr is the actual daily rate demand (Fig. 6.63).

What is the appropriate way to achieve a lean value stream? What is certain is that the road passes by the suppliers with only one item on the negotiations table: the search for a common VAS or how stepwise the various inconsistent VAS will be harmonized into one common one. It is obvious that the supplier VAS will be VDS for the customer if obliged to buy material and non-material articles that are not parts of orders coming from their own customers. The harmonization of the two value streams will be the context of negotiations. In particular, this subject will be addressed in the next section that refers to purchasing processes. Gradually, and in

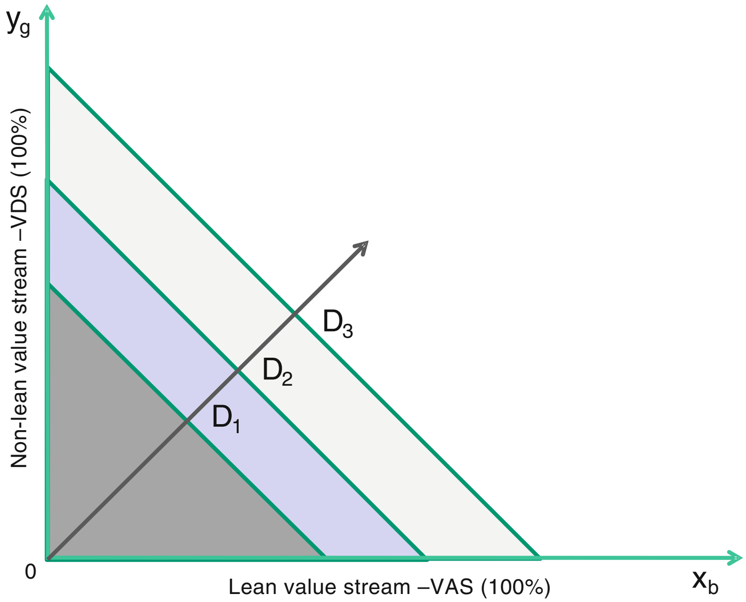


Fig. 6.62 Topos of inventory value stream

VALUE STREAM TOPOS	1	2	3
TOPOS QUALITY	STORES	SUPERMARKET	CROSS-DOCK
consciousness	forecast	Dc – daily demand at capacity	Dr – actual daily demand
openess	in-stock	JIT	in-flow
praxis	supply	replenishment	production
entelehia (IT)	speed (6)	+ agility (12)	++ agility (24)
VALUE STREAM	$y = \Sigma(F \times Q)$	$y = \Sigma(Dc \times Q)$	$y = \Sigma(Dr \times Q)$

Fig. 6.63 Properties of value stream topos

the context of cost reduction collaboration is necessary with the suppliers as far as stores replenishment is concerned. The target is any central stores of any customer to be any topos RIP (by analogy to production) which will be organized in such a way so that the storage of packed articles is performed based on the principle of

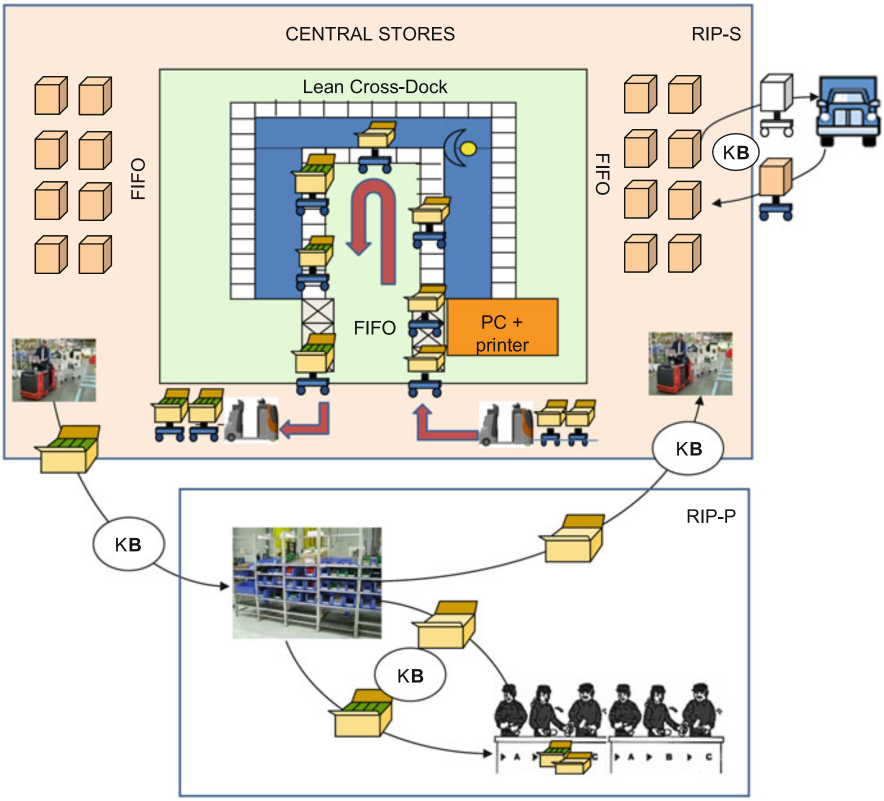


Fig. 6.64 Operations of internal logistics

single-card, two-bin Kanban, while the method of unpacking articles and their preparation for the internal distribution is always the same. As a first step, the process of replenishment on demand (ROD) needs to be set up using the logic of lean flow. One of the significant benefits from the introduction of lean flow into storage processes in this way will be the medium-term capability of a third party operating in the same space (outsourcing), an activity which falls in general to the category of 3PL (3rd party logistics), for internal material circulation. However, a service provider in this area would undertake the operation (but not the management) of the stores under the name third party internal logistics (3PiL). The long-term goal is for the suppliers themselves to undertake the management for replenishing inventory of material articles in stores, an activity known as vendor managed inventory (VMI). The displacement of non lean stores to lean stores will lead to significant benefits regarding the costs of operations and management. The way towards the displacement of stores into RIP passes through the piecemeal displacement to an internal cross-dock and particularly a lean cross-dock for internal distribution. Figure 6.64 illustrates the operation principle of the internal

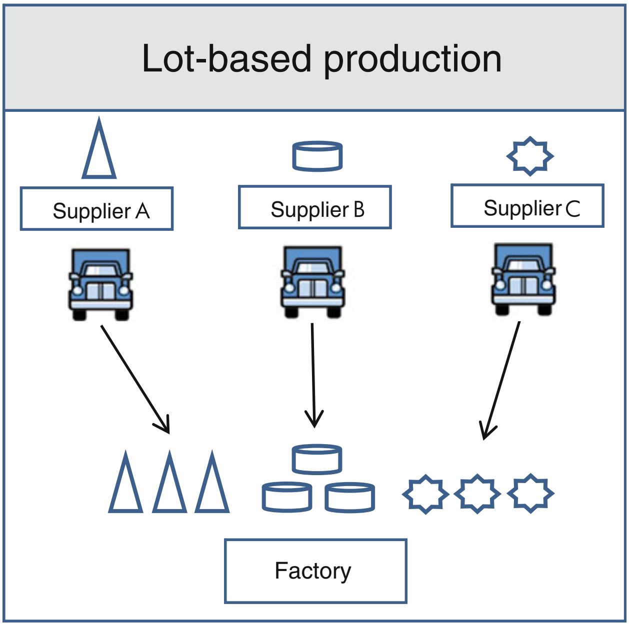


Fig. 6.65 Logistics in lot-based production

distribution by means of Kanban pull sequences and lean cross-dock, the operation of which is described below.

In the following, a description of how the method of lean flow can be implemented to the process flow and to the materials flow in stores respectively. Firstly, let us see how logistics operate in a typical lot-based production, illustrated in Fig. 6.65. In this case, each supplier transports, independently of the others, the articles in lots to the factory. In the case of lean production the milk-run method is used in which a line bus operates which stops each time at predetermined points (bus stops) to let passengers on and/or off the bus.

A similar process occurs in the case of lean logistics, as illustrated in the following Fig. 6.66.

In other words, by following a particular path and stopping at each supplier, the various articles needed are collected and transported to the factory creating mixed loads. In this case, need in storage space is reduced in comparison with the logistics for lot-based production in which orders are frequently based on forecasting. In a lean production environment, the articles are introduced into the lean cross-dock and through this they are distributed directly to the production RIPs as illustrated in Fig. 6.67.

Operation of the stores as a lean cross dock may give significant benefits to a lean supply chain. The smaller the lots of the articles sent by the suppliers, the quicker they arrive through the cross-dock to the points of use in the various RIPs. A lean cross-dock organizes, through lean flow, lines for the preparation of Kanban

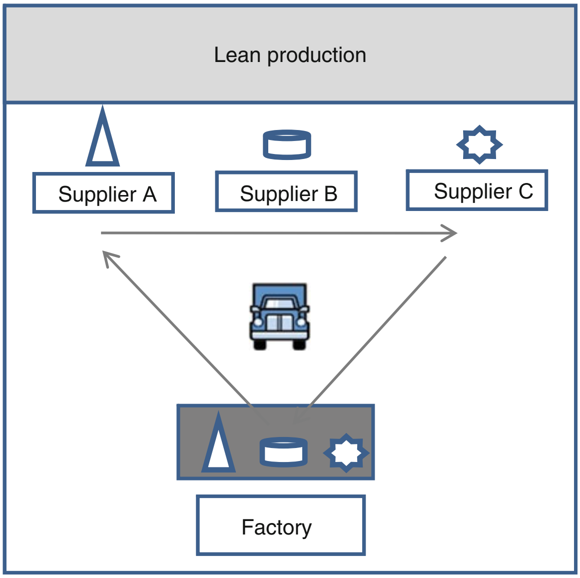


Fig. 6.66 Logistics in lean production

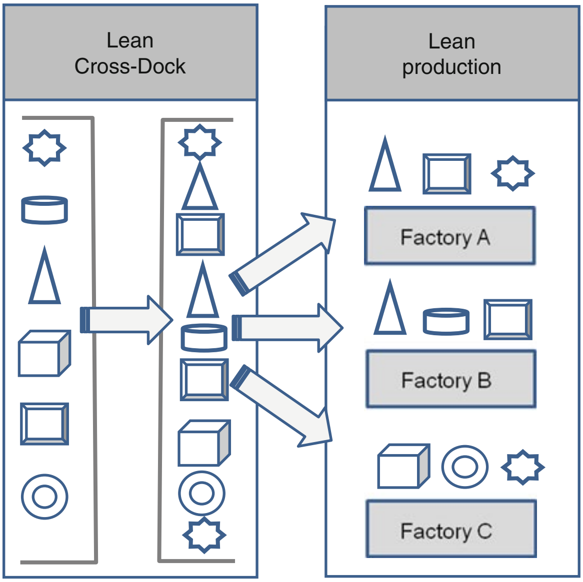


Fig. 6.67 Lean cross-dock in internal logistics

containers in order to replenish on demand (ROD) the empty containers which have arrived from production in order to be filled. Based on the number of containers needed to be prepared per day and the time needed, the basic parameters for the calculations of lines and resources within the cross-dock area is determined for the preparation of articles to be distributed to production. This same topos is a special RIP where the storage activity operates as a communication point between internal and external logistics. The operation of this special cross-dock RIP is analogous to a production RIP, where the targets for inventory turns (IT) remain high. This means acceleration in the ordering cycle to the suppliers, a reduction in the necessary storage surface and, last but not least, a drastic reduction in working capital needs.

6.8 Lean Flow in Purchasing and Procurement

The purchasing and procurement department traditionally plays a key role in the operation of a company. We would say that, although the sales department is on the time axis closest to the customer and writes the invoices, the invoice is paid only if the product is delivered on time, i.e. on the time agreed with the customer. For executing orders and on time delivery, production and procurement are responsible. Production must produce value on time from the perspective of the customer and procurement must procure the availability of raw material and parts to production from the perspective of the company in the sense of maintaining and preserving a VAS instead of a VDS as described above. The two perspectives, which may appear conflicting, are nevertheless identical through the VAS. The goal of procurement in a lean enterprise is the continuous and permanent search for ways of achieving VAS in order to re-conciliate the sometimes conflicting interests of customers with those of the enterprise, which is not usually the case in non lean enterprises. What frequently happens in the daily routine of the factories is that sales blame production and production, in turn, blames procurement because a final product or service did not reach the customer on time resulting in a delay in money collection. The central key point therefore in the operation of a lean enterprise is procurement from the executive perspective and purchasing from the strategic perspective, which are upgraded as these make part of the common goals of lean management. The strategic role relates to the continuous and permanent search for, and development of, suppliers who are able and willing to be part of a lean logistics programme, as described in the previous section. The role and responsibility of the executive is transferred in practice to the topos where the execution of the order takes place, i.e. in production, since the main way for replenishing materials is the pull mechanism Kanban. The basic operations and responsibilities of purchasing and procurement related to the planning of the supply requirements, the replenishment policy and the development of relations with the suppliers in a lean environment, are described.

6.8.1 Materials Requirements Planning

In non lean enterprises, planning the material and parts requirements, is broadly performed by means of information systems known as Materials Requirements Planning Systems (MRP systems). The logic of these systems is based on the knowledge of the demand for final products (independent demand) and given the bill of materials (BOM) for each final product, the requirements for raw materials and parts (dependant demand) are calculated. Before the final orders are forwarded to suppliers, the system takes into account the inventory on hand (available inventory in the warehouse) which deducts them from the total needs. In a lean enterprise, the need for using this type of systems is limited to the totality of the items which have long lead times (long lead time items – LLI). The following practical rule can be used: all articles which have an IT less than half (1/2) of the average IT of all articles production needs are characterized as *indirectly* regulated by means of the information system, as opposed to the other articles which are characterized as *directly* regulated by means of the pull mechanism Kanban. All articles directly regulated though the Kanban mechanism do not need an information system for the calculation of material requirements. The greater the amount of direct articles, the less the procurement management cost of these articles. In a lean enterprise the percentage of directly regulated articles must be higher than 60–70% of the total number of articles. It is important to continue or to set up supplier development programs in order to be able to contribute to the VAS of the enterprise supply chain by adding more articles to the list of direct material.

Scheduling and execution of supplies for directly regulated articles takes place through the pull mechanism Kanban. In a lean environment the word *scheduling* typically does not exist, because it is not connected to the time dimension, but solely to the calculation of the quantities of the articles to be replenished by means of the Kanban mechanism. These quantities are calculated and are commonly decided by production management and the suppliers in cooperation with the sales department who know significant details with respect to market demand. The quantities should be reviewed at least once per year in order to include possible demand changes and more often, even twice per year, in particular cases where the market has a seasonal character, as for example the air conditioner market. These articles are excluded from a MRP system, which undertakes solely the planning and scheduling orders of indirectly regulated articles. Order dispatching in both cases can be completed by means of electronic information transfer to the immediate knowledge of the supplier of a supply request. Having decided on the property of *direct* and *indirect* regulation for each article, procurement activities concentrate on determination of their replenishment policy and, based on this strategy, relationship development for implementing the supply strategy.

6.8.2 Replenishment Strategy of Lean Inventory

The supply targets are twofold. The first is related to the in time availability of materials for the execution of orders and the second to the requirement that this availability occurs at the lowest cost. However, from the point of view of the non lean enterprise, the biggest weight of the research in theory and practice has been devoted to the issue of minimizing the cost of holding inventory not tied to customer needs. The targets do not change in the case of a lean enterprise. While operations research faces the issue as a problem of mathematical optimization of the objective function concerning availability and cost of materials, the lean enterprise sees it as a subjective function between *customer satisfaction* and the *customer satisfaction* establishing policies of a lean inventory to resolve the problem. These policies, referred to above, will become operations through co-operation with suitable suppliers. There is a conflict between the availability and the cost of materials from the point of view of the enterprise. However, if the problem extends towards the suppliers, the dynamics will change in order for the suppliers to get involved and contribute to a respective VAS, accompanied, if possible, by cost reduction. There are ways far and beyond the logic of mathematical optimization which looks one-dimensionally at the problem i.e. only from the logic of mathematics, far from the entrepreneurial logic. As discussion about the situations known as *win*-*win*, that is, there are simultaneous benefits for all stakeholders, frequently takes place, in such cases we would stress the fact that the target is the benefits themselves, even if they come deferred in a time horizon for the two sides going through a process of *win*-*lose* and *lose*-*win*. It is possible, in order to see benefits in a visible time horizon that one side must lose or in the best case not win, a situation which will be balanced later.

In a lean enterprise, the target in supplies is the achievement of a high IT speed. This can be achieved by means of an agreement with the suppliers. In Sect. 6.6.2 a detailed discussion was conducted about the way with which it is possible to examine the feasibility of the articles as far as the use of the pull mechanism Kanban is concerned and how this method can support the choice of inventory policies for each article category. In negotiations with suppliers with respect to the cost of fulfilling the selected inventory policies, there will be a clear picture of appropriate pull sequences so that these can be estimated cost wise from both sides and a balance found in order to improve it in the future at a particular point in time. The agreements must be contractually fixed after the necessary legal clarifications.

6.8.3 Relations with Lean Suppliers

It frequently occurs in cases of closing agreements with suppliers, that clarification of legal details takes up the largest portion of time, mainly because legal advisers worldwide must justify their compensations, we reckon. We definitely do not neglect the fact that their intention is to ensure that their customers are safe from any risk or damage that may result from the non-compliance of the agreement. In the majority of agreements, articles which cover risks make up 90% of the agreement. Namely, the percentage of the text which refers to what it has been agreed is about 10% with respect to the percentage of the text referring to what has not been agreed. From the lean perspective, the time required for covering all the eventualities which have not been agreed is time that does not add value, although many would support the opposite. There is a contradiction here referring to addition of value. Reimbursement does not constitute addition of value, because in this case the goal would be to try not to do things in order to get reimbursed, which is definitely not the goal of an enterprise i.e. an enterprise cannot have as an objective the production of reimbursements towards itself. Agreements are made exclusively for remembering what has been agreed and not what has not been agreed.

6.9 Integrated Demand and Supply Management

Discussion about the role of sales and marketing in managing demand of a lean enterprise has been left to the end, once production and supplies have been discussed, for only one particular reason: sales and marketing is the point closest to the customer. Sales promise what production can execute. Lean production constitutes the cornerstone and the spearhead of sales in the battle of enlarging the market. A higher market share means more profits. To see how this happens, let us look at the following example. Let us suppose, for instance, that there is a 10% increase in production volume. Under the assumption there is full absorption of overheads under the current production rate, then the only additional production cost is the cost of materials. Given that lead time has been reduced by 60% or more and the performance for on time delivery 99% as a result of lean production, most managers would agree that the market share would increase. If the increased production quantity can be sold, then 30–60% of each sale signifies an increase in profits, because the only additional cost is the material cost. The result of a saleable increase in production can increase the profits up to 5% or more than €500,000 for each €10 million in sales.

The customer is the meeting point for production and marketing. Consequently, it is necessary to care about the timely demand planning which starts from sales with the purchasing department to care about procurement planning, and production to care about the rapid orders execution. It concerns a permanent planning cycle, which starts from the customer and ends at the customer. Planning activities are incorporated into the procedure called: integrated demand and supply management (IDSM). The procedure includes the following steps

1. Demand smoothing and agility borders
2. Daily smoothing in product mix and volume

In step 1, demand smoothing refers to the way the enterprise responds to market demand. It is the cornerstone of the enterprise’s ability to achieve speed at low cost to customer satisfaction (of all customers). Based on demand planning, raw material quantities and components required for the execution of the program at the planning horizon are calculated. In step 2, the product mix and volume is determined based on lean flow line design. In the following section we will refer in detail to the procedure of demand planning.

6.9.1 Demand Planning and Agility Borders

The goal of demand planning is for each company to choose those parameters which will influence the availability and the cost of carry products with respect to their replenishment speed based on market needs. This means, in practice, that the degree of agility in availability with respect to customer expectations will be determined by the characteristics of the product. The degree of agility refers to the capability that a company wishes to sustain in the level of raw materials and components availability in order to satisfactorily respond to demand variations in the planning horizon. This way is different from the classic way based on demand forecasting. In the case of forecasting, the result, either through the use of mathematics or by means of expert opinion, is based on the percentage of error in the forecast procedure. It is certain that there is a possibility of erroneous estimation of forecasting which may often surpass 60%. On the contrary, responding to demand based on the percentage of desired agility is a strategic choice which influences, and is at the same time the basis for, the design and the operation of a lean flow system, from the availability of resources to the inventory policy, response time to market and working capital. The degree of agility characterizes the lean enterprise and constitutes the means for delimiting between unknown demand and the demand that the lean enterprise chooses to satisfy. In practice, it is frequently heard that the enterprise wishes to satisfy all and any demand at any time. However, unlimited agility leads to unlimited cost. Thus, the company must position itself and set borders in the time interval between zero and infinite agility. A realistic initial starting position will allow the enterprise to control the path of repositioning on the agility axis. There is a purpose and a way. The agility borders determine a front which is called *agility front*. Agility in the availability of raw materials and components allows for adjustments to the product mix and volume every day for improved smoothing and response to possible demand changes. The agility front creates metaphorically the profile of a desirable topos for inventory called lean agile inventory (LAI). Agility fronts are useful for two reasons: the first addresses the calculation of materials requirements and the second the absorption of abrupt demand variations. For time positioning of agility fronts the following are valid. The first agility front is called the *demand time front* (DTF). It is positioned at the interval defined by the time TPct extended by the time interval required for managing orders until they reach production for execution called *administrative response time* (ART). Further fronts are placed at intervals related to supplier response time and replenishment frequency. The difference lies in the fact that response time is defined as the difference between the point in time the order is placed by the supplier to the point in time the supplied materials are received. Replenishment frequency is defined as the rhythm with which orders are placed to

Table 6.18 Deviation agreement with a lean supplier

Order change before procurement	Deviation from quantity agreed
2 weeks	0
4 weeks	+/−10%
8 weeks	+/−20%
12 weeks	+/−30%
16 weeks	+/−lead time + 50%
>16 weeks	Unlimited

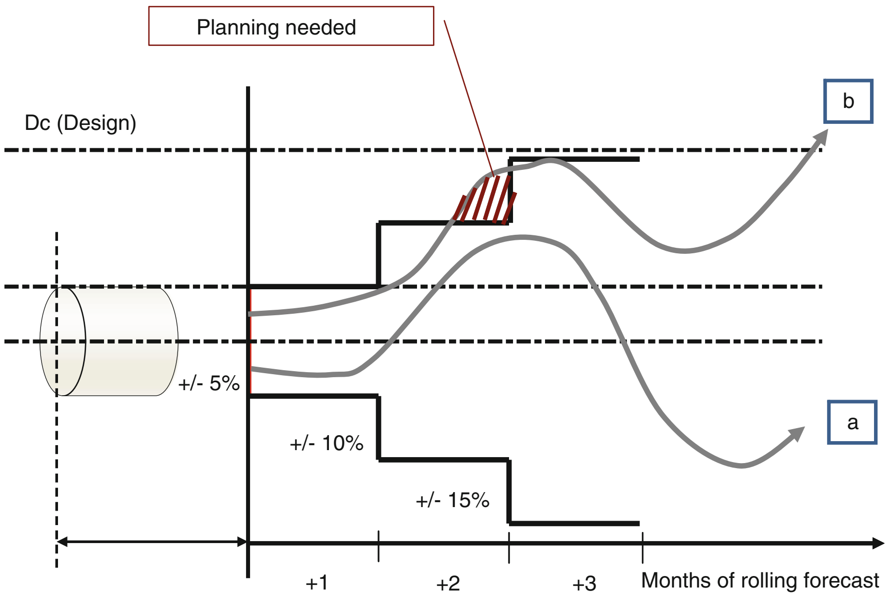


Fig. 6.68 Planning horizon and agility fronts

the supplier. For example, if the response time is 1 month and the replenishment frequency is 1 week then it is possible to place the agility front on a weekly basis if the enterprise has chosen to maintain the capacity of higher detail in planning materials requirements. The supplier response time does not change, however, what changes in this case is the rhythm of receiving the goods, where after the first time of placing the order, goods reception will occur at a weekly rhythm. This capability allows the enterprise to store 80% of the inventory value in the Supermarket (Sect. 6.6.2). In addition, deviation in each replenishment order may be possible if, in the meantime, there are changes in forecast which happens within the time interval agreed with the lean supplier. An example of such an agreement is given in the Table 6.18.

Figure 6.68 illustrates a realistic demand situation in the planning horizon at any point in time and the demand agility fronts. As shown in Fig. 6.68, demand variation (a) lies within the agility fronts and so there is no need for any intervention

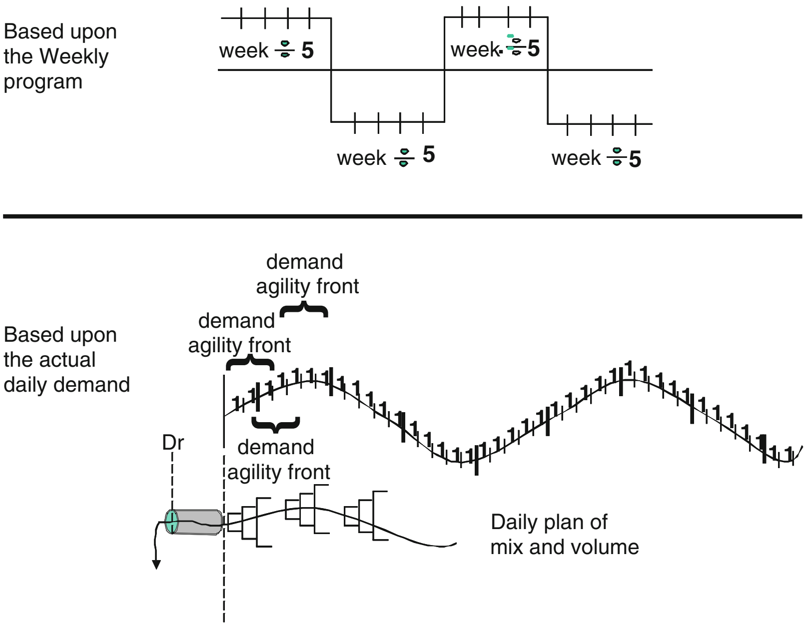


Fig. 6.69 Differences in the way of production planning

related to materials planning. However, demand variation (b) violates the agility front towards the end of the second month. Hence in this situation, if there is no correction then there will be materials shortage during the period of time concerned.

How can we react to such a situation? The answer is that if the violation is due to a forecast then demand fulfilment should be postponed to a later point in time, however, if infringement is due to real orders then these should be re-planned to an earlier point in time and to a time period where materials are available, such as around the beginning of the second month as shown in Fig. 6.68. The plan is created from the production planner who plans daily product mix and volume taking into account total demand in the specific planning horizon. The goal is, as much as possible, the smoothing of demand variation so agility fronts are satisfied. This work is performed daily as in a lean enterprise planning is executed every day in the planning horizon. Hence, there is immediate awareness of any eventual demand change that need taking into account and the necessary adjustments can take place. There are two types of investigations that are are undertaken by the planner before the final decision. The first addresses the availability of raw materials and components and the second addresses the availability of resources. In the non lean enterprise, production planning is typically performed once per week, with the danger that reprogrammed demand variations may lead to problems of resources availability. The differences are illustrated in Fig. 6.69.

Table 6.19 Total demand

	Today	Next day	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Total
Forecast		105	120	125	105	100	110	120	785
Orders	110	105	130	120	85	75	80	40	745
Total demand	110	105	130	125	105	100	110	120	905

Agile fronts are determined for each final product or product family and influence the calculation of material requirements which should be available for production. The materials calculation is based on the bill of materials (BOM) and the quantity used for each material in the final product. The calculation of the quantity for each material is performed each time at the maximum agility fronts. This calculation technique addresses all components not selected to be replenished via the pull mechanism Kanban that are excluded from the planning activity. The inventory level in materials and components which will result from the choice of agility is called strategic inventory, because it is the decision of the enterprise for defining its capability of responding to demand variations. For the choice of agility front per final product the following basic information must be taken into account:

- Market product maturity
- Criticality of suppliers (single source)
- Suppliers response time
- Total cost of ownership for materials above and beyond price
- Frequency of introducing engineering changes
- New product introduction and marketing strategy

Demand planning in the chosen planning horizon is necessary as well for the determination of the daily mix and volume per product. The procedure for the calculation and planning of demand and supply follows the following steps:

1. Total demand (TD) = Maximum (forecast, actual orders)
2. Determination of agility fronts (AF) % per time period
3. New total demand (NTD) = $1 + (TD \times AF)$ in the agility horizon
4. Executability of plan against capacity
5. Agreed production plan (Dr)

In the example, a production plan with a horizon of 5 weeks for a SKU A (stock keeping unit) is requested.

Step 1: Total demand – SKU A (Table 6.19)
Step 2: Agility fronts – SKU A (Fig. 6.70) (Table 6.20)
Step 3: Demand agility front – SKU A (Table 6.21)
Step 4: Plan executability against capacity (Table 6.22)
Step 5: Agreed production plan (Dr) (Table 6.23)

In the time period Δt = TPct + ART the agreed production plan stays constant and unchanged. In order for the proposed plan to be accepted, apart from the necessary and available resources, the mixed requirements in materials for the production feasibility must be calculated. The next step deals with the availability

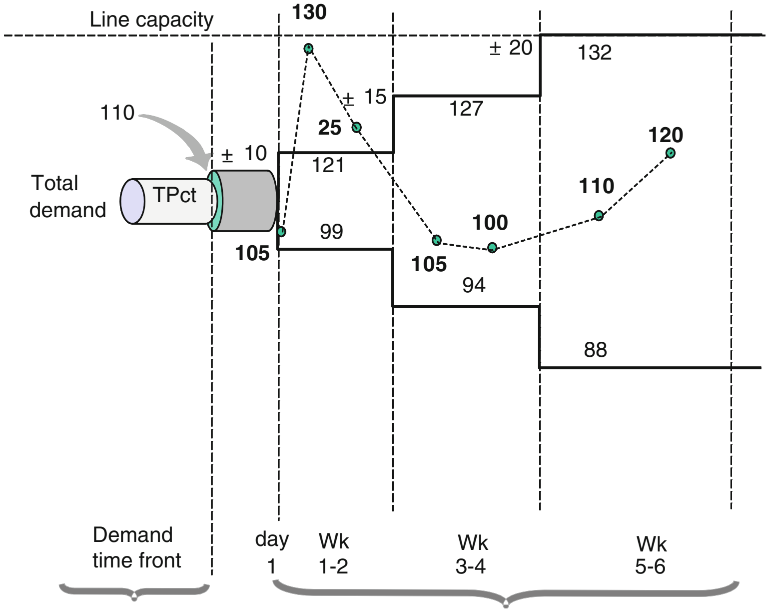


Fig. 6.70 Total demand and agility fronts – SKU A

Table 6.20 Agility fronts

	Today	Next day	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Total
Agility		5%	10%	10%	15%	15%	20%	20%	
Minimum	110	105	99	99	94	94	88	88	776
Maximun	110	116	121	121	127	127	132	132	985

Table 6.21 Demand agility front

	Today	Next day	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Total
Forecast		105	120	125	105	100	110	120	785
Orders	110	105	130	120	85	75	80	40	745
Demand agility front	110	116	121	121	127	127	132	132	985
ATP		11	−9	1	42	52	52	92	240

Table 6.22 Plan executability against capacity

	Today	Next day	Week 1	Week 2	Week 3	Week 4	Week 5	Week 7	Total
Forecast		105	120	125	105	100	110	120	785
Orders	110	105	130	120	85	75	80	40	745
Total demand	110	105	130	125	105	100	110	120	905
New total demand	110	116	121	121	127	127	132	132	985
Production plan	110	115	120	120	110	100	110	120	905
Capacity	130	130	130	130	130	130	130	130	1,040
Capacity %	85%	88%	92%	92%	85%	77%	85%	92%	

Table 6.23 Agreed production plan

	Today	Next day	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Total
Forecast		105	120	125	105	100	110	120	785
Orders	110	105	130	120	85	75	80	40	745
Total demand	110	105	130	125	105	100	110	120	905
New total demand	110	116	121	121	127	127	132	132	985
Production plan	110	105	120	120	110	100	110	120	895
Daily production	110	105	120	120	110	100	110	120	895

of resources and if there are not enough resources, then materials are ordered to the limit set by the agility front. The way the agility front is calculated is described below.

6.9.2 Planning of Lean Agility

Calculation of initial agility fronts

The following steps are required to calculate the agility fronts for demand-based planning. The steps make use of a worksheet containing the following individual sheets

Agility fronts – calculation worksheet

Maximum agility (BOM) – base data worksheet

Maximum agility (demand) – base data worksheet

The steps below are arranged in sequence to allow initial definition of the fronts with the considerations to be made at appropriate stages in the process.

Base data required:

The following base data is required:

Demand history – for each product

Demand at capacity – for each product

Production family/Cell
Total product cycle time (TPct)
Demand time front (DTF)
Customer quoted lead time (CQLT)
Maximum demonstrated production cell output volume (max Dr)

Maximum agility – base data (worksheet)

1. Populate the Worksheet with all product and option part numbers with their description and Demand at capacity.
2. The data needs to be grouped in production cells with sub-totals for each line grouping of these cells. A grand total for all lines then needs to be added to complete the worksheet.
3. A determination of the validity of the Dc for maximum agility and a number, either Dc or some other volume, transferred to the production volume column of the worksheet. Then each grouping of products (production cell/family) needs to be sorted based on descending quantity of production volume.
4. Define a position for each cell grouping by moving some product volume from the column *production volume* to the actual orders. The basis for this selection is as follows.

Production volume: Items that have high demand and are expected to sell regularly. These items will also be expected to be subject to "Best Date Smoothing" and potentially be manufactured every day. These are the items that are the best candidates for the Demand calculation = Forecast consumption.

Actual orders: Items that have less frequent demand. These items would definitely be expected to be manufactured less frequently than daily. These are items that would attract a Demand calculation = Actual orders and not typically be demand smoothed. In some cases, there could be limited smoothing performed manually for these products.

5. Enter the Maximum Demonstrated Production Output Cell. Volume to the Worksheet into the Total of the "Demonstrated Max. Output" column.
6. For each item that is a candidate for Agility Fronts (Line Design Dc or Production Volume) starting at the top of the list, enter a Maximum Agility percentage in the column and use the basis that the higher the volume demand, the less agility will be required. Good general rules to follow are:
   (a) Production Volume / Day > 15–5%
   >10–10%
   >5–15%
   >1–20%–30%
   (b) As the values are entered, the worksheet should calculate the high agility for each item and populate the Maximum Agility column. As these cells are populated between agility changes, the numbers should continue to decrease when compared.

(c) Following the entry of all agility percentages to all production volume items, compare the Max. Volume total quantity with the Maximum Demonstrated Output Quantity. The Max. Volume quantity should be slightly less than this output quantity to ensure that the agility does not exceed the plant's ability to manufacture the demand at the agility front. It is important to remember that these agility settings are preliminary and provide only a starting point for further evaluation.

7. The grand total of the worksheet items should provide a Maximum Agility Comparison that is very close to 100%. Print the worksheet for review.
8. Have the appropriate sales and marketing person and the manufacturing planning person review the data defined in the worksheet. They will identify any changes required to the items: Production Volume to Actual Orders or reverse; changes to agility %; validation of the Production Output. Having completed the review, the worksheet should be updated for the changes made.
Agility front: worksheet
9. Populate this worksheet with only those items that have been designated as having an Agile Front Policy. These will be those items from the Maximum Agility Worksheet designated as those that will be smoothed (Production Volume or Line Design Dc). This population will list the items in Production Cells to maintain the groupings that were created in the Maximum Agility Worksheet.
10. From the data files of Demand History of each item, extract the following parameters:
    (a) Average monthly demand – simple average across 12 months of the data
    (b) Monthly demand peak – extract the monthly peak demand from the history

Transfer these parameters to the Agility Front Worksheet. The Worksheet will calculate the Peak % and populate a column on the Worksheet.

11. Populate the Worksheet with the following data:
    - Total product cycle time (TPct) in Days (Flow Lead Time)
    - Demand time fence (TPct + Administrative Response Time) in Days
    - Customer Quoted Lead Time in Days
    - Maximum agility percentage from the maximum agility worksheet
    - Demand at capacity from the maximum agility worksheet as the demand used as production volume
12. The worksheet will populate the fields for the first agility front. The basis is to use the agility % required as either the maximum agility front or a lower agility based upon the peak. The result should be reviewed for some validity of the peak (%) and/or maximum agility (%) by the Sales & Marketing person responsible.
13. The second and third agility fronts should not be considered in the above considerations. These fronts are to be considered in conjunction with material and components agility requirements. Similarly, the range (length) of the agility fronts should not be reviewed at this time. The main focus must be to validate the first agility front amplitude.

14. All other parameters should not be reviewed at this time since they will become a focus following confirmation of the initial agility front values.

6.9.3 Smoothing Daily Production in Mix and Volume

How will daily production planning be performed? Lean flow is already prepared and has been designed to produce a product mix in the desired quantities every day. What will be required is to define the sequence in which orders should be executed at the flow line. The sequence should be defined in such a way so that mixed model TAKT is respected. This is important since in this way smoothing of the production line with respect to the designed daily demand in mix and volume is achieved. By means of the process map, the number of resources necessary for production is calculated for the particular quantity. During planning the product mix and volume selected will not cause line imbalances which may be provoked through overloading or under-loading of the flow line. The process map is the basis for the definition of the proportionality of the product mix to be produced for orders fulfilment. The target is to produce any model every day at customer demand no more no less. The way to measure this capability is called *linearity*. Linearity of 100% signifies that every day what is produced exactly what has been planned, and it is planned only what it has been produced. In Sect. (6.9.4) the way of calculating linearity is described, the maximization of which is the condition for a good and reliable operation of the pull mechanism Kanban in internal and external logistics. It follows the way of calculating appropriate mix and sequencing of products for orders execution.

6.9.3.1 Based on the Toyota Philosophy (TPS)

The aim of TPS is the achievement of fully smoothed production to avoid waste in time thus increasing line efficiency. The technique is known as Heijunka in Japanese. Achieving full smoothing in production is possible only in the case where demand is constant. In this case, production produces at a constant rate. However, in reality where real demand exhibits variations, Heijunka cannot be used, unless the approach is to produce a constant average and at the same time carry inventory proportionally to the demand variation, the stability of the production process and the frequency of shipments. A variation of the technique concerned has been developed in the West for the case of demand variation. Smoothing in this case is performed based on product mix and the definition of the sequence with which products should be produced in production line (just-in-sequence). For facilitating production smoothing with varying demand levels, the so called “Heijunka box” is used, a visual tool implemented for achieving efficiency of Heijunka type, as has been described above. For a description of the way to define the quantity which should be produced each time per product, see the following case of lean flow. There is enough information in the international literature and on the Internet and for reasons of economy we will not expand further on this issue at this point.

Product	Dc	Final Assembly L	RES	0,7 x RES	1,1 x RES	index
RWK 30	33	26,42	5,57	3,90	6,12	JUST
RWK 21/24/25	18	20,61	4,34	3,04	4,78	HIGHER
RWK 16	27	20,04	4,22	2,95	4,64	HIGHER
RWK 10	5	19,03	4,01	2,81	4,41	HIGHER
WMK 4	22	26,42	5,57	3,90	6,12	JUST
H		8,23				
ΣDc	104	104				
TAKT		4,75				
ATw		23,45				
RESw		4,94				

Fig. 6.71 Product time indexing

6.9.3.2 Based on Lean Flow

In lean flow, production planning is based on the combination of demand smoothing and line balancing. The benefits are the following. Since production lines are designed under the assumption that their capacity is about 20% higher than the capacity required for usual every day operation, it means that there is balancing potential already incorporated by design. Flexibility in line capacity is adjusted based on the number of workers who can staff the flow line and each time is calculated by the process map based on the actual daily demand. The condition needed to be fulfilled for line balancing is given by the relation 6.18.

$$0,7 \times \ RES_i < \ RES_w < 1,1 \times \ RES_i \quad (i \ = 1,2\ldots, \ n)$$

The equation states that all products (i = 1.2,. . .n) which satisfy the condition (6.18) do not create imbalances in the line and can be produced to actual daily demand. However, if the proposed product mix and volume violates the condition it must be adjusted so that the balancing condition is satisfied. When this is not possible, the non homeoformic mixes should not be planned for same day production. An example of homeoformism is given in the Fig. 6.71.

In the above example, the problem of non homeoformism in the product mix based on the demand at capacity is illustrated (Dc) for each product in the mix. As shown in Fig. 6.71, there are three products which if they stay in the mix the line will not be able to satisfy the required daily demand due to imbalance. In this case there are two ways of solving the problem. One way is through smoothing demand by means of reducing the daily quantities of those three products until the balancing condition is fulfilled. The second is through separating the products from the mix and producing them at different days.

The target in lean flow is smoothing daily demand so that the designed line balancing is not violated. If daily demand exceeds the limits or frequently exceeds them, the approach must take into account the possibility of choosing an inventory policy which will protect the lines from demand variation requiring additional capacity not available by design. Through the process map, daily demand and the

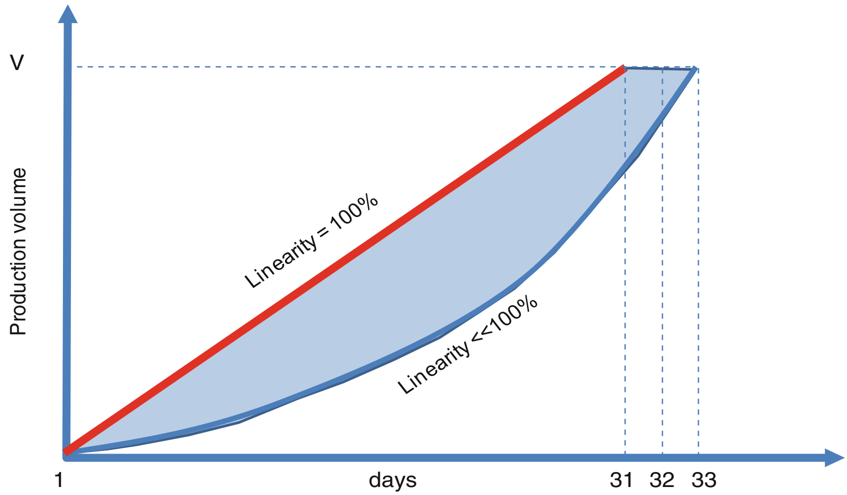


Fig. 6.72 Production linearity

number of resources is planned every day. If daily demand exceeds 50% of the designed demand (ΣDc) the line must be redesigned, or the hours of operating the line must be increased, if this is feasible based on the valid work flexibility.

6.9.4 Production Linearity

The target is to produce any model every day at customer demand no more no less. The way to measure this capability is called *linearity*. Linearity of 100% signifies that every day what is produced exactly what has been planned, and it is planned only what it has been produced. It has been observed that some factories frequently start slowly at the beginning of the month, in the middle they speed up, but not adequately enough, and towards the end of the month they work overtime in order to achieve the monthly target. Indeed, quite frequently, the month may last longer than 30 or 31 days (unofficially). Namely, although the month has finished, production occurring the following month is credited to the previous month in order to make up the target of the month. This type of practice creates imbalances in production, many types of waste and inhibits the smooth operation of the pull mechanism Kanban. Graphically the situation may be illustrated as shown in Fig. 6.72.

From the illustration, the problem that appears is obvious. The surface covered between the straight line which corresponds to 100% linearity and to the curve which corresponds to linearity much less than 100%, represents the cost of non linearity. This cost is due to the low line efficiency, that is to the bad exploitation of the resources caused by overtime consumed in order to recover the hours lost due to hysteresis and also the cost and additional energy that must be consumed due to non

Day	Dt	Dr	Dt - Dr	Sum of deviations	ΣDr	Linearity
1	4	3	1	1	4	75,0%
2	5	3	2	3	9	66,7%
3	3	6	3	6	12	50,0%
4	3	4	1	7	15	53,3%
5	4	3	1	8	19	57,9%
6	5	5	0	8	24	66,7%
7	4	4	0	8	28	71,4%
8	5	2	3	11	33	66,7%
9	5	6	1	12	38	68,4%
10	3	5	2	14	41	65,9%
11	4	4	0	14	45	68,9%
12	5	3	2	16	50	68,0%
13	4	4	0	16	54	70,4%
14	4	3	1	17	58	70,7%
15	4	3	1	18	62	71,0%
16	5	6	1	19	67	71,6%
17	3	4	1	20	70	71,4%
18	4	3	1	21	74	71,6%
19	4	4	0	21	78	73,1%
20	4	4	0	21	82	74,4%
21	4	5	1	22	86	74,4%
22	7	9	2	24	93	74,2%

Fig. 6.73 Calculation of production linearity

homeoformic and smoothed production. In parallel to cost increase the quality is diminished. In the following, the way of calculating linearity is described and an example of its calculation and use is given.

$$\text{Linearity} = 1 - \frac{\sum |\text{Dt} - \text{Dr}|}{\sum \text{Dr}} \qquad (6.37)$$

Where Dt is the planned quantity to be produced and Dr is the quantity finally produced (Fig. 6.73).

From Table 6.28, the linearity of production for the period of 22 working days in the month is 74.2%. The following graphical representation illustrates the time evolution of linearity during the month (Fig. 6.74).

Linearity higher than 85% is a precondition for the use of pull mechanism Kanban. Furthermore, linearity can be used for the development of personnel rewarding systems. The improvements in linearity are mainly due to the people in production.

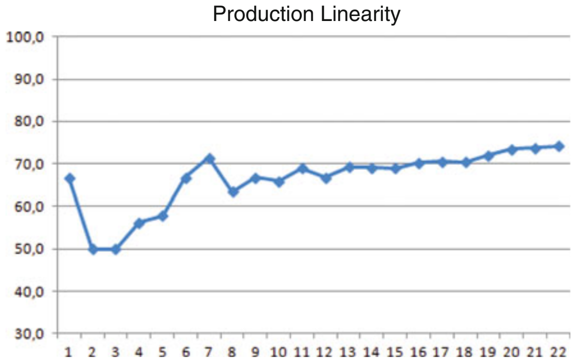


Fig. 6.74 Time evolution of linearity

ENGINEERING CHANGE REQUEST (ECR)

PENDING

PRODUCT: CHASIS MODEL –10101

PENDING	PART NUMBER	AUTHORIZATION DATE	PENDING DATE	DISPOSITION	ECR POS
ECR 4934	WAS KA 3030 IS KA 3040	18/5/2011	8/7/2011	UNTIL FULL DEPLETION	OP120

Fig. 6.75 Engineering change request

6.10 Change of Engineering Specifications

Changes of engineering specifications of products are a frequent phenomenon in companies which produce customized products or for reasons of upgrading or improving a product. Implementing engineering changes in a lean environment takes place exactly at the operation in production where the change should take place. In the following the procedure and the basic differences existing with respect to a non lean environment is described.

The procedure always starts through issuing a so called Engineering Change Request (ECR). On an ECR (Fig. 6.75), in addition to the technical change characteristics which we will not deal with at this point, the following information must exist: the product part number for applying to the ECR, the component part number that will be replaced, the part number of the new component which will

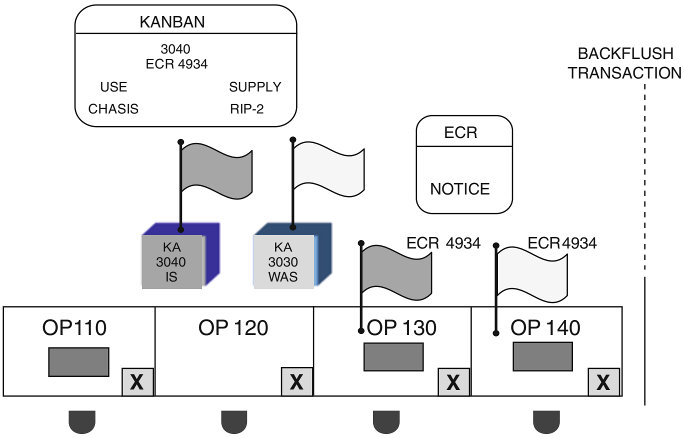


Fig. 6.76 Implementation of an ECR

replace the current one, the final date of use of the old component and the implementation date of its replacement by the new one.

One of the problems arising during the implemention of ECR at the point of concern is the uncertainty related to respecting the planned date for realizing the replacement of the old by the new component. In the example presented in Fig. 6.75, the planned replacement date of the old article is 17.5.2011 and use of the new one to start on 18.5.2011. Finally the change was performed on 8.7.2011. What can this uncertainty in respecting the plan be due to? The uncertainty has many causes; however the basic one is described as follows. The prerequisite for passing from the old article to the new one is typically the complete consumption of the old article before starting to use the new one. The exact scheduling at the day level of the particular point in time is very difficult, almost impossible to calculate a priori, even through the use of information systems. In enterprises which do not use lean flow, implementation of ECR, through the use of information systems, creates information ambiguity with respect to whether the change has been performed or not. There is ambiguity with respect to the accuracy of the BOM. Ambiguity and non accuracy concerning BOM has multiple and quite often chain reaction consequences in the operation of both internal and external logistics. The phenomenon is very common and our experience confirms it. In a lean flow environment, the procedure is performed exactly at the point the line and the operation where the article is consumed (Fig. 6.76). The sequence of events concerned is the following.

The necessary containers and the corresponding Kanban cards for the new article are prepared. On the day when the last container with the article to be replaced is about to be consumed, at the point in time when the last piece is consumed, a mark-up is placed on the product that receives it. Next, the last container carrying the information of the old article is removed from the production line and two Kanban containers with the new article are placed in its position. When, at this point, the first piece of the new article is consumed, then a mark-up sign of a different colour is placed on this product. At the same time the old production instructions are replaced by the new ones. At the end of the line, when the product with the last piece of the old article appears then, keeping to the currently valid BOM, the consumption of all parts to the information system is declared. Right after this event, the new BOM including the new article is activated in the information system. When the first product with the new article appears at the end of the line, the new BOM is taken into account for the declaration of the consumption of all parts. With this step, implementation of an ECR is complete. During the execution of the sequence of events at the line at the point of production that are about to perform the changes, there is a synergy of the line supervisor, the quality control inspector, the representative of the Engineering department and the materials handler responsible for the operation of the Kanban system.

6.11 Lean Flow in Cost Accounting

Despite the impressive improvements brought to industrial practice by lean thinking, many enterprises fail to see the impact on economic performance. There are primarily two reasons for this phenomenon. The first reason is that lean production eliminates many hidden activities and therefore hidden cost which is not followed up by the costing system of the company. As a result, there is no point of reference for a comparison of the current and future state with respect to cost accounting. The second reason is the different perspectives from which a lean and a non lean enterprise look at a cost accounting system. Standard product cost or production cost in a lean enterprise has a different calculation basis from the standard cost in a non lean enterprise. What do the major differences focus on? In lean production cost accounting, focuses on the flow as a combination of materials and information. The goal is an accelerating and efficient flow to satisfy the customer order. The method of cost accounting must have an impact on working capital, the speed in inventory turns and the cost of carrying materials inventory. In a non lean enterprise cost accounting focuses on increasing work productivity performed by persons or machines aiming to reduce product unit cost. In lean production a different way of calculating the product cost is required otherwise there is a danger in taking decisions which are operationally ambiguous. The way therefore, is a single one: the introduction of lean flow to classic cost accounting, rather than classic cost accounting in lean flow. Before proceeding to the practical part of replacing the method, a brief approach to what we call economic efficiency of the enterprise to customer demand is presented.

6.11.1 Economic Efficiency to Customer Demand

The cost does not exist on its own. What exists is value. Therefore what is all about cost? The answer is given indirectly by Aristotle in Politics, in which the founder of Western thought views work as a good which has value but does not give value. Rejecting work as a source of wealth, Aristotle founded the labour theory of value which held that work dexterity is not a determinant of exchange value. Instead the value of work dexterities is given by the goods which dominate in the market. He claims that value is not created exclusively at the expense of work during production activity. Noticing that work dexterity is a necessary but not a sufficient factor of value, he explains that both the usefulness as well as the work are related to the determination of the exchange value and the proportions of exchange. Finally, he mentions that the basic value requirement is usefulness which is related to a person's desires. Thus, demand is governed by whether a good is desired. According to Aristotle, exchange value is derived from use value through market demand. Money, he mentions is the means that makes desires commensurable. Therefore, applying the above mentioned, when we talk about cost we mean when something which has value, does not provide commensurable value with respect to the use of the product. Work which does not add value with respect to the use of a product is unnecessary work and therefore the related expense is waste. This is precisely the contemporary concept of cost in lean production. Aristotle, therefore, is the true founder of lean thought and not the Japanese of Toyota.

Work and its value can be improved continuously if two independent categories of process are activated simultaneously: increase the activities related to the increase of the product's use value and at the same time decrease the activities not related or diminish its use value. These two categories are independent and not complementary, as claimed by many practitioners of lean thinking. Waste is frequently related to the expense of activities which are necessary when concerning the use value of the product. Activities such as, for example, the method of planning and satisfying demand are directly related to the use of the product and therefore the related expenses can be considered waste in the case they are redundant or time consuming with respect to the speed with which a customer is satisfied in its desire fulfilment by the enterprise. As far as the customer is concerned, we distinguish three categories of expenses which should be accounted for in determining the exchange value related to the part concerning the activities which influence desire fulfilment: the first concerns expenses for the product work time (w) and the second concerns expenses for the product cycle time (ct). Both categories concern the capability of the enterprise to differentiate itself in the market. A third category refers to the expense concerning material articles necessary for producing the product. The availability of material articles is the prerequisite for the exploitation of the work dexterity and the speed of satisfying customer desire. The category of expenses relating to materials includes expenses necessary for the availability of materials in the factory for on time fulfilment of customer desires, not earlier and not later. If materials come earlier, then activities involved in managing them are hyper-redundant with respect to customer order fulfilment. If they come later there is a danger that the customer is not satisfied and, for a different reason, the same activities are hypo-redundant. In both cases they are redundant and for that reason the corresponding expenses constitute waste.

Hence, for the determination of the exchange value of a product or a good in general, knowledge of the use value of a product or good which has a component the value of work dexterity as necessary, but not sufficient as referred to above, is necessary. The expense for the cycle time of the product must be added to this value as a second component. The third component is expense in purchasing and managing materials. The measurement addressing the totality of expenses related to the product is typically called *product cost*.although it should be called *product value*. Since in a lean enterprise the discussion is about self-regulated work, materials and information flow for the creation of value connected to product use, the corresponding cost refers to the cost of the related work, material and information stream (WMIS) and not to the value stream cost. The stream does not concern the value of the product, but the components of the expenses which should be taken into account in order to create a potential use value which aims at the determination of an exchange value (sales value). Mathematically, the function of cost for the WMIS can be written as follows:

Product cost (Kp)	=	Cost of work	Kw
	+	Cost of cycle time	Kct
	+	Cost of materials	Km
		Cost of information	Ki

$$Kp = Kw + Kct + Km + Ki \tag{6.38}$$

In the lean enterprise the main goal is the drastic reduction of product cycle time so that the product use may start as quickly as possible by the customer. Work dexterity is a fixed factor for the reduction in the cycle time. Therefore, salaries (and wages) paid for work are part of the fixed prerequisites. If an enterprise has products for which there is no market demand, it is only a matter of time before this enterprise will run out of customers, regardless of the production cost and the increase in dexterities they possess. In production, worker influence use value and therefore from the point of view of management accounting, expenses related to their salaries must be faced as depreciable assets, as part of the overhead (OH) and not as a variable cost. Efficiency, namely the ability of the enterprise to respond to demand, is calculated by the division of the overhead by the product cycle time, which in lean flow is the time TPct. TPct is predictable, tangible and controllable, as well as independent of the production volume. Therefore, it is compatible with accounting standards – GAAP (Generally Accepted Accounting Principles). From the above, a method for calculating the standard product cost in lean flow is presented.

Table 6.24 Ratio overhead/work (JCIT, USA, 1996)

	1930	1940	1970	1990
Overhead $	1,000	1,000	1,000	1,000
Labour (hours)	100	90	50	25
Overhead/Labour	10$/h	11$/h	20 $/h	40 $/h
Wage	10 $/h	10 $/h	10 $/h	10 $/h
Total burden	20 $/h	21 $/h	30 $/h	50 $/h

6.11.2 Product Cost and Lean Flow

It is called standard product cost, only for reasons of comparison with corresponding terminology used in a non lean enterprise. In this case, the standard product cost is calculated once, when the product enters production. What producttion accounting seeks to know are deviations from standard cost on a daily basis, a high resources consuming task. In lean flow, it is not necessary to count deviations, because the aim is not knowledge of the cost of the product, but the improvement in the efficiency of the response to customer demand and therefore the continuous decrease of TPct. The result will be a decrease in working capital, an increase in the speed of inventory turns and the decrease in the cost of carrying inventory. The product cost in lean flow will be taken into account for calculating the product use value in order to determine the value of exchange, namely the sales value. In a non lean enterprise, efficiency refers to how well the enterprise exploits the work offered by the workers and therefore overhead is absorbed by the direct labour. The accounting methods used today and which are based on the absorption of the overhead by the work were created in the thirties when labour was the biggest portion of the cost of production. In that era, this was a reasonable way for this purpose. Nowadays though, the cost of labour makes up the smallest part of production cost. The ratio overhead to labour has completely changed during the past years. Let us follow this development (Table 6.24).

From the above table, even if we consider that salaries have not changed (something that is apparently not the case), it shows that the method of calculating cost based on the absorption of the overhead by labour, increases the cost of production artificially, because the enterprises began to become more productive and production time decreases continuously. Therefore the absorption of the overhead by labour leads to false conclusions. A correct and fair approach must involve investment in inventory in the internal and external logistics that a company needs to satisfy the customer. Consequently, at the factory level, the production activity is the best basis for the absorption of the overhead, mapped by the TPct, than the total product work time. For the absorption of the overhead by TPct, a homogeneous pool to concentrate overhead is created called a homogeneous overhead pool. If all the products absorb overhead in a homogeneous way, then there would be only one such pool. For rendering though economic fairness, it is desirable to create pools for collecting overhead for product families which may eventually have a different treatment in the path of their individual product life cycle.

As an example, we refer to work execution. The cost of work in a lean flow is not traced or tracked in detail, but viewed in exactly the same way as the cost of lighting buildings and providing electricity to machines. Therefore there is a significant decrease in opportunity cost, quality and information volume which would be necessary in any other case and this cost does not burden products with this part of the overheads which is significant. There are cases of enterprises which occupy whole departments for the collection and processing of information, especially in production environments which are organized to produce many hundreds of thousand production orders per year. The cost of work is part of the homogeneous overhead (HOH), which includes the usual overhead as a percentage (%) of the Cost of Goods Sold (COGS). The HOH is equally apportioned to all products. The scrap is considered as spending variance. Only materials are deducted automatically from the RIP, through the transaction of back-flushing based on the BOM. For the calculation of the standard product cost the following procedure is followed:

1. Determine planned volume (Pv)
2. Calculate manufacturing / assembly time from SOE's (AT) for all products
3. Calculate the **Gross Labour hours** for all products = Sum (Pv * AT)
4. Calculate **Labour costs** = Gross Labour hours * Average wage
5. Determine **Total product cycle time** per product (TPct)
6. Calculate **Gross TPc/t hours** = Sum (Pv * TPct)
7. Calculate **Homogeneous Overhead** = (Overhead as % of COGS + Labour costs)
8. Calculate **Efficiency** = Homogeneous Overhead / Gross TPct hours
9. Calculate the **Total Overhead** per product = Efficiecy * TPct
10. Add to the Total Overhead, product specific **variable overhead** (for example, due to marketing costs, Design costs, space costs etc) depending on specific cost drivers defined by the company. This determines the Total Overhead cost per product.
    Total Overhead per product = Overhead per TPc/t hour * TPct + variable overhead
11. Determine the **Standard material cost** = Material cost + Acquisition cost + cost of carry
12. Calculate the **Standard product cost** = Total Overhead + Standard material cost

6.11.3 Failures of the Non Lean Cost Accounting

We quote some of the failures and disadvantages of the non lean way in cost accounting:

- Encourage companies to produce in large lots with the purpose to sustain machines high efficiency in production and the manpower occupied as much as possible for absorbing the overhead.

- They do not provide daily information on performance, necessary for the support of continuous improvements at the level of flow lines.
- Need of a high number of resources in information technology and activities that do not add value for the collection and processing of thousands of production orders (these may exceed 300,000 per year in many cases).
- Inability in detecting the major advantages which lean flow create in form of higher quality, shorter lead times and particularly the regained capacity through overuse of resources imposed by lot based production.

Summarizing the section of cost accounting, we wish to stress that the conventional way of calculation and use of the standard cost imposes heavy work load on indirect personnel for the collection and processing of a huge amount of information and will not help company management for taking the right decisions for specific actions. Instead, in lean flow the way is simple mainly because of the lean environment which has the inherent characteristic of not needing to account for everything in order to have it all under control. In a lean environment it is not valid the dogmatic position: to keep everything under control everything should be measured mainly due to self regulation of the production system.

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Successful Implementation 7

Abstract
Having carried out multiple lean flow implementations across every type of industry, we have developed several guidelines that will prove invaluable for each and every implementation. These considerations based on experience will provide the implementation teams with points to focus on and the many traps to avoid during the implementation phases. All implementations will involve significant and often radical changes to the production processes and facilities.

7.1 Features of a Successful Implementation

Having carried out multiple lean flow implementations across every type of industry, we have developed several guidelines that will prove invaluable for each and every implementation. These considerations based upon experience will provide the implementation teams with points to focus on and the many traps to avoid during the implementation phases. All implementations will involve significant and often radical changes to the production processes and facilities. Preparation of the implementation team member *mindsets* and the support resources such as maintenance for this significant amount of hard work and change, are keys to success.

7.1.1 Product Synchronization Flows

- Defined for all major volume products in the process.
- All possible paths for products (relationship of flow) are defined, taking into account option processes, rework processes, and feeder processes.
- The scope of product synchronizations flows should not be limited to a preconceived *target area* for the implementation program.

Success and failure are sisters. . .

A.C. Tsigkas, *The Lean Enterprise*, Springer Texts in Business and Economics,
DOI 10.1007/978-3-642-29402-0_7, © Springer-Verlag Berlin Heidelberg 2013

7.1.2 Sequence of Events

- Sequence of events is very powerful when defined for all products in the process. At a minimum, all of the high-volume products produced should be defined.
- Create a standard sequence of events for each process, including rework processes.
- Work elements are not batched in large groups. Identify discrete work steps that will facilitate achieving balance in operational definitions. Include specific quality criteria.
- Time estimates are those that are reasonable to perform each work element with time for recognition and verification of quality criteria. Time estimates are measured in minutes.
- Individual work element times are accurate, as well as total times for a series of work elements. These have been observed and validated in the process. Total time estimates for each process should be accurate within 10% of actual observations.
- Non-value-adding setups and moves are clearly identified. The new lean flow line design may eliminate many of these. Therefore, the ability to quickly regenerate total time estimates will be desired.

7.1.3 Designed Capacity

- Demand at capacity (Dc) should be defined jointly by marketing, manufacturing, and senior management looking a minimum of 12 months into the future, preferably longer. It is helpful when developing demand at capacity to review shipment history.
- This data is collected for all products produced, not just a subset limited to a preconceived *target area* for the implementation program.
- Marketing has developed this information, acknowledges strategic market objectives, and recognizes that their input into this process will drive plant capacity for at least the next two years.

7.1.4 Materials

- Accurate bills of material exist that directly and sensibly tie to all current manufactured product part numbers and have been verified prior to implementation.
- Provisions for Kanban containers have been made to allow quick addition to the Kanban containers required to support the lean flow line.
- A lean flow line will typically have two line Kanban containers and two Supermarket Kanban containers for each component part. The line Kanban containers will hold about 1–2 days' worth of material and the Supermarket containers will hold at least 3–5 days.
- Shelves for a Supermarket stock location are available or can be purchased.
- Flow racks to present material to the workstation are available. These should be of a very flexible design and should have a slight gravity feed angle toward the

operator. The operator can pull material from the front of the flow rack, while material handling can replenish material from the rear of the flow rack without disturbing the operator.

7.1.5 Facilities

- The maintenance team leader will be intimately involved in the design of the lean flow line and will prepare a milestone chart of the physical installation of the new line.
- When the facility implementation plan is created, the maintenance team will be responsible for installing the new line.
- A lean flow facility will have the following features to complement the new line design:
  – Sufficient lighting placed for the highest quality of work.
  – The floor cleaned and painted to identify the area where manufacturing disciplines and controls are in place.
  – Machines, fixtures and roller systems cleaned, lubricated, and painted if needed.

The new lean flow line will be *proved-in* during an installation period. Proved-in means:

- All equipment and fixtures are moved to the proper place, but not yet bolted to the floor in case some adjustments are necessary.
- All fixtures and jigs are bolted down to work surfaces, especially ones that have been moved or modified.
- All tools and machines have been powered up and down several times. A good facility prove-in by the maintenance group will allow valuable time to be spent training the production employees while the lean flow line is live.
- At least one product has been assembled or built using each tool, fixture and machine required to ensure that they work properly. If test equipment is used in your process, these initial products have been built through the process and have then passed the test.

No facilities work should begin prior to the official completion of a facility implementation plan that has the approval of an external expert.

7.2 Results from a Successful Implementation

1. *Products*
   - Number of products in flow as a percentage (%) of the total number of products in the factory. The target is the increase of the ratio Number of products in flow/Number of products non in flow based upon the rule 80/20

- For the maximization of the flexibility in production is necessary to reduce the number of products which belong to 20% of the sales turnover through rationalization and standardization
  X = Total number of part numbers
  Y = Total number of parts numbers which belong to the group 80% of the total sales turnover
  D = Total number of part numbers in flow. The ratio D/Y % gives the level of flexibility level in production. The maximum is 100% while the ratio D/X % must be used for indicating the level of differentiation we have in the factory, which may limit the increase of benefits that the lean flow infrastructure offers.

2. Kanban (quantity)
   - M = number of parts under MRP planning (Long lead time items – LLI)
   - N = number of parts of non-replenishable parts
     K = number of parts under Kanban management up to suppliers
   - The ratio K/M% gives the improvement level with respect to the reduction of the number of LLI parts. The target is the increase of the ratio concerned
   - The ratio K/N% gives the improvement level with respect to the reduction of the number of non-replenishable parts. These parts are typical MRP parts

3. Kanban (value)

- Repetition of the point 2 based upon the value. The use of the categorization ABC/XYZ is recommended

7.2.1 Measurements Suggested for Performance and Flow Improvement

1. Three to seven days

- Working to Takt time targets (TPct)
- 60% linearity
- Kanban shortages
- Rework %
- Yield % by process
- Return units from field
- % of graphical method sheets on the line

2. Three to six weeks

- 90% and above linearity
- Kanban shortages
- Rework %
- Yield % by process
- Return units from field

- % of graphical method sheets on the line
- 95% and above on time shipment
- 95% order fill rate

3. Three months

- Working capital
- Kanban shortages
- Rework %
- Yield % by process
- Return units from field
- % of graphical method sheets on the line
- 98% and above on time shipment
- 98% order fill rate
- 98% fulfilment of set FGI levels
- 98% fulfilment of set Supermarket levels
- 98% fulfilment of set Raw materials level

7.3 ERP Systems and Lean Flow

In a lean flow environment, the need for information is reduced. The main reason is since a large portion of the organization and production planning is undertaken and executed by the pull mechanism Kanban, it is, to a large extent, a self-regulated environment. A second reason is that, because of a high inventory turn achieved by design, the exact knowledge of every event that happens in production during order execution at any time is not necessary. A third and fundamental reason is the abandonment of the model of tracing the work time and productivity at the operation level. Many Enterprise Resource Planning (ERP) systems are based on the need of the enterprise to have detailed information about the issues mentioned above. The lean enterprise has low information requirements for organizing and executing production. Therefore, the issue is to ask what happens in cases when the enterprise has invested in information systems like ERP. The quick answer is that, because it is not possible to change history, the enterprise should orient itself towards how to use ERP in order to direct investment towards *useful* information availability for the new environment in which it has opted to operate. For companies which have not yet made the leap towards an ERP system, they have the opportunity to do everything right from the beginning and therefore avoid unnecessary investments which are usually very expensive in both the acquisition and operation of the system. In both cases the question is clear and direct: how is it possible to incorporate an ERP system in a lean environment to the benefit of the company?

A very interesting and useful article on the issue has been published by Szemler, a specialist in the subject of lean supply chain (Szemler 2001). Szemler writes that for maximization on the return of the investment of an ERP system, a way must be found for the incorporation of ERP into the lean environment of the company, a way which will not replace or bind lean flow in an operational system, but enhance and complement the ERP, in order to operate synthetically for the improvement of the customer response time and to maximize profits. For a better synthesis it must be decided beforehand in which areas lean flow should focus.

1. A determination of how to compete, in terms of
   - Inventory
   - Orders backlog
   - Engineer or configure to order
2. The strategic goal for production, in terms of
   - Reduction in work in process (WIP)
   - Reductions in final products inventory (FGI)
   - Quality
   - Throughput
   - On time delivery
   - Effectiveness and utilization

Deming claimed that the biggest problems companies face is created right here at home by managers who are out of touch with the contemporary competitive world. These individuals, says Deming, fail to recognize that making a distinction between stable and unstable systems is vital for the future of their organization (May 1986). Many managers today continue to make improper distinctions between areas where ERP finishes and those where lean flow begins. Often the result is a productive process reorganized under lean flow which uses ERP concepts of capacity management to manage ongoing operations. Lean flow suffers under this management technique because resource calculation in lean flow is based on the premise that enough capacity will be available to build any model every day thereby accommodating to a wide variation in daily demand. With respect to the architecture of ERP operations, many of these are not needed because of the way lean flow is planned and organized. This can be illustrated on the basis of an ERP hierarchy ERP (APICS) in Fig. 7.1. In this diagram it is clear that the operations

1. Resources requirements planning
2. Rough cut capacity planning
3. Capacity requirements planning

are not used in the case in which (typically in 90% of the cases), the required capacity corresponds to expected demand, namely demand within the agility fronts established during design. Furthermore, a number of operations are replaced through in-process Kanban (IPK) signals for work execution and therefore are abandoned or are redundant. It refers to the following operations:

1. Order release and priority control
2. Shop floor control
3. Capacity control and finite loading
4. Operations sequencing
5. Input/output analysis

From the above discussion it is concluded that any investment in ERP systems must be realized in relation to whether the system covers the needs of lean flow and at the same time has been designed based on these needs. The reasons are obvious.

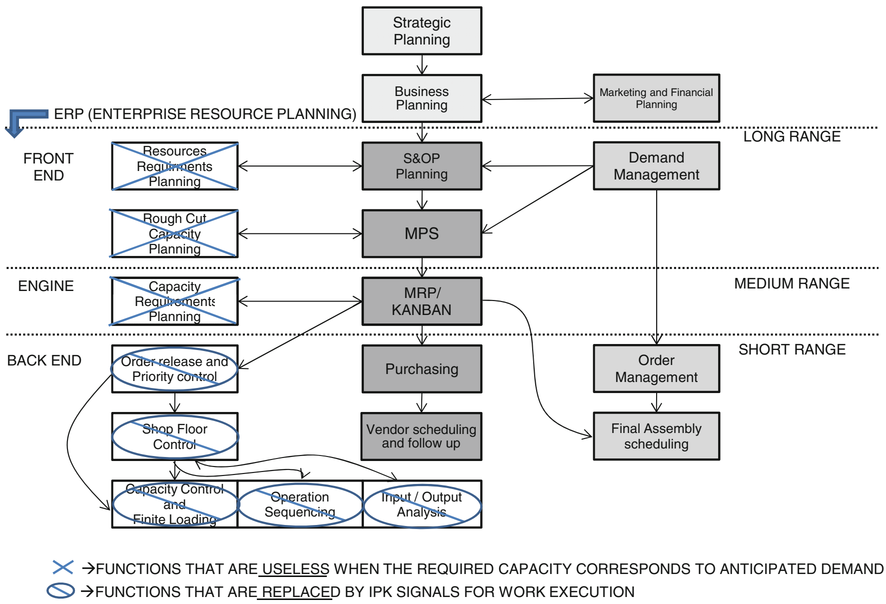

Fig. 7.1 Relation of lean flow and ERP operations (Szemler 2001)

The truth is that in the ERP systems market, there are few systems which fulfil the above conditions. With the expansion of lean flow techniques worldwide and with the suitable training of the executives which co-decide for the purchase and operation of such systems the development of lean ERP is a one way street. The problem frequently relates, as referred to by Szemler, to executives inside the enterprise who insist on, frequently in a fanatic way, the overuse of such systems and in this way retract the benefits achievable through lean flow. Deming claims similar findings and our personal experience confirms the above too.

For the lean enterprise, lean extends to the supply chain. There is an on-going discussion about the meaning of lean supply chain suggesting a synergy among ERP, APS (advanced planning and scheduling) and MES systems, promoting the equation:

$$\mathrm{ERP} + (\mathrm{APS} + \mathrm{MES}) = \mathrm{LEAN}$$

It remains to be proved in practice. Since this discussion exceeds the frame of this treatise we quote a source from the Internet (Novels 2010) which I find interesting.

7.4 Organization in a Lean Environment

We will close this chapter about a successful implementation with a significant issue which is usually ignored and neglected. It refers to the way of organizing the enterprise after implementing lean flow techniques. It is a fact that the

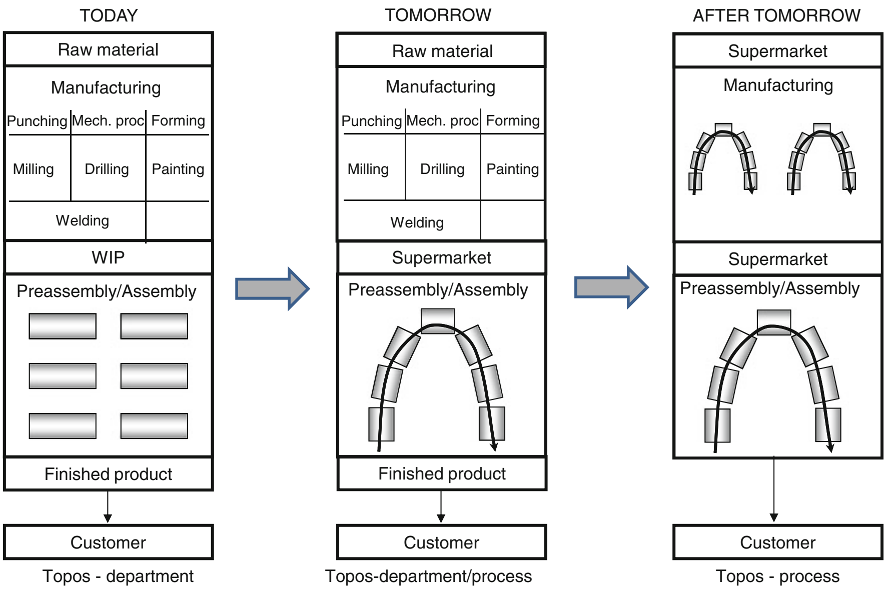

Fig. 7.2 Displacement from the department to the process (Leonardo Group)

reorganization and the way of operation in the new reality necessarily influence the current hierarchy structure of the enterprise. Lean flow brings processes physically closer so there is no need for multiple management levels. Besides, the changes in the way of thinking, from department thinking (vertically) to process thinking (horizontally) and the product view from the moment production starts and even earlier from design and marketing to customer delivery, requires a horizontal approach to organization. In such types of organization, future departments will have a role purely as the owner of expertise and not of management. Today, both roles are united at the level of a department. Already in many enterprises, the management levels have been reduced to two in medium size enterprises with approximately 150–250 employees, while in enterprises with 500 employees the levels do not exceed three. This is a reasonable development if one observes how the centre of gravity is gradually being displaced from the department level and the segmented production to the process level and united flow (Fig. 7.2).

It is recommended that the future organization is formed gradually so gaps can be avoided. Moreover, because of stepwise displacements, the organization learns and adjusts easier in order to reach quicker organizational stability in the lean flow environment. Displacements in the support departments of marketing, product design and sales should be analogous. The target is that organization from vertical become horizontal from the point of view of product management, sustaining and reinforcing the power of the departments exclusively at the level of expertise and not of management.

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Part III

Lean Enterprise in Practice

Lean Factory

8

Abstract

Based on the method developed in Sect. 6.2, its step-by-step application to different production typologies is exhibited. Each step is explained, based on real cases from our personal experience. The purpose of these examples is to support the reader more into comprehending how the method can be applied to deal with particular situations and less to give recipes for specific problems. The journey of lean flow is an exciting adventure for anyone who decides to follow it. It was for me personally an experience and every time it happens, I always learn something new, thus becoming a valuable means for its next implementation. The saying, 'One is never too old to learn permanently from new situations is completely true and I wish to confirm that on this journey there is no chance of reaching saturation or falling into a rut'.

8.1 Introduction

The third part of the book is devoted to a series of lean flow implementations in production companies. Following the method developed in the second part, its step-by-step application to different production typologies is exhibited. Each step is explained, based on real cases from our personal experience. The purpose of these examples is to support the reader more into comprehending how the method can be applied to deal with particular situations and less to give recipes for specific problems.

The journey of lean flow is an exciting adventure for anyone who decides to follow it. It was for me personally an experience and every time it happens, I always learn something new, thus becoming a valuable means for the next implementation. The saying, 'One is never too old to learn permanently from new situations is completely true and I wish to confirm that on this journey there is no chance of

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Practice without theory is blind, while theory without practice is empty

A.C. Tsigkas, *The Lean Enterprise*, Springer Texts in Business and Economics,
DOI 10.1007/978-3-642-29402-0_8, © Springer-Verlag Berlin Heidelberg 2013

reaching saturation or falling into a rut'. Moreover, I have observed that, in the passing years between the first time I autonomously supported companies in achieving set targets and today, lean flow neither has boundaries nor sets size prerequisites or complexity of the operational environment. It can be used in all production typologies independently of what is produced, excluding processes of continuous flow such as those met in the chemical industry. I discovered that its use fits equally well to the production of low mix, high volume products, or high mix, low volume as well as for make to order, or high tech as well as low tech and of mass customized products. From this high number of implementations I was fortunate to lead, I have chosen examples covering a wide range of lean applications, each with a different typology. The chapter of lean applications is concluded with one more application vision from lean production and mass customization in the generation of electricity. The sequencing in presenting the applications does not follow any particular rules. As a supplement to this book, we intend to provide further applications through the Internet to update the knowledge base on lean manufacturing.

8.2 Lift Trucks

This application relates to a German company with a factory in France, situated about 50 km north of Paris. In 2007, the mother company decided to implement lean production in all their factories in Europe (two in Germany and two in France). The company is known worldwide for the design and production of forklifts. Its sales catalogue includes a high number of products covering the internal logistic needs of a company. The project lasted from January 2007 until June 2008. The company had already started a program of outsourcing sub-assemblies in cooperation with suppliers from the region. The mast, as the basic sub-assembly of the forklift, remained in the factory, mainly because it distinguishes the final product, depends on the customer order and can have either a single, double or triple mast. The other basic component of the product is the chassis, which is standardized at the level of the product family.

The initial concern of the factory was related to the supply chain, primarily with their suppliers, while, according to the managers responsible, production had no serious issues to resolve and had no need for improvements. Following an initially performed audit, it was determined that a high percentage of problems in the materials supply chain had a direct effect on the programming and execution of production. The basic problem was attributed to loss of synchronization in the execution of orders due to lot production. Loss of synchronization forced assembly lines to assemble whatever final products could be finished with the existing materials and not necessarily what the customer wished. This event frequently led to missing parts for the various orders. The solution chosen followed a dual path. The first action taken was to implement lean flow for synchronizing production and secondly, to simultaneously improve the means of procuring materials from suppliers. The following discussion focuses on the creation of lean flow in production.

The main target was to decrease lead time in production from 5.5 to 2 days. The situation as we found it is described hereafter. With four stages in production, scheduling was based on allocating 1 day per stage. Lot production led to desynchronizing flow in work, materials and information. Although production planning defined the preferred sequence in the final assembly, this target was frequently not achieved. The flow starts with the manufacture of the mast, then the mast, chassis and small parts are painted, before the product is finally assembled. In these 5.5 days of lead time a large portion of the time was consumed due to the stockpile of masts and chassis in front of the painting booth (2 days), as well as in the manufacturing of the mast due to lot production (2 days) which influenced the waiting time of the lots in front of the painting booth. One day of delay existed due to the accumulation of painted masts and chassis before the final assembly lines.

The problem was confronted through the creation of one piece flow, starting with the manufacture of the mast, through the painting booth until the final assembly lines. The point of interaction of the flow with the customer was the point where production of the mast starts based on the customer order. Implementation of lean flow was scheduled to commence in two major phases. The first phase deals with one piece flow between the beginning of the painting booth and the final assembly lines and the second concerns one piece flow from mast production to the painting booth entrance. According to the pull principle, lean flow is implemented in steps, starting at the point closest to the customer. After the completion of the second phase, lean flow from the beginning of mast production until final assembly was a reality. The lead time was ultimately reduced from the originally 5,5 to 1,5 days. In Fig. 8.3, the value stream of the future state of production is illustrated.

8.2.1 One Piece Flow From Painting to Final Assembly

8.2.1.1 Targets of the Phase

Adjust the flow of masts, forks and chassis between the entrance to the painting booth and the assembly through a visual system.

Pursue the creation and smoothing of parts inventory based on TAKT of the final assembly line.

8.2.1.2 Way of Creating Flow

The idea quickly born was to use visual IPK (In process Kanban) in the form of tokens to signify the start of a new unit on the assembly line. The visual signal was decided to be activated by means of a token each time a new chassis is placed at the first operation of the assembly line. While in the theory of lean flow the IPK is fixed, in this case it is mobile and attached to the chassis (Fig. 8.1). Based on the line TAKT, each time a chassis goes on the assembly line, the corresponding

Fig. 8.1 IPK sign (token) on a fork chassis

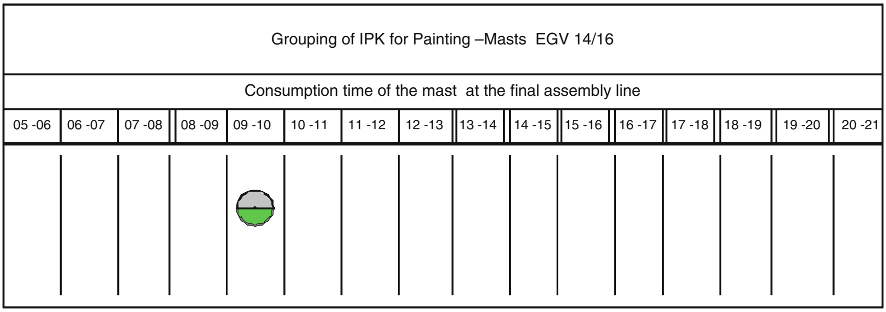

Fig. 8.2 Board for IPK grouping, collection, and release (Domange)

IPK is detached and placed on a metal board specially designed for collecting the IPK.

The IPKs collected on the board are transferred by the line material handler to a particular collection board placed at the entrance to the painting booth for painting the chassis and the forks, determined by the daily schedule (Fig. 8.2).

A similar technique for signalling consumption at the assembly line was used for the forks. Each final assembly line was driven by its own coloured IPK tokens for product identification purposes.

8.2.1.3 Calculating the Number of IPK

For the calculation of IPK, the potential down time of the painting booth in a repair case has been taken into account so that assembly lines will not be starved of

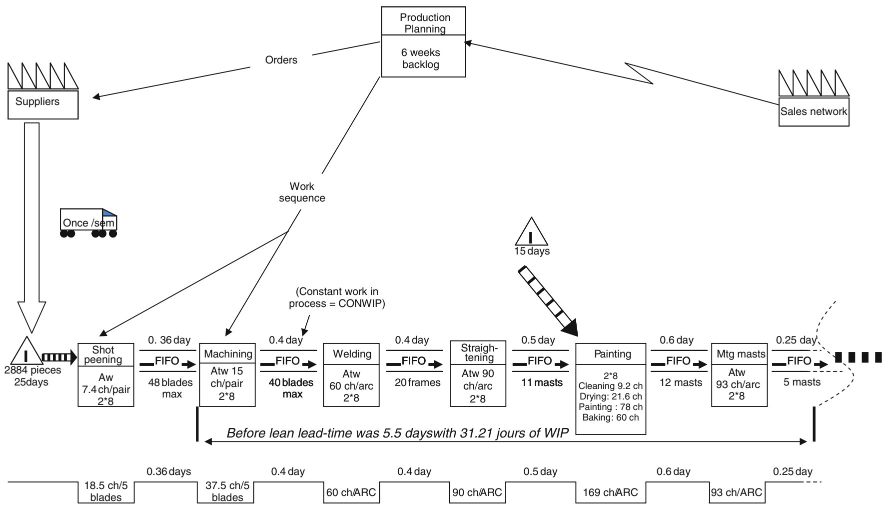

Fig. 8.3 Value stream map of mast production – current state (Domange)

Table 8.1 Calculation of the number of IPK for chassis and forks

Description	Explanation	Result
Painting time (AT)	4 h × 60 min	240 min
Dc (assembly)	final products	28
Operation time	7.25 h × 60 min	425 min
TAKT = H/Dc	425 min/28	15.17 min
IPK = AT/TAKT	240 min/15.17	16

missing chassis or forks at the beginning of the lines. Furthermore, operation of the painting booth in two shifts and the assembly line in one shift has been considered. The calculations result form the data presented in Table 8.1 and refer to a family of final products assembled on an assembly line.

Calculations show, that there is a need for 16 IPK to balance the difference in time that exists between the TAKT of the line and the painting time. Moreover, in front of the assembly line, a number of IPK equal to the number calculated, namely 16 IPK, will need to be created, because the painting booth operates two shifts, while the line operates one. Therefore, there will be an accumulation of chassis and of forks during the second shift in front of the forklift final assembly line. In Fig. 8.4 the mode of operation described above, is illustrated.

In reality and for practical reasons, the number of IPK is increased from 16 to 19 in order to achieve a certain level of agility for facilitating the necessary synchronization in the flow between the painting booth and the assembly line. The calculated WIP is called CONWIP (constant work in process), because of the constant WIP, which follows the FIFO rule and is regulated by means of Kanban signals (IPK).

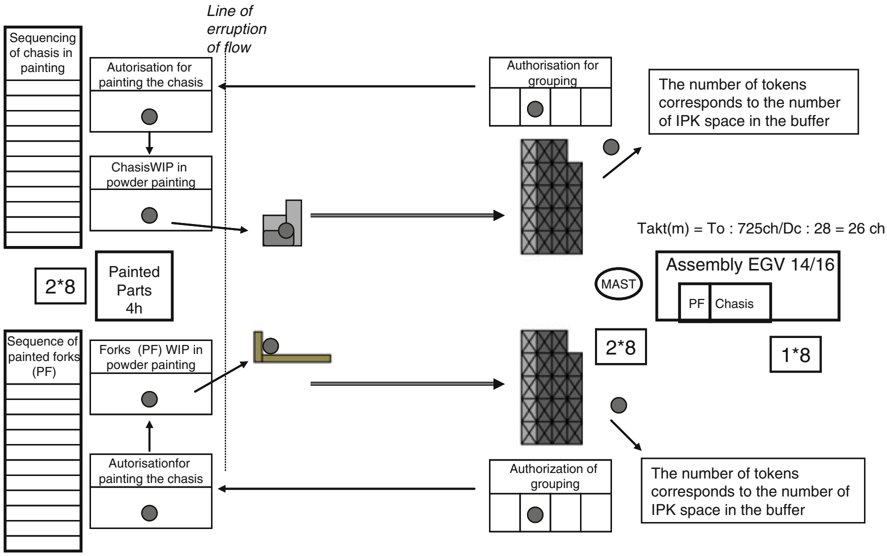

Fig. 8.4 Organization of one piece flow for chassis and forks (Domange)

Table 8.2 Calculation of the number of IPK for masts

Description	Explanation	Results
Painting time (AT)	4 h × 60 min	240 min
Dc (assembly)	Masts	28 + 8 = 36
Operation time	2 × 6.25 h × 60 min	750 min
TAKT = H/Dc	750 min/36	20.8 min
IPK = AT/TAKT	240 min/20.8	21

Below, there is an analogous analysis relating to the masts. The masts, unlike the chassis and the forks, are next to parts for the final products and the final products of the company also manufactured under contract for a number of customers. The mast arrives in the form of a KIT at the assembly line and before its mounting on the forklift the KIT is assembled, and completed with various parts. The percentage of masts manufactured for external customers is around 25%. Furthermore, a two-shift operation of the painting booth and the mast assembly line has been considered. In the case of masts, the total time of the two shifts is accounted at 750 min of production time in total. The calculations are based on the data presented in Table 8.2 and refer to a family of final products assembled on an assembly line.

Calculations show a need for 21 IPK for balancing the difference in time between the TAKT of the mast assembly and painting time. Moreover, in front of the line, a number of IPK will need to be created equal to the number calculated, namely 21 IPK, because the painting booth and the mast assembly line operate two shifts, while the forklift final assembly line operates one. Therefore, there will be an

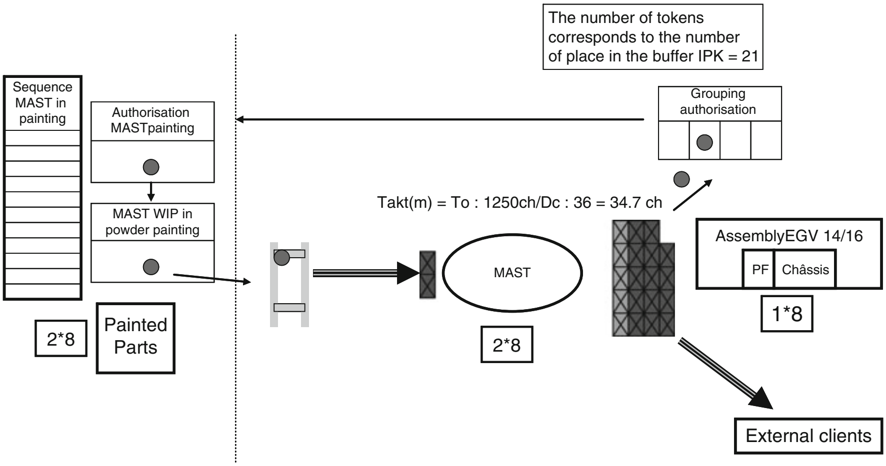

Fig. 8.5 Organization of one piece flow for masts (Domange)

accumulation of masts during the second shift in front of the forklift final assembly line. In Fig. 8.5 the mode of operation described above, is illustrated.

In reality and for practical reasons, the number of IPK is increased from 21 to 23 to achieve a certain level of agility for aiding the necessary synchronization in the flow between the painting booth and the mast assembly line. The two extra IPK are placed in front of the mast assembly line. The calculated WIP is called CONWIP, which follows the FIFO rule and is regulated by means of Kanban signals (IPK).

8.2.1.4 Sequencing of Voluminous Parts in the Painting Booth

The IPK collected by the board are transferred by the line material handler every hour to a particular collection board placed at the entrance of the painting booth for painting the parts determined by the daily schedule (Fig. 8.2). The theory of lean flow recommends that the IPK signals be executed according to the FIFO rule, but in which order? The sequence depends on the daily customer's orders schedule that must be assembled at the final assembly lines. Production planning should fulfil the following targets:

- Managing the flow of parts between the painting booth and the lines of final assembly through a manual and visual system
- Achieving flow and WIP smoothing based on the consumption rate of the final assembly lines

In Fig. 8.6 the circulation of IPK between the painting booth and the final assembly lines is illustrated and described below:

8.2.1.5 At the Powder Painting Booth

The total number of IPK gives the maximum amount of pieces in flow as CONWIP. A part enters the painting booth only if there is an IPK and there is demand declared in the book for order sequencing.

1 IPK → 1 piece

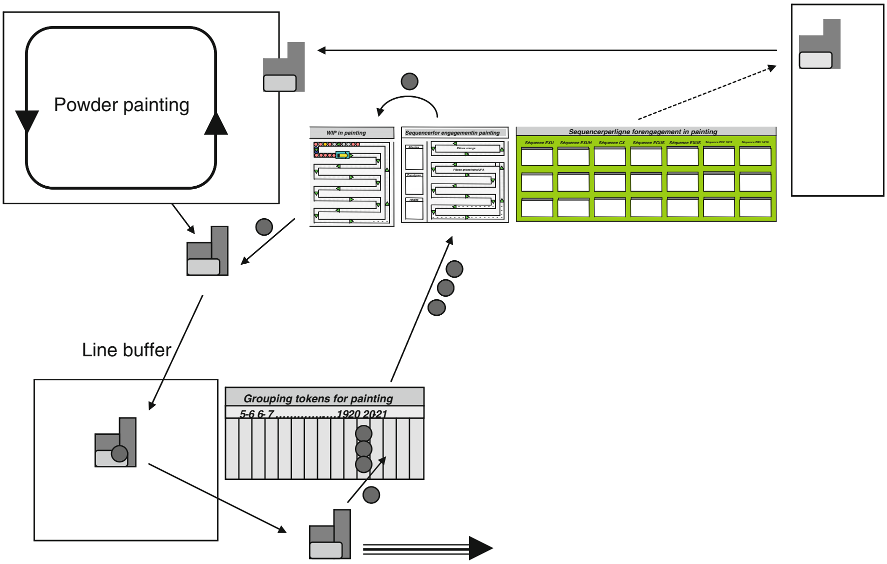

Fig. 8.6 Circulation of IPK and parts (Domange)

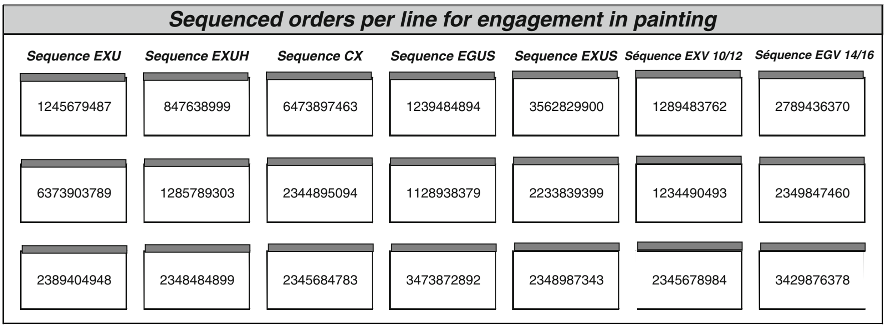

Fig. 8.7 Orders for the painting booth (Domange)

The IPK determines the type of piece

The orders sequence in the book defines the exact part numbers of the pieces which should be painted

Start entering of the pieces into the painting booth:

Production execution follows the sequence from left to right and from top to bottom on the sequencing board (Fig. 8.7).

When an IPK arrives from final assembly, it is placed on the sequencer of the painting booth respecting the FIFO rule (Figs. 8.8 and 8.9).

When a new part enters the painting booth, the attached IPK is detached and placed in the WIP sequence, respecting the FIFO rule and the corresponding line in

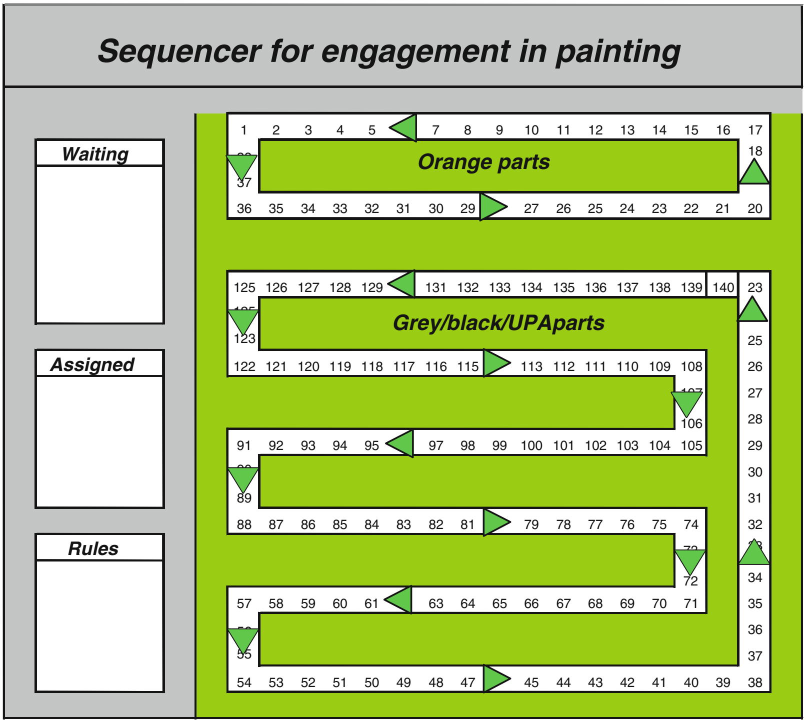

Fig. 8.8 IPK sequencer at the entrance of the painting booth (Domange)

the orders book is crossed out. When one part exits the painting booth, the corresponding IPK from the WIP sequencer is attached again to the part and the part is transferred to the appropriate final assembly line.

8.2.1.6 At the Final Assembly of the Forklift

When a part is moved to the assembly, the corresponding IPK is detached from that part and placed on the grouping board which corresponds to the column of the particular point in time. The material handler at the assembly line collects the IPK from the grouping board and transfers them to the painting booth sequencer. Thus, a new paint cycle can begin.

8.2.2 One Piece Flow in Mast Assembly

There are three types of masts: single, double and triple. The manufacture of the mast signals the point of interaction with the customer, as mentioned above. The order is completed with the assembly of the mast on the final product. From the mast value stream map of the current state (Fig. 8.3) can be seen, that production

Fig. 8.9 IPK sequencer at the entrance of the painting booth

phases in sequence are the following: granulate, cut to length, mechanical treatment, welding and straightening. There is a further phase called matching which is only needed in the manufacture of the triple mast. Before the implementation of lean flow, the mast was manufactured in lots. This resulted in delays due to grouping in the execution of the orders and to the frequent loss of synchronization in the sequence of the execution of the orders. The causes leading to this phenomenon were analysed using the method developed by Ishikawa and which is viewed as one of the seven basic tools for quality control. The Ishikawa method is based on the philosophy that everything that happens is a result of an action. Although in many cases this is true, however, it is a necessary, but not a sufficient condition. The result of the analysis is shown in Fig. 8.10 and it confirmed that the process of welding is the place where flow loses its synchronization in the execution of the orders as determined by production planning.

The diagram illustrates five categories of the root causes, for each category (work, method, materials, machine and means), and the reason for loss of synchronization. A quick analysis of the diagram shows that synchronization is lost predominantly as a result of lot production of the push mechanism used by production planning and the lack of work balancing in the mast production line. Lean flow would solve this major problem facing the factory. The solution would mean that a typical lead time of 3 days would fall to something less than 1 day, under full synchronization concerning the execution sequence of the orders based on the pull mechanism. Consequently, the first target was reduction of the lot size to the size of one piece and the synchronization of processes at the level of the single mast. The target of this phase is the following.

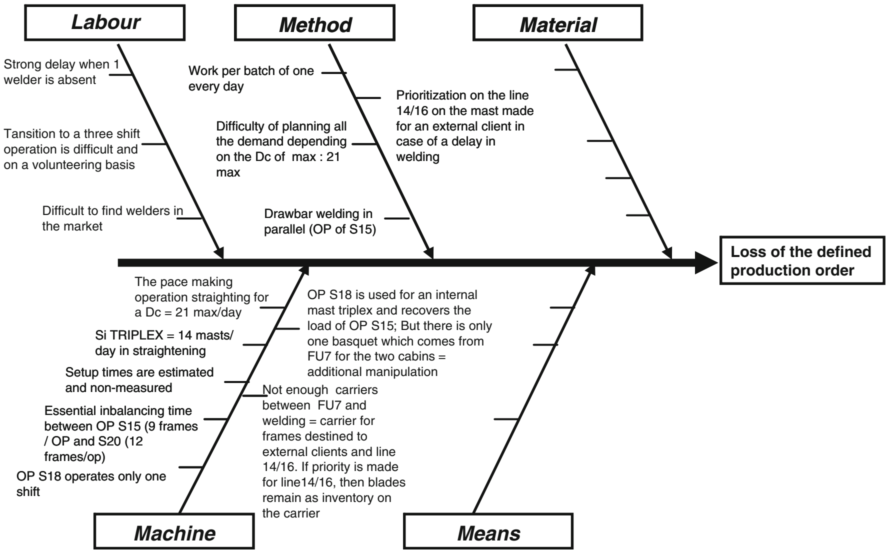

Fig. 8.10 Ishikawa diagram for the process of mast welding (Domange)

Target of the phase is the organization of work to achieve the following:

- Synchronization throughout the mast manufacturing process
- Reduction of intermediate inventory (WIP) in each welding cabin
- Acceleration of mast throughput inside the welding cabins
- Reduction in lead time from three (3) days to one (1) day

The processes that will be affected by the changes are: granulate, cut to length, mechanical treatment, welding, and straightening.

8.2.2.1 The Way to Flow Creation and Operation

Targeting synchronization of the above stated processes, the work was organized on the basis of a sequence of eight (8) masts at the mechanical treatment, welding and straightening areas. For facilitating work, instructions with synchronization information were created for the mechanical treatment and the welding. Moreover, it was initially decided to use twelve (12) carriers, each with eight (8) masts (each part number introduced by the naming convention starting with ARC). In Fig. 8.11 the principle for the creation and operation of lean flow in mast manufacturing is illustrated. In the diagram the use of IPK in creating and sustaining lean flow is shown. IPK are placed between the production phases, in order to signal the movement of the mast towards painting.

Operation of the flow is the following:

Granulate (GR2): the machine operates two shifts. It is sufficiently quick to produce the daily demand in materials needed for mast production. These materials are placed into appropriate buffers in order to make them available for the following processes which are:

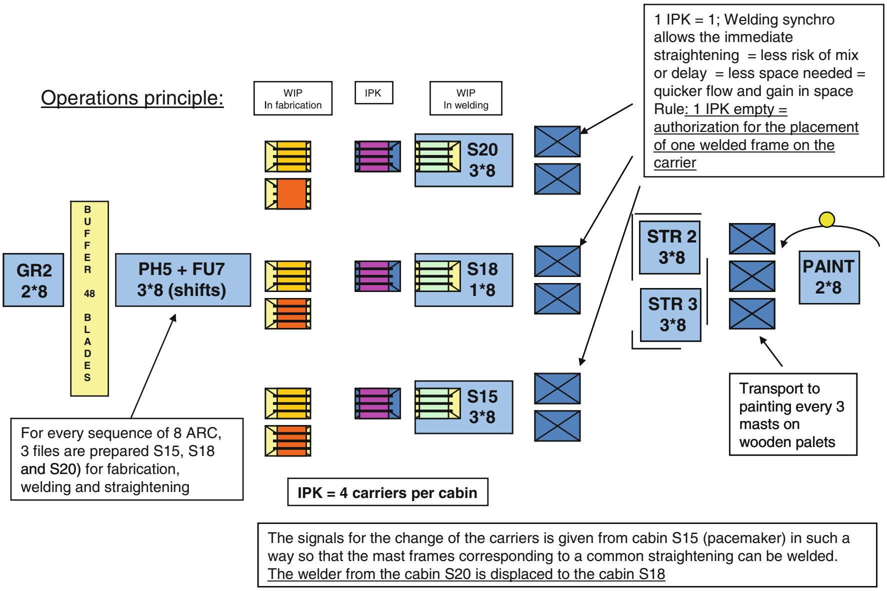

Fig. 8.11 Lean flow organization in mast manufacturing (Domange)

Cut to length (PH5) and *mechanical treatment* (FU7): In these processes, the iron bars are cut to the appropriate length and receive in turn mechanical treatment in order to manufacture the frame of the mast according to the customer order. At this point, the part number (ARC) is created which accompanies the mast until it is placed on the forklift at the final assembly line. To aid the work at the mechanical treatment and the welding, instructions with synchronization information are created. Furthermore, it was eventually decided to use nine (9) supports, instead of initially planning for twelve (12), each with eight (8) masts (ARC) in sequence. In order to help flow synchronization towards welding, each sequence was colour coded (blue, orange, green). The ARC sequences are prepared in the mechanical treatment process based on the following rules:

- A support exists for each welding cabin (S15, S18, S20) for every sequence of the eight (8) ARC. Three supports of the same colour correspond to the same sequence.
- In welding, work must be performed on the ARC sequence which is on the support of the same colour in order to sustain synchronization
- The welding cabin S15 is the cabin which sets the pace, namely it sets the signal for changing the ARC sequence i.e. of the support which comes from the mechanical treatment
- At the mechanical treatment, the change should take place in the same order as the cabins in welding S20 → S18 → S15 → S20 → S18 → S15 → S20 → and so on.

In Fig. 8.12, the sequence followed in mechanical treatment to assure and sustain the synchronization process in the downstream welding cabins is shown. In

Sequence		S15	S18	S20
123	8 ARC			
124	8 ARC			
125	8 ARC			
126	8 ARC			
127	8 ARC			
128	8 ARC			
129	8 ARC			
130	8 ARC			
131	8 ARC			
132	8 ARC			
133	8 ARC			
134	8 ARC			
135	8 ARC			

Fig. 8.12 Production sequence in mechanical treatment (Domange)

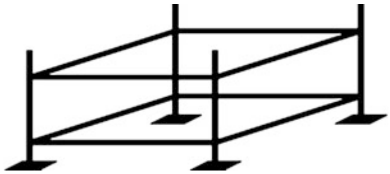

Fig. 8.13 Supports for the mechanical process (Domange)

Fig. 8.13 a model for the carrier, similar to the one used for the preparation of the mast in the mechanical process is illustrated. Later wheels where used to facilitate transportation.

Welding process (S15, S18, S20): Nine (9) supports have been calculated in total since three (3) supports are needed for the preparation of welding (one for each cabin) in the mechanical treatment, three more supports (3) must be situated in welding for work execution. The additional three (3) supports facilitate the balancing of the mast manufacturing line. In practice, therefore, it has been chosen to have eight (8) ARC in the form of WIP earlier than needed (1 TAKT earlier).

- Cabin S15 – Pacemaker i.e. signals the start of welding the mast in the other cabins as well. It is the operation for the welding of the frame of the external mast and operates for three (3) shifts
- Cabin S18 – It is the operation for the manufacturing of the frame of the triple mast and operates one shift, because the demand of the triple mast is relatively low with respect to the rest of the masts
- Cabin S20 – It is the operation for the welding of the frame of the internal mast and operates three (3) shifts

Fig. 8.14 Training of personnel in the way of operation (Domange)

The work procedure is guided by a document from production planning where the order in which the masts should be manufactured is given. The frame parts are already placed on the supports and arrive at welding from the mechanical treatment in the order in which they should be welded. This is decided by production planning. The signal for switching carrier is given by the welding process in cabin S15 (pacemaker process) in a way that those frames of a mast are welded which relate to a common straightening process. Thereafter, the welder from cabin S20 moves to cabin S18.

Straightening process: After welding, the mast frames are placed on the supports ready for transportation to the straightening process. Straightening is necessary so that, when the internal frame is slid into the external frame of the mast, this can be freely moved in and out along its total length. In the case of a triple mast, an additional process, known as matching, is necessary. After straightening – matching, the masts are transported in groups of three on wooden pallets to the painting booths about thirty (30) metres away.

8.2.2.2 Design of a Pull Mechanism Kanban for the Production of Rods

Further to the application of lean flow to the whole production process, which was completed with success, another significant step taken by the company was the use of the pull mechanism Kanban for the production planning of parts needed in the assembly of the final product. Common types of rods were used for many models of final products. The decision taken was to centrally produce all the rods needed for all types of the final product. The targets and advantages were the following:

- Reduction of intermediate inventory in the form of (WIP)
- Production in the order of quantity needed based on the demand of the final assembly lines
- Status of the parts and information flow by means of visual management

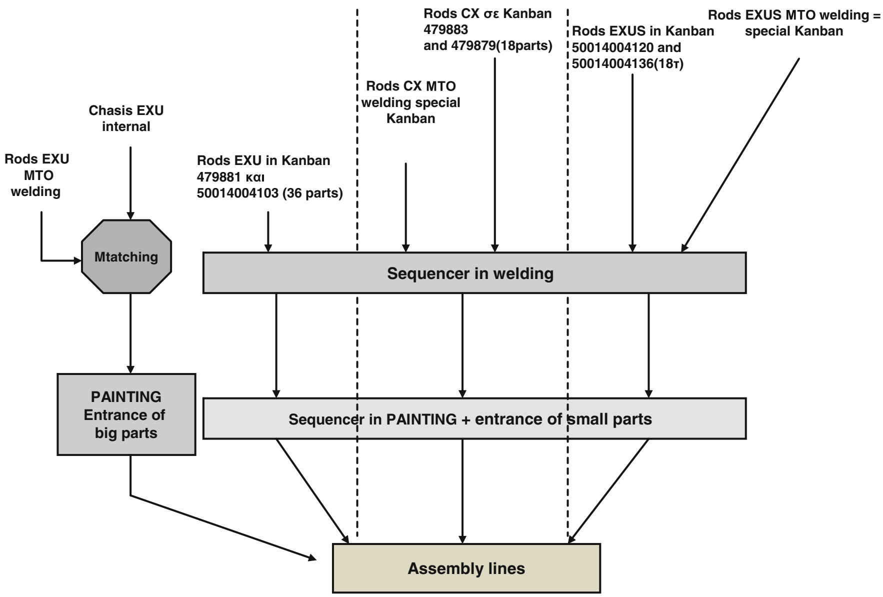

Fig. 8.15 Principles of pull organization in the rod production (Domange)

- It allows the definition of the entrance order to the welding and the painting booth

  The principles of the new organization are illustrated in Fig. 8.15.

Before describing how the pull mechanism operates, let us look at which rods are involved in implementing the mechanism, as well as the materials and information needed:

- Standard rods, produced by means of a replenishable Kanban card (metallic plate) that carried information related to production path and quantity.
- Special rods, produced only on order, by means of a non-replenishable Kanban card (metallic plate) that carries information related to production path and quantity.

8.2.2.3 Standard Rods

Below, two examples of supports for standard rods are given (Fig. 8.16).

8.2.2.4 Special Rods

An example of a Kanban plate for a special rod is shown below. It consists of a metal plate with a cover made (partly) of plexiglass. For the needs of production, such plates are created for all part numbers of the special rods, which in this case are six in total (Fig. 8.17).

Below, two examples of supports for special rods are given (Fig. 8.18).

The principles of the new organization are illustrated in Fig. 8.19 below.

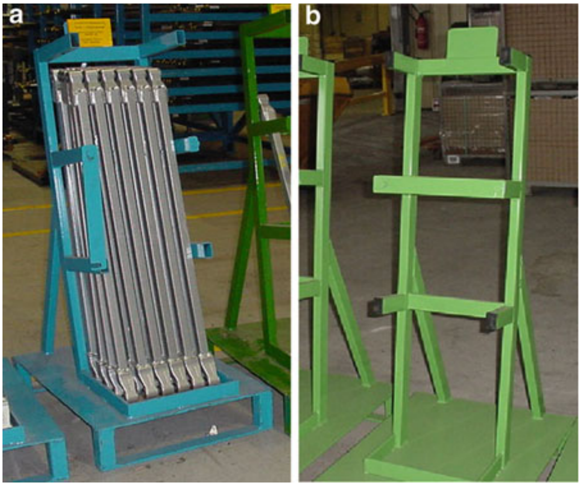

Fig. 8.16 Carriers for 36 standard rods A (**a**) and 18 standard rods B (**b**) (Domange)

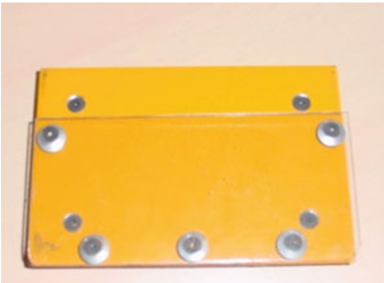

Fig. 8.17 Kanban plate for special rods (Domange)

The rules for the operation of the pull mechanism are described below, in the order they appear in Fig. 8.20. For better understanding of the procedure, a sequencer used in rod welding is presented, the operation of which is similar to the way the sequencer operates in the painting booth described above.

The board carries a card-locomotive, which signals the start of the production sequence. At the beginning of use of the board, there is only the card-locomotive. A new Kanban card which arrives at the board is placed exactly behind the card-locomotive and each new card should be placed behind the former one. Below the way is described, how production operates at the welding and which is the procedure at the painting booth and the assembly before the Kanban cards and the support return back to welding for reproduction.

8.2.2.5 In Welding

Welder: The next rod part number to be welded corresponds to the Kanban card right behind the plate at the head of the sequencer. The welder detaches the Kanban

Fig. 8.18 Carrier for special rods with 28 corridors 8 rods each (Domange)

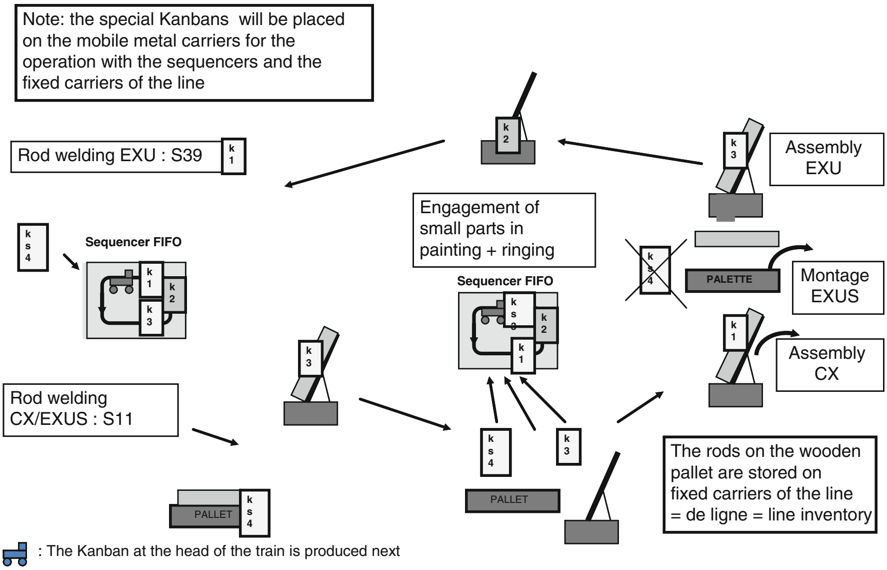

Fig. 8.19 Operation of the Kanban pull mechanism (Domange)

card from the sequencer, moves the leading card towards the gap created by the detached Kanban card and executes the work. The welder places the Kanban card on the carrier assuring that the Kanban card is well placed on the carrier or the rods (in the case of wooden pallets). He fills the work order with the Kanban quantities produced and informs the material handler at welding. An example of such a Kanban order is illustrated in Fig. 8.21. It is noted that accounting of what has been produced is only needed when welding is taking place within its own RIP where from other RIPs are supplied. This depends on the way flow has been

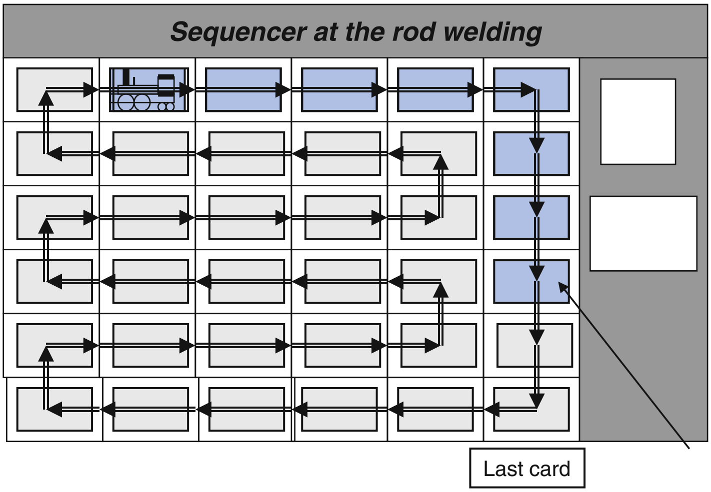

Fig. 8.20 Sequencer at the rod welding (Domange)

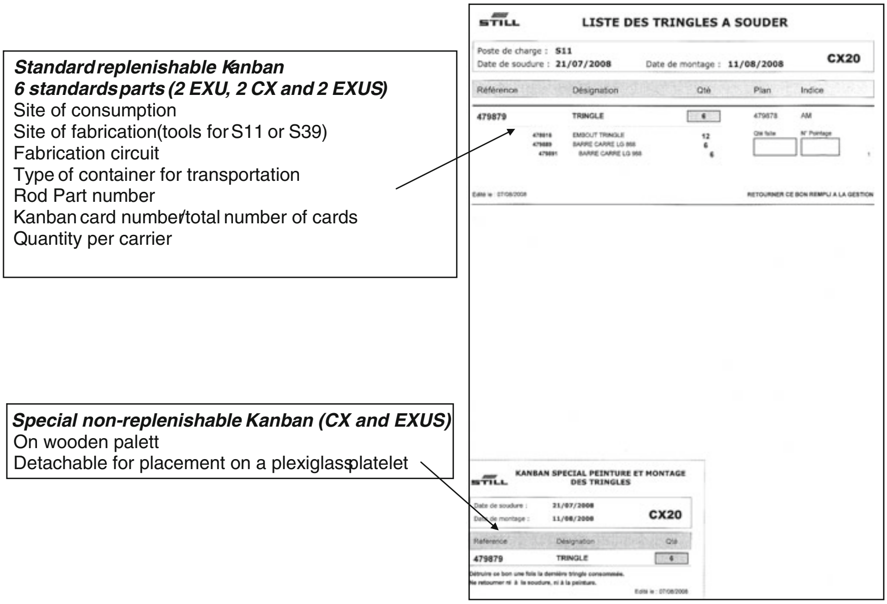

Fig. 8.21 Production order for a special Kanban (Domange)

designed, described in detail in Part II, with respect to material flow and pull sequence architecture. In many factories where the Kanban pull mechanism is introduced, the design of RIPs is omitted or neglected. This leads to the necessity of detailed tracking of material consumption and work time for any production movement, a requirement not needed in the RIP.

Material handler: As soon as the work is completed for the production of rods for a support or a wooden pallet, the material handler transfers it to the designated entrance into the painting booth only for small parts. The material handler ensures beforehand that the Kanban are correctly placed on the supports or the wooden pallets. The handler in the welding section places the Kanban card in the last position on the sequencer at the painting booth.

8.2.2.6 In Painting

Painter: The next rods to be painted correspond to the Kanban card right behind the head of the sequencer. The painter detaches the Kanban card from the sequencer, displaces the plate at the head of the sequencer and executes the work. When a Kanban is produced, the painter places the Kanban card on the support or on the rods in the case of a wooden pallet. It is noted that the packaging type that must be used is written on the Kanban card.

Material handler: As soon as a support or a pallet is completed, the handler transfers them to the corresponding final assembly line and ensures in advance that the Kanban cards are correctly placed on the supports or the pallets.

8.2.2.7 In Final Assembly

Material handler: The handler places the rods received as follows.

- The rods on pallets are placed on the supports of the line, the handler places the Kanban card on the support existing on the line concerned
- The rods on fixed supports are placed on the predefined points at the line. In this case the Kanban card remains on the supports
- He returns the empty supports and the Kanban cards as well as the supports with the Kanban cards in plexiglass to the welding process
  Assembler: He installs the rods to the product
- As soon as the support is emptied, he must inform the handler, who must quickly return the support to the welding section together with the Kanban card
- After installation of the special rods, the paper card is destroyed. The support with the Kanban plate in plexiglass is placed on the predetermined point for welding, as illustrated below (Fig. 8.22).

8.2.3 Epilogue

The purpose of what has been presented was to show a way of approaching and solving the aforementioned problems. Although each enterprise is different, the issues are similar, the method is the same and only the translation of the problems by means of the method for each particular enterprise, remains. It is not always simple and easy, however there is always a path. The path which leads to the sources, namely to the starting point and the path, every enterprise should define by themselves. The contribution of an expert must be focused on this point: to aid and assist the enterprise to find its own path and not to impose his/her own. The factory is one of three that the company operates in Europe. Two more, one in Germany and another one in France, were closed. There are two reasons for this development. The first reason is that worldwide, the trend is to reduce inventories and therefore

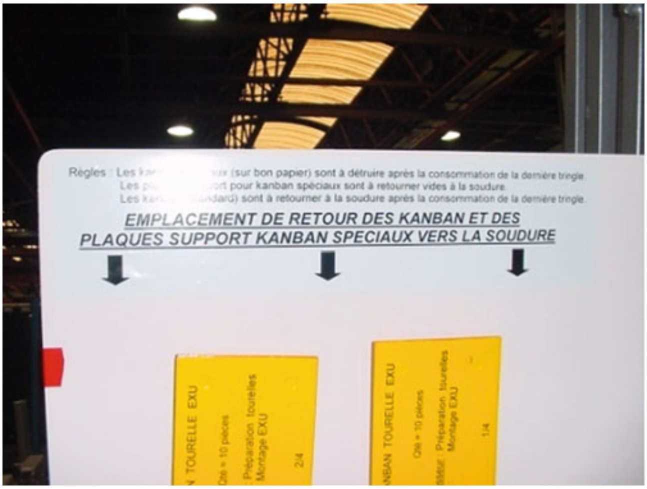

Fig. 8.22 Kanban of special rods (Domange)

warehouse space. As a result of this trend, the demand for forklifts has declined. The second reason is that this particular factory has shown that, in a relatively short time, implementation of lean flow could increase its flexibility, reduce production costs by 15% and increase productivity, mainly through eliminating work that did not add value by 20%.

8.3 Coffee Machines

The company is known worldwide for production of automated coffee machines. The factory is built in a beautiful village on the Apennine mountains in Italy and supplies the world market with automated machines covering the needs of consumption as well as professional catering. It consists of two business units: one business unit for consumer products and one for vending machines.

It was in the spring of 2004 when I received a call from a former customer informing me that he was leading the company concerned. The main problem, he told me, was the huge working capital bound in finished products inventory and he wanted my opinion as to how this could be reduced. The cooperation lasted for about 2 years. At our first meeting in the factory I was informed about the following:

- The total inventory in raw materials and final products was approximately €120 million corresponding to about 50% of the turnover.
- The inventory of final products frequently do not match customer orders because of the wrong product mix.
- Sales reach 1.200.000 machines/year.

- The response time in the market is about four (4) months, because forecasting in production is performed with a fixed horizon of four (4) months
- There is no provision for modification of the forecast procedure and therefore, it does not change when fixed.
- The budget has an horizon of twelve (12) months established in October each year.

Taking the data into account and considering a working capital corresponding to 50% of the turnover, the company would have gone bankrupt, because this is exactly the recipe for potential bankruptcy. In 2003, the company was sold to Capital Investment Fund for approximately €400 million, equal to 2 years turnover. In those days the sale was considered successful. However, it was not long before the problems of working capital and slow cash flow became intense. My proposal was to perform an audit detailing the potential advantages of implementing lean flow in the factory. The proposal was accepted and several weeks later the audit was executed. The results are stated to better illustrate the situation. Following the results from the audit, the extended value stream of the final products was constructed, covering the whole of the supply chain. The aim was to make the problem visible, a problem which had to be faced at the level of the supply chain and not individually and in isolation from each stage in the supply flow. The result was the development of a method in observing and improving the efficiency of the supply chain of the company.

8.3.1 Audit Report

We examined the operations from the viewpoint of the company's strategy to substantially increase cash flow and, in this case, to reduce working capital needs. Under this aspect the objective was, on the one hand, to detect the short-term benefits if lean flow manufacturing techniques were applied, and on the other hand to aid and assist top management in deciding whether or not to adopt these techniques in forming business strategies within the entire group.

We visited two factories that produce the automatic coffee machines, one factory that produces vending machines and also one factory that produces OEM (Original Equipment Manufacturing) products and mobile air-conditioning units. Lean flow manufacturing efforts concentrated on the factories that produced the automatic coffee machines. In order to quantify the benefits that could be achieved through implementation of lean flow methodologies, the current business conditions were defined and projected performance goals established. Our analysis derived from data provided by the financial department. The results of the audit are summarized in Fig. 8.23.

8.3.1.1 Response and Associated Inventory Savings

All monetary amounts used in this analysis are expressed in Euro unless otherwise stated. The Cost of Goods sold for the target area is 71.4% of Sales, material cost of goods sold for the target area for the year 2003 (MCOGS) was €108.704.552

Benefit Area		Pre Lean Flow	Post Lean Flow	Savings	Improvement
	2003	2003			
COGS		181.174.253 €	163.056.828 €		
Material (MCOGS)	60,00%	108.704.552 €	108.704.552 €		
Labour	20,00%	36.234.851 €	32.611.366 €	3.623.485 €	10%
Overhead (manufacturing overhead)	20,00%	36.234.851 €	21.740.910 €	14.493.940 €	40%
Total	100%				
Inventory					
Raw material		22.531.479 €	6.917.562 €	15.613.917 €	69%
WIP		0 €	0 €	0 €	
FGI		12.400.318 €	4.117.597 €	8.282.721 €	67%
Total Inventory (only material)		34.931.797 €	11.035.159 €	23.896.638 €	68%
Inventory Carrying Costs	12%	4.191.816 €	1.324.219 €	2.867.597 €	68%
Total Inventory Turns		3,11	9,85		
Response					
Response time for export market					
Response time local market - average-					
Raw material	5 turns	45,6 days	14,0 days	16 turns	69%
WIP			5,0 days		
FGI (for local + export)	9 turns	25,1 days	8,3 days	26 turns	67%
Working Capital					
Sales		253.745.453 €	253.745.453 €		
COGS (Material, Labour, OH)	71,4%	181.174.253 €	181.174.253 €		
Accounts Receivable (A/R)		92.159.949 €	92.159.949 €		
Account Payable (A/P)		70.049.347 €	70.049.347 €		
Total Inventory		34.931.797 €	11.035.159 €		
Working Capital		57.042.399 €	33.145.761 €		
Percentage of Working Capital/$ of Sales		22%	13%		
Working Capital reduction				23.896.638 €	42%
Return on Assets (ROA)					
Throughput (Sales – MCOGS)		145.040.901 €	145.040.901 €		
Operating Expenses (OE)		72.469.701 €	54.352.276 €		25%
Net Profit (Throughput-OE)		72.571.200 €	90.688.625 €	18.117.425 €	
Current Assets (Total Inventory + A/R)		127.091.746 €	103.195.108 €		
ROA = NP/Current Assets		57%	88%		31%
Company Productivity (Net Profit/effort)		62,29 €/hr	77,84 €/hr		20%
Floorspace		40 €			
Production Area	16.970 sqm	678.800 €	11.879 sqm	203.640 €	30%
Store Area	23.010 sqm	920.400 €	4.602 sqm	736.320 €	80%
Total Floorspace	39.980 sqm	1.599.200 €	16.481 sqm	939.960 €	
Productivity					
Working days per year	220 days				
Number of employees (all organisations)		874			
Number of employees (direct + indirect) B.Collars		662			
Number of employees (direct) B.Collars		487			
Avg. Hourly wage - € (direct + indirect)	62,20 €				
Working hrs (at full capacity)	1.165.120 hrs		1.048.608 hrs	116.512 hrs	10%
Total wages		72.469.701 €	65.222.731 €		
Adjusted Labour cost (only production group)		36.234.851 €	28.987.881 €	€ 7.246.970	
Sales € per person		383.301 €			
Marketing inventories		€ 60.000.000	€ 42.000.000	€ 18.000.000	30,00%

Fig. 8.23 Overview of the audit results

(60% of COGS). Labour is assumed to be 20% of COGS and the manufacturing overhead is determined to be 20%. The current total inventory on hand (raw material, WIP and finished goods) for the target area is €34.931.797. The break-down of the current inventory into raw, in-process and finished goods is presented below. The conversion to days of inventory was made by dividing the material cost of goods sold by the value of each inventory level. That figure is then divided into working days per year, given as 220 days, to calculate the days of inventory by inventory-category. The data provided declared zero WIP. WIP is typically different from zero. After implementation of Flow techniques, the product will be in a flow. An average *response time* (TPc/t and administrative response time) of 3 days is projected for manufacturing. This number represents the *Response Time* to the market. Based on the provided data, the actual response time to the market is 4 months. With lean flow techniques, 1 (one) week is realistic provided that materials are available. The reduction in response time will result from the increase in productivity, especially through the drastic reduction in overhead activities due to lean flow implementation.

Raw material and components improvement has been calculated by initially allowing 10 days of raw material kept in the Raw and In-Process Inventory Pool (RIP) for 80% of the raw materials and 30 days for about 20% of the materials kept in Stores. This results in an average of 14 days and 16 turns for raw materials and components. Today the inventory turns for raw materials is 5. Note that reductions in raw and purchased material will only be possible after manufacturing has been put under flow and has achieved a repeatable and predictable process that produces to demand every day. It is strongly advised to initially keep the stock of raw and purchased materials the same so as to avoid material shortages in responding to customer demand. Once the manufacturing process becomes linear (at a minimum 85% linearity), it is time to gradually start reducing the material inventory.

Interestingly, although response to the market is declared as being 4 months, the calculated days of inventory for FGI are 25.1 and the calculated days of inventory for Raw materials and components are 45.6. Today the inventory turns for FGI is 9 and it is projected to reach 26 after implementation of lean flow techniques. The recurring inventory carrying costs (ICC) savings were projected to be €2.867.597 based on total inventory savings. The company account for ICC costs at the rate of 12% of the total inventory value. In Germany the ICC rate is around 25%.

8.3.1.2 Working Capital Efficiency

Calculating working capital efficiency is as follows: [(Accounts Receivable + Inventory) – Accounts Payable]/Net Sales. Accounts receivable for all products was given as €92.159.949, total Inventory as €34.931.797, accounts payable as €70.049.347 and sales, excluding margins, €253.745.453.

€ [(92.159.949 + 34.931.797) − 70.049.347]/253.745.453 = 22 per 1.00 Euro of sales or 22% of sales

Applying the net asset inventory reduction to cash, the post Flow working capital inefficiency would then be as follows:

€ [(92.159.949 + 11.035.159) − 70.049.347]/253.745.453 = 13 cents per 1.00 Euro of sales or 13% of sales

This is an improvement of **€23.896.638** on working capital or 42%.

We believe that, through the savings that will be made from the implementation of lean flow techniques, a zero working position should be targeted. The objective is to pay the suppliers the moment the product leaves the factory and at the same time get payment from the Sales Organization. Getting payments from customers and not paying the supplier at the same time does not support the formation of the necessary partnerships with suppliers. Strong supply chain networks are the future for further reductions in material costs.

8.3.1.3 Return on Assets – *ROA*

The calculation of the ROA is made as follows:

ROA = Net Profit/Total Assets

Net Profit = Throughput – Operating Expenses

Throughput = Sales – MCOGS

Operating Expenses = Direct Labour Cost + Overhead

Total Assets => Current Assets = (Total Inventory + Accounts Receivable)

Concerning the Total Assets we will refer to the Total Inventory before and after implementation of lean flow, because these are the assets that can be influenced by this method. We will assume in this analysis that the Operating Expenses in production will be reduced by 35% (10% the direct labour cost and 40% the Overhead). Therefore, the ROA before and after implementation of the lean flow method is:

[Sales – MCOGS – Operating Expenses]/[Total Inventory + Accounts Receivable]

[253.745.453 − 108.704.552 − 72.469.701]/127.091.746 = 57 cents for each 1.00 sales or 57%

Applying the reduction in Operating Expenses to the ROA, the new ROA can be calculated as follows:

(We assume that Sales remain constant so that the two results are comparable before and after implementation of the methodology).

[253.745.453−108.704.552−54.352.276]/103.195.108 = 88 cents for each 1.00 sales or 88%

This means an increase in Net Profit of: €18.117.425.

Furthermore, if productivity is defined (the capacity of a company to generate additional profit per working hour with a constant number of working hours in the year) as [Net Profit/Total Effort], where Total Effort = Sum of working hours per year (1.165.120 h = 662 persons × 8 h × 220 days), the result for 2003 is **62.29€/h**, while the value after implementation of lean is projected to be **77.84€/h**. This means an increase in company productivity of 20%.

8.3.1.4 Manufacturing Floor-Space Consolidations

An estimated reduction in 30% of the production floor area and 80% of storage space is projected. The reduction in production area needs will follow as a result of new line design compatible to lean flow manufacturing rules. Reduction in the storage area will result from the drastic cut in primarily finished goods inventories and also handling and receiving inspection as well as intermediary storage location of raw materials and components before final storage. In order to estimate shop floor monetary benefits we have assumed that the freed space can be offered for rent at €40 per sqm. Although we would advise selling the freed building space, we suggest moving the plastic moulding factory operations closer to the coffee making machines factories (eliminating a distance of approximately 300 km) and also to pull the currently outsourced sub-assembly work into the main factory in order to achieve just in time delivery of plastic parts and sub-assembly parts to the final assembly lines.

8.3.1.5 Labour-Based Overhead Allocation and Focus on Productivity

A new manufacturing environment under lean flow principles will require a new set of measurement tools. The current focus on labour productivity, representing approximately 20% of the product cost, will need to be replaced by measurements such as linearity, customer response and total product cycle time. Without a new set of measurement tools, the temptation will always be to optimize areas of business that will not impact on the company goals of improved response, reduced overhead cost and improved working capital position. For example, under a method of overhead allocation based on direct labour only, improvements in manufacturing lead-time or inventory turns may have little or no impact on product cost reported. These methods may lead to misleading business decisions being taken. During a formal implementation process, members of the finance team will need to focus on these types of issues.

8.3.1.6 Impact on the Marketing Inventories

The inventories in the marketing organizations represent today 2 months of stock. Due to the introduction of lean flow practices between the marketing organizations and the factories, we estimate a minimum of a 30% reduction in the level of inventories needed to be kept in stock. This is a conservative estimation based on our experience of implementing demand flow methodologies in similar environments in consumer goods industries. Marketing organizations will have to specify inventory policies that are needed to satisfy their markets. These policies will be used to define the demand needed for line and Kanban design and drive daily production plans.

The results of the audit confirmed that implementation of lean flow in the factory would lead to the gradual decrease in inventory and would have significant improvements in resources efficiency for even higher financial performance. In order to turn the target into reality, the planning horizon should be significantly and sharply decreased from four (4) to one (1) month at least. The long time horizon for order reception based on sales forecasting of each individual company, followed by the grouping of orders by product, the time for material requirement planning for a huge amount of products, as well as the coordination of many subcontractors, all these factors together prolong and increase quantitatively the supply chain. Certainly, for those already aware of the workings of the supply chains, a long supply time path creates problems in the effectiveness of the work i.e. synchronization can only be sustained through the use of strong information systems which support collaborative forecasting. All the above mentioned problems are manifested in increased requirements for working capital and consequently in reduced cash flow capability. The longer the supply chain the more cash should be available through bank loans. This problem is more obvious today than ever before. It does not relate to the productivity or performance capability of the company, but to the efficiency and the effectiveness of the supply chain. Below, the metrics and way of use in the supply chain are presented. Furthermore, modern methods for the improvement of the efficiency of supply strategies are proposed.

8.3.1.7 Efficiency of the Supply Chain

Although not necessary, mapping of the value stream helps in the study of a supply chain (Fig. 8.24). It helps to quickly conceive the current state of supply flows. In the value stream concerned, the flows of raw materials and finished products along the complete supply chain (SC) have been mapped, including two collaborating subcontractors and the commercial companies who undertake the distribution of finished products worldwide. The quantities shown map the situation for the first quarter of the year. The targets set for inventory reduction in finished products and raw materials have been determined. The related financial targets set for the end of the year were the following:

- Raw materials inventory: from €60 million to €20 million
- Finished products inventory from €40 million to €20 million
- Space savings: 15.000 m^2

It was an ambitious program, but necessary for the improvement of the working capital position and the liquidity of the company represented in cash flow. Based on the audit results and given the decisions about inventory reductions taken thereafter, the strategy for the new approach in the supply chain was discussed. It was pointed out that reductions in inventory should not in any sense also mean a reduction in customer service level. Consequently, a supply chain, which is at the same time both effective (measured by service level – extroversion – outflow) as well as efficient (measured by efficiency of the company – introversion – inflow), is required. Even though these two targets must be reached simultaneously and are essentially interconnected, they are not pursued with the same dedication. Frequently, narrowly defined efficiency is preferred to effectiveness, due to the isolated target costs of the company. Efficiency has immediate and accountable financial results. Effectiveness, since it is not directly related to money value of a commercial exchange but to use value, is not directly related to financial results. The interrelation of the two indicators takes place through the service level that a company selects to reduce the risk of not responding to a customer order because of the possibility of running out of stock. If that happens then the effectiveness of the SC is reduced, because the net profit is reduced due to lost sales. In this case, the current assets are reduced because of a reduced inventory due to low service level and a reduction in receivable accounts (Table 8.3). The target is the optimization of the

Table 8.3 Return on assets

Return on assets	Net profit/current assets
Current assets	Inventory + accounts receivable

efficiency of the SC, taking into account the risk involved in the selection of a suitable strategy with respect to the service level. The service level depends on the level of demand uncertainty for the products concerned. Uncertainty in demand can be expressed in terms of the related standard deviation in the resupply interval needed to be defined for each producer. Demand variation influences the service level to be chosen as well as the net profits (Table 8.3).

One method to determine the optimum efficiency frontier between efficiency and effectiveness is to apply the modern portfolio theory of Markowitz (MPT), to the evaluation of the SC portfolio of the company. This theory states (Markowitz 1991) that the effectiveness of the SC, namely the effectiveness of the current assets of the SC, is influenced by the degree of demand uncertainty aimed to be reduced through increasing the customer service level. This event includes the risk, the strategy chosen in holding inventories to have a negative impact on the net profits, defined here as the value difference between work performed by the company and operational costs (Fig. 8.23). Applying portfolio theory will help in mapping the company position (topos) with respect to the optimum efficiency frontier (Yuvanezas 2011). The goal is to define an inventory policy (finished products and/or materials) for improving the company position with respect to optimum efficiency frontier. To apply the theory the following steps should be followed:

1. Categorization of finished products or materials according to the method ABC/XYZ at the month level for a time period of as many years as the company decides to consider for studying its position on the diagram of efficiency frontiers. Typically five (5) to six (6) years is advised.
2. Calculation of the optimum efficiency frontier of the supply chain based on the percentage of contribution for each of the nine (9) categories, which result from the ABC/XYZ analysis, to the totality of the products in the time period chosen in step 1.
3. Calculation of the position of the current supply chain of the company based on the calculation in step 2.
4. Modification policy for sustaining inventory based on the evaluation and re-evaluation of the results from step 3.

Application of modern portfolio theory on the issue will assist the company into designing and redesigning supply chain strategies. This subject is a recent practice oriented research topic at the laboratory for Logistics under my supervision.

8.3.2 Epilogue

The case study dealt with in this section exhibits similarities with hundreds of companies worldwide. The problems discussed are characteristic and in practice the same for any supply chain. The major challenge is flow synchronization which is quite often lost due to lot thinking. Efficiency improvements and its consequent cost

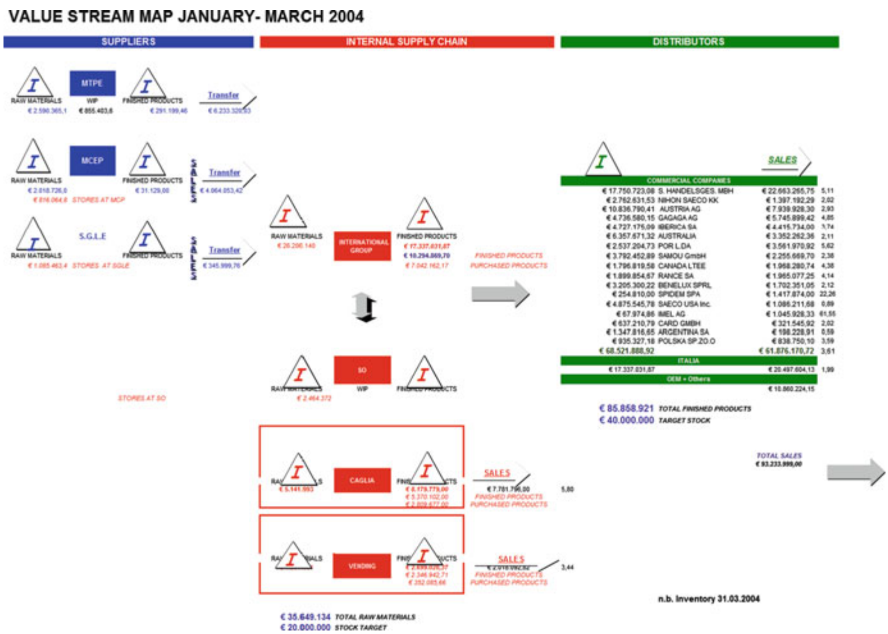

Fig. 8.24 Value stream map of the supply chain air conditioning units

reduction is a serious target, but should not be seen independently from supply chain effectiveness in serving the customer. Approaching the issue, it is advised that companies should look to optimizing not merely cost but the efficiency frontier based on strategic risk objectives. Strategic objectives should be re-evaluated annually with respect to past performance and market needs (Fig. 8.24).

8.4 Air Conditioning Units

In the summer of 1997, I was invited by a large group of companies to audit two factories in Israel and, a short while later, a factory in France in order to evaluate possible implementation of lean flow in the manufacture of air conditioning units. The company designs, develops, manufactures and distributes air conditioning units of various types for consumer and industrial use. The group belongs to one of the world leaders in manufacturing air conditioners and the decision to examine the possibility to implement lean production concerned all their factories.

The audit projected significant benefits for the enterprise and a decision was taken to go ahead with the project. The implementation took place simultaneously in all three factories. The project was basically completed in September 2002, but some extensions carried on until 2004. The results of the implementations were significant and impressive. The main success was the substantial improvement in productivity and the significant reduction in the cost of production with a corresponding reduction in customer response time from 20 to 2 days for the local market. Above and beyond the impressive improvements in performance

			1996	1997	1998	1999	2000
1	Quality	Errors in assembly	10,00%	8,70%	7,00%	6,00%	10,00%
2	Inventory turns	Final products-Total	9	10	13	15	20
		Finall products-Local market	11	10	15	20	25
		Raw materials	3	4	5	6	8
3	Response time to local market	Days from order to stock	10	10	2	2	1
4	Response time to export market	Days from order to shipping	60	30	14	14	7
5	Productivity	Requested hours for production			10,00%	7,00%	5,00%
	Remarks						
1	% of products that go to rework from the lines						
2	COGS divided by the cost of average inventory						
3	Due to mixed model lines and the Kanban system						
4	Due to mixed model lines and the Kanban system						
5	Change in hours needed per weighted box						

Fig. 8.25 Summary of lean flow results (Salinger)

indicators and financial benefits, the essence of the project was given by the factory manager in Israel when I asked him about the real benefit according to his opinion. His answer was breathtaking: *I cannot imagine operating the factory again in the same way as we did before implementing lean flow*». A summary of the results achieved is shown below (Fig. 8.25).

The implementation of lean flow was performed simultaneously in three factories, two in Israel and one in France. We will present typical implementation examples which appear in similar situations in other factories, mainly those with assembly operations targeting line design and a system for material replenishment flow. An algorithm for the replenishment of the warehouses with raw material and parts as well as the way of replenishing commercial daughter companies with final products is developed. Finally a list of myths of how to achieve low cost in production is presented.

8.4.1 Redesign and Resupply of Lean Flow Lines

The two factories in Israel have been completely redesigned by implementing the lean flow in production presented in part II. The success in improving efficiency was 70% due to the line redesign and 30% to the implementation of the Kanban pull mechanism to internal logistics. Moreover, due to lean flow implementation, the installation of a long transportation band for connecting parts manufacturing with the final assembly lines, was avoided, saving the company 200.000 dollars at that time. The installation of such a band had as target the direct coupling of lines operating in different TAKT times and therefore the problem that would arise would have been the accumulation of materials in front of the assembly lines. The band installation would cause further productivity deterioration. During the audit, we observed that line operations were designed with excess space with respect to production rhythm resulting in operators building inventory in advance. It was obvious, through the first evaluation, that line redesign would reduce the space concerned by at least 50%. Before redesign, there were seven independent assembly lines. The redesign study proposed four (4) mixed model production lines with a common line for vacuum control and finishing operations, as well as the functions test and packaging (Fig. 8.26).

Through redesign, 2,000 m^2 were saved, primarily as a result of lower space requirements set by lean flow. In the example discussed below, the design of the pull mechanism for the production of metal parts produced in the factory will be focused on. Line replenishment with materials is a common issue for a large

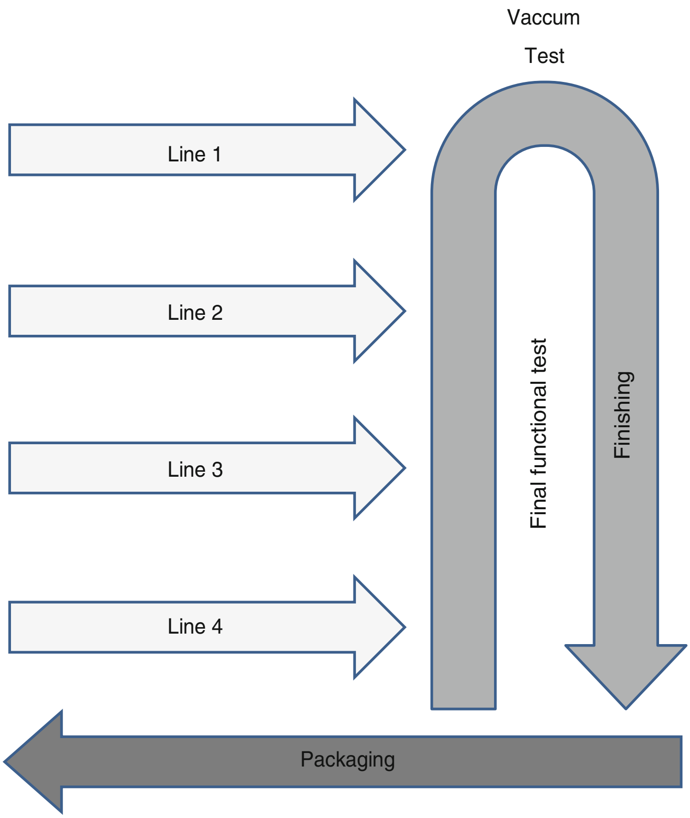

Fig. 8.26 New concept of assembly lines

number of factories. In lean flow, the design of material replenishment focuses on two basic points: definition of RIP areas and the pull sequences required for the calculation of material Kanban quantities. The RIP choice was led by the particular management needs for monitoring cost and inventory efficiency in production operations related to specific product families. The choice of materials to be placed under the pull mechanism Kanban was performed by means of ABC/XYZ categorization. In the following example, it is assumed that the line design for the two product families has been completed. What is requested is the design of the desired number of RIP and the calculation of all material Kanban involved in the production of metal parts based on the defined pull sequences for the two lines. The following four (4) points were viewed as extremely significant by management, who spoke about the dramatic change in the way the factory was operating:

1. Inventory control
2. Subcontractor monitoring
3. Availability of raw materials
4. Production documentation

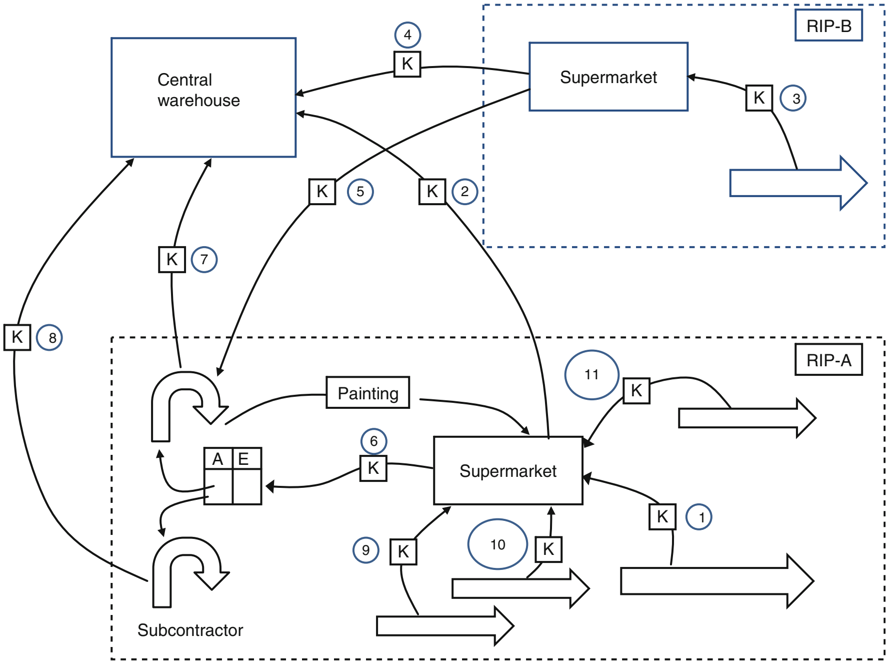

Fig. 8.27 Diagram of metal parts pull sequences

Figure 8.27 reflects the decision taken by the project implementation team, mainly in order to respond to points 1 and 2. Particularly with respect to point 1, production lines before lean flow implementation, were directly resupplied from central stores. Based on weekly planning, the metal parts produced by metal sheet manufacturing centres were initially stored in the raw materials warehouse, though not characterized as WIP as it ought to be. The change in organizing production by introducing RIP and the related Supermarket, would precisely give the capability of controlling inventory, which was the desire of management. Furthermore, better monitoring and control of subcontractors would be achieved in a similar way.

In the pull sequence diagram, two RIP are shown (RIP-A, RIP-B). RIP-A includes two sheet metal processing centres. One of the processing centres belongs to a subcontractor and geographically lies outside the factory, it is however part of the pull sequence. The reason why it has been included into the RIP-A lies in the fact that it provides exclusive production service with materials pulled via Kanban by the company (8). In the case of subcontractors, this way of organizing and accounting for value is recommended. The number of parts produced for each product is shown in Table 8.4. The number, the type and the related part numbers of the pull sequences are also illustrated in the same figure. A total of eleven (11) pull sequences have been defined.

For point 3, the wish and the plan was to expand the pull sequence up to suppliers which is the aim of every lean supply chain. Concerning point 4, production documentation is fulfilled through the single and clear way lean flow line and

Table 8.4 Mapping of pull sequences (PS) for metal parts

K (PS)	1	2	3	4	5	6	7	8	9	10	11	
Products												No. of parts
RWK			X	X	X		X	E				50
PX			X	X	X		X	X				40
WMN			X	X	X		X	T				20
FCR						X	X	E		X		60
EMD	X	X				X	X	R				60
CUE	X	X				X	X	N				100
WINDOW						X	X	A	X			60
SIDE PANELS						X		L			X	80

the pull mechanism are designed to operate. Implementation of the resupply model has been performed with success. The steps defined by the method described in part II have been followed and in particular those steps which concern Kanban size calculations for machine cells operations.

One of the problems that had to be faced in production was the relatively long setup times which led to the increase in the minimum Kanban quantity for the cell (Kc). This initially led to an increased size of the Supermarket from five (5) days (according to the practical rule) to ten (10) days. In order to decide which policy should be followed for the parts inside the RIP, the categorization ABC/XYZ was used. For parts which were good candidates, the Kanban method was applied. For all other parts and for a certain percentage of them the method M*in-Max* was employed, based on the following rule: when the material quantity falls below a predefined level (minimum) then replenishment is signalled until the quantity does not surpass a maximum preset point.

The categorization ABC/XYZ assumes knowledge of the quantities consumed in a time interval (e.g. 1 year) and the value of the parts. Usually the value per part is known, however the information related to parts consumption is not immediately and easily accessible. The problem is exacerbated when bill of materials (BOM) exhibit several levels, where Kanban parts may often be seated in levels 3, 4, 5 etc. The way to access the appropriate level is through the analysis of the BOM by means of information systems for example MRP, a painful and time consuming activity. In lean flow, because of process synchronization, the structure of the BOM can be flat with two, three levels maximum in a complex product. Although it is not necessary, on the occasion of the implementation of the lean flow in the factory, it is advisable to restructure the BOM in order to flatten it as much as possible. A flat BOM simplifies many activities, not only during design, but also during production operations, reducing work which does not add value, in particular in production planning as well as in maintaining complex BOM. Before implementing lean flow, six (6) professionals were needed in the production planning department. After the changes, one person was sufficient for the needs of planning activity. The redundant personnel were moved to other departments which had more needs.

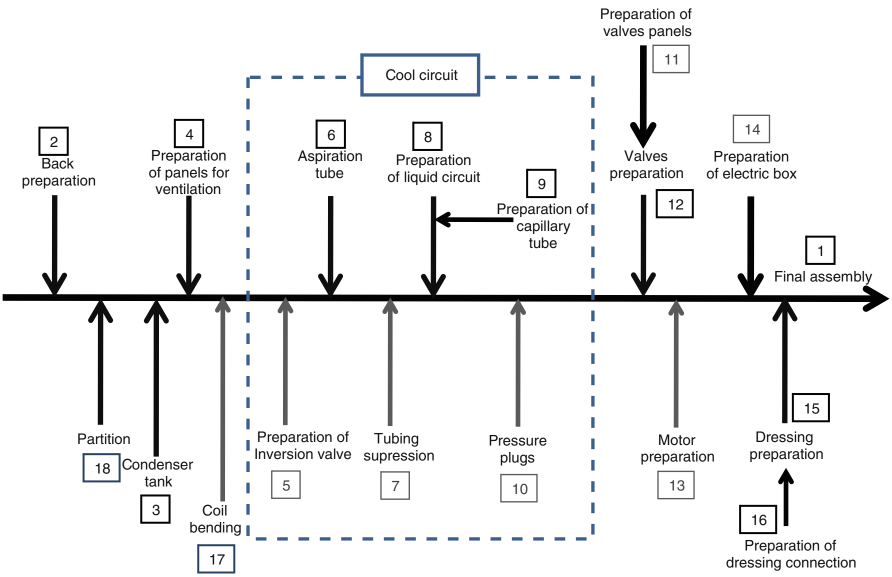

Fig. 8.28 Mixed model product synchronization flow

Table 8.5 Calculation of resources

	Group A	Group B
Number of products	41	31
ΣDc	22.9	14.3
TAKT (assembly)	16.7	26.7
Resources	8.8	7.7

Below, an example of the design of a lean flow line, as well as the design of a pull mechanism for material replenishment is presented. Furthermore, the issue of the BOM structure is discussed. Based on the method of lean flow, the first step in the design of the mixed model line is the development of product synchronization flow (Fig. 8.28).

The mixed model product synchronization flow concerns a family of air conditioning units. The processes mapped in bold black lines are common for all family members. The processes mapped in normal black lines declare optional processes which may differ from product to product. Furthermore, each process has been numbered in order to facilitate matching to the process map. A first analysis of the process map data shows that the products (72 SKU part numbers) should be divided into at least two families and a separate flow line should be designed for each one of them. Precisely this was the decision taken. The basic division characteristics, as set by the method, are common processes with similar total process times mainly in final assembly and as much as possible common materials and parts. The results are summarized in Table 8.5.

		Back Preparation	Preparation of Condenser tank	Preparation of panels Ventilation	Preparation of inversion valve	Tube Aspiration	Tubing Supression	Preparation of liquid circuit	Preparation of Capillarytube	Pressure plugs	Preparation of valves panels	Valves preparation	Motor preparation	Preparation of electric box	Dressing preparation	Preparation of dressing connection	Coil bending	Partition	Final assembly	Indexing
NO	PRODUCT	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	1	Atw
																				93,57
1	CHU-101-1	3,41	3,21	6,87	0,00	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	23,99	2,08	0,00	0,00		88,38	JUST
2	CHU-101-3	3,41	3,21	6,87	0,00	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	23,99	2,08	0,00	0,00		88,38	JUST
3	CHU-101-1 R	3,41	5,54	6,87	3,81	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	32,74	2,08	0,82	0,00		93,83	JUST
4	CHU-101-3 R	3,41	5,54	6,87	3,81	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	32,74	2,08	0,82	0,00		93,83	JUST
5	CHU-121	3,41	3,21	6,87	0,00	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	23,99	2,08	0,00	0,00		88,38	JUST
6	CHU-121 R	3,41	5,54	6,87	3,81	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	32,74	2,08	0,82	0,00		93,83	JUST
7	CHU-151	3,41	3,21	6,87	0,00	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	23,99	2,08	0,00	0,00		88,38	JUST
8	CHU-151 R	3,41	5,54	6,87	3,81	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	32,74	2,08	0,82	0,00		93,83	JUST
9	CHU-181	3,41	3,21	6,87	0,00	3,28	0,39	4,10	6,74	3,08	2,96	5,64	15,50	33,04	2,08	0,00	0,00		91,49	JUST
10	CHU-181 R	3,41	5,54	6,87	3,81	3,28	0,39	4,10	6,74	3,08	2,96	5,64	15,50	41,39	2,08	0,82	0,00		96,94	JUST
11	CHU-211	3,41	3,21	6,87	0,00	3,28	0,39	4,10	6,74	3,08	2,96	5,64	15,50	33,04	2,08	0,00	0,00		91,49	JUST
12	CHU-211 R	3,41	5,54	6,87	3,81	3,28	0,39	4,10	6,74	3,08	2,96	5,64	15,50	41,39	2,08	0,82	0,00		96,94	JUST
13	CVJ-151	3,78	1,11	7,06	0,00	3,28	0,39	1,24	4,22	3,08	4,61	8,15	0,00	23,99	3,88	0,00	0,00		93,48	JUST
14	CVJ-151 R	3,78	1,11	7,06	3,81	3,28	0,39	1,24	4,22	3,08	4,61	8,15	0,00	32,74	3,88	0,00	0,00		99,31	JUST
15	CVJ-181	3,78	1,11	7,06	0,00	3,28	0,39	4,10	6,74	3,08	4,61	2,69	15,50	33,04	3,88	0,00	0,00		96,09	JUST
16	CVJ-181 R	3,78	1,11	7,06	3,81	3,28	0,39	4,10	6,74	3,08	4,61	2,69	15,50	41,39	3,88	0,00	0,00		101,92	JUST
17	CVJ-211	3,78	1,11	7,06	0,00	3,28	0,39	4,10	6,74	3,08	4,61	2,69	15,50	33,04	3,88	0,00	0,00		96,09	JUST
18	CVJ-211 R	3,78	1,11	7,06	3,81	3,28	0,39	4,10	6,74	3,08	4,61	2,69	15,50	41,39	3,88	0,00	0,00		101,92	JUST
19	CVJ-301-S	5,71	1,53	9,90	0,00	3,28	0,00	3,86	8,44	3,08	11,44	2,95	15,50	40,14	4,66	0,00	0,00		105,20	JUST
20	CVJ-301-S R	5,71	1,53	9,90	3,81	3,28	0,00	3,86	8,44	3,08	11,44	2,95	15,50	46,92	4,66	0,00	0,00		111,93	JUST
21	CVJ-301	5,71	1,53	9,90	0,00	6,86	0,78	2,48	8,44	6,16	11,44	2,95	15,50	47,04	4,66	0,00	0,00		105,20	JUST
22	CVJ-301 R	5,71	1,53	9,90	7,62	6,86	0,78	2,48	8,44	6,16	11,44	2,95	15,50	56,82	4,66	0,00	0,00		160,12	LOWER
23	CVJ-361-S	5,71	1,53	9,90	0,00	3,28	0,00	5,94	13,48	3,08	11,44	2,95	15,50	40,14	4,66	0,00	0,00		105,20	JUST
24	CVJ-361-S R	5,71	1,53	9,90	7,62	3,28	0,00	5,94	13,48	3,08	11,44	2,95	15,50	46,92	4,66	0,00	0,00		111,93	JUST
25	CVJ-361	5,71	1,53	9,90	0,00	3,28	0,78	8,20	13,48	6,16	11,44	2,95	15,50	47,04	4,66	0,00	0,00		153,09	LOWER
26	CVJ-361 R	5,71	1,53	9,90	7,62	3,28	0,78	8,20	13,48	6,16	11,44	2,95	15,50	55,82	4,66	0,00	0,00		160,12	LOWER
27	CVJ-421	5,71	1,53	9,90	0,00	3,28	0,78	8,20	13,48	6,16	11,44	2,95	15,50	47,04	4,66	0,00	0,00		153,09	LOWER
28	CVJ-421 R	5,71	1,53	9,90	7,62	3,28	0,78	8,20	13,48	6,16	11,44	2,95	15,50	55,82	4,66	0,00	0,00		160,12	LOWER
29	CVJ-451	5,71	1,53	9,90	0,00	6,86	0,78	8,20	15,00	6,16	11,44	2,95	11,50	47,04	4,66				160,74	LOWER
30	CVJ-451 R	5,71	1,53	9,90	7,62	6,86	0,78	8,20	15,00	6,16	11,44	2,95	11,50	55,82	4,66				168,12	LOWER
31	CVJ-561	5,71	1,53	9,90	0,00	6,86	0,78	8,20	15,00	6,16	11,44	2,95	11,50	47,04	4,66				160,74	LOWER
32	CVJ-561 R	5,71	1,53	9,90	7,62	6,86	0,78	8,20	15,00	6,16	11,44	2,95	11,50	55,82	4,66				168,12	LOWER
33	EHJ-101	3,11	3,47	4,39	0,00	1,53	0,00	1,24	4,22	0,00	2,46	8,45	0,00	15,87	1,14	0,82	0,00		43,30	HIGHER
34	EHJ-121	3,11	3,47	4,39	0,00	1,53	0,00	1,24	4,22	0,00	2,46	8,45	0,00	15,87	1,14	0,82	0,00		43,30	HIGHER
35	EHJ-151	3,11	3,47	4,39	0,00	1,53	0,00	1,24	4,22	0,00	2,46	8,45	0,00	15,87	1,14	0,82	0,00		43,30	HIGHER
36	EHJ-181	3,11	3,47	4,39	0,00	1,53	0,00	4,10	6,74	0,00	2,46	8,45	0,00	15,87	1,14	0,82	0,00		43,30	HIGHER
37	EHJ-211	3,11	3,47	4,39	0,00	1,53	0,00	4,10	6,74	0,00	2,46	8,45	0,00	15,87	1,14	0,82	0,00		43,30	HIGHER
																				HIGHER
38	EVJ-151	4,63	1,18	14,93	0,00	1,53	0,00	1,24	4,22	0,00	5,16	8,45	0,00	15,87	2,13	0,00	0,00		49,25	HIGHER
39	EVJ-181	4,63	1,18	14,93	0,00	1,53	0,00	4,10	4,22	0,00	5,16	8,45	0,00	15,87	2,13	0,00	0,00		49,25	HIGHER
40	EVJ-211	4,63	1,18	14,93	0,00	1,53	0,00	4,10	4,22	0,00	5,16	8,45	0,00	15,87	2,13	0,00	0,00		49,25	HIGHER
41	EVJ-301-S	7,32	1,66	8,62	0,00	7,19	0,00	3,86	8,44	0,00	2,48	5,05	11,19	0,00	1,47	0,00	0,00		81,74	HIGHER
42	EVJ-361-S	7,32	1,66	8,62	0,00	7,19	0,00	5,94	8,44	0,00	2,48	5,05	11,19	0,00	1,47	0,00	0,00		81,74	HIGHER
43	EVJ-301	7,32	1,66	8,62	0,00	6,06	0,00	2,48	8,44	0,00	2,48	5,05	11,19	0,00	1,47	0,00	0,00		66,22	HIGHER
44	EVJ-361	7,32	1,66	8,62	0,00	6,06	0,00	8,20	13,48	0,00	2,48	5,05	11,19	0,00	1,47	0,00	0,00		66,22	HIGHER
45	EVJ-421	7,32	1,66	8,62	0,00	6,06	0,00	8,20	13,48	0,00	2,48	5,05	11,19	0,00	1,47	0,00	0,00		66,22	HIGHER
46	EVJ-451	7,32	1,66	8,62	0,00	6,06	0,00	8,20	15,00	0,00	2,48	5,05	11,19	0,00	1,47				71,50	HIGHER
47	EVJ-561	7,32	1,66	8,62	0,00	6,06	0,00	8,20	15,00	0,00	2,48	5,05	11,19	0,00	1,47				71,50	HIGHER

Fig. 8.29 Process map – all products (part)

This table illustrates that the largest number of products (about 25%) are produced in line A, which has lower production time and higher demand (about 37%). However, the number of operations is similar. Consequently, the layout for both lines concerning the length and the width and therefore the surface will be similar. It was chosen to set up the lines in parallel so that the intermediate space can be used for common tools and materials. Balancing the two lines was a very interesting activity. In Figs. 8.29 and 8.30 the process maps of all products concerned are exhibited. After time indexing two groups of products were formed, i.e. group A and group B, the process maps of which are illustrated in Figs. 8.31, 8.32 and 8.33. Line balancing are exhibited in Fig. 8.34 for group A and in Fig. 8.35 for group B. Line balancing diagrams show that production planning should use smoothing techniques so that the mixed model TAKT of every line is fulfilled.

Line design for the products mentioned above is inextricably part of the total design, which includes material replenishment for the flow lines. In the non lean enterprise, assembly lines operate in isolation, as in isolation operate (frequent for the organization in departments) even the processes which prepare the sub-assemblies which the final assembly needs in the planning horizon. The sub-assemblies are usually programmed 5–10 days (quite often even earlier) in advance and stored in WIP areas, waiting to be transferred to the final assembly. However, in

48	AHJ-101-1	6,52	4,39	11,26	0,00	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00		126,00	JUST
49	AHJ-101-3	6,52	4,39	11,26	0,00	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00		126,00	JUST
50	AHJ-101-1 R	6,52	4,39	11,26	3,81	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00		132,00	JUST
51	AHJ-101-3 R	6,52	4,39	11,26	3,81	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00		132,00	JUST
52	AHJ-121	6,52	4,39	11,26	0,00	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00		126,00	JUST
53	AHJ-121 R	6,52	4,39	11,26	3,81	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00		132,00	JUST
54	AHJ-151	6,52	4,39	11,26	0,00	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00		126,00	JUST
55	AHJ-151 R	6,52	4,39	11,26	3,81	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00		132,00	JUST
56	AHJ-181	6,52	4,39	11,26	0,00	1,90	0,39	4,40	13,48	3,08	5,42	14,09	15,50	40,00	3,22	0,00	0,00		129,00	JUST
57	AHJ-181 R	6,52	4,39	11,26	3,81	1,90	0,39	4,40	13,48	3,08	5,42	14,09	15,50	40,00	3,22	0,00	0,00		135,00	LOWER
58	AHJ-211	6,52	4,39	11,26	0,00	1,90	0,39	4,40	13,48	3,08	5,42	14,09	15,50	40,00	3,22	0,00	0,00		129,00	JUST
59	AHJ-211 R	6,52	4,39	11,26	3,81	1,90	0,39	4,40	13,48	3,08	5,42	14,09	15,50	40,00	3,22	0,00	0,00		135,00	LOWER
															0,00					
60	DN 205 H	3,33	0,00	2,80	3,80	0,59	0,74	18,67	0,00	1,20	7,54	0,00	0,00	26,27	0,00	0,00	2,98		80,40	HIGHER
61	DN 255 H	3,33	0,00	2,80	3,80	0,59	0,74	18,67	0,00	1,20	7,54	0,00	0,00	26,27	0,00	0,00	2,98		80,40	HIGHER
62	DN 305 H	3,33	0,00	2,80	3,80	0,59	0,74	18,67	0,00	1,20	7,54	0,00	0,00	26,92	0,00	0,00	2,98		80,40	HIGHER
63	DN 405 H	7,90	0,00	4,80	7,60	1,18	1,48	38,74	0,00	2,40	17,15	0,00	0,00	33,07	0,00	0,00	32,49		155,06	LOWER
64	DN 505 H	7,90	0,00	4,80	7,60	1,18	1,48	38,74	0,00	2,40	17,15	0,00	0,00	33,07	0,00	0,00	32,49		155,06	LOWER
65	DN 605 H	7,90	0,00	4,80	7,60	1,18	1,48	38,74	0,00	2,40	17,15	0,00	0,00	33,07	0,00	0,00	32,49		155,06	LOWER
66	RM 105	7,07	0,00	0,00	6,46	1,09	0,66	15,31	0,00	2,44	6,98	2,94	3,05	29,70	5,49	0,00	2,68	4,81	117,04	JUST
67	RM 125	7,07	0,00	0,00	6,46	1,09	0,66	16,03	0,00	2,44	6,98	4,05	3,05	29,70	5,49	0,00	2,81	4,81	124,63	JUST
68	RM 155	7,07	0,00	0,00	6,46	1,09	0,66	16,03	0,00	2,44	6,98	4,05	3,05	29,70	5,49	0,00	2,81	4,81	124,63	JUST
69	RM 185	7,07	0,00	0,00	6,46	1,09	0,66	16,03	0,00	2,44	6,98	4,05	3,05	29,70	5,49	0,00	2,81	4,81	124,63	JUST
70	RM 235	7,07	0,00	0,00	6,46	1,09	0,66	16,03	0,00	2,44	6,98	4,05	3,05	36,93	5,49	0,00	2,77	4,81	127,14	JUST
71	RM 255	7,07	0,00	0,00	6,46	1,09	0,66	16,03	0,00	2,44	6,98	4,05	3,05	36,93	5,49	0,00	2,77	4,81	127,14	JUST
72	RM 305	7,07	0,00	0,00	6,46	1,09	0,66	16,03	0,00	2,44	6,98	4,05	3,05	36,93	5,49	0,00	2,77	4,81	127,14	JUST
	Σ Dc	37,21	14,86	33,81	25,41	37,21	27,71	37,21	14,86	28,75	37,21	18,26	12,83	31,99	18,26	1,39	22,35	3,40	37,21	
	Takt	10,08	25,24	11,09	14,76	10,08	13,53	10,08	25,24	13,04	10,08	20,54	29,22	11,72	20,54	270,49	16,78	110,29	10,08	
	Actual time (Atw)	5,02	2,12	5,98	4,76	2,08	0,77	14,28	8,71	2,07	7,28	6,29	10,33	29,50	3,10	0,82	6,97	4,81	93,57	
	Operations	0,50	0,08	0,54	0,32	0,21	0,06	1,42	0,35	0,16	0,72	0,31	0,35	2,52	0,15	0,00	0,42	0,04	9,29	

Fig. 8.30 Process map – all products (continuation and completion)

			Back Preparation	Preparation of Condenser tank	Preparation of panels Ventilation	Preparation of inversion valve	Tube Aspiration	Tubing Supression	Preparation of liquid circuit	Preparation of Capillarytube	Pressure plugs	Preparation of valves panels	Valves preparation	Motor preparation	Preparation of electric box	Dressing preparation	Preparation of dressing connection	Coil bending	Final assembly	Indexing
No	Sequence	PRODUCT	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	1	Atw
																				78,85
1	1	CHJ-101-1	3,41	3,21	6,87	0,00	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	23,99	2,08	0,00	0,00	88,38	JUST
2	2	CHJ-101-3	3,41	3,21	6,87	0,00	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	23,99	2,08	0,00	0,00	88,38	JUST
3	3	CHJ-101-1 R	3,41	5,54	6,87	3,81	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	32,74	2,08	0,82	0,00	93,83	JUST
4	4	CHJ-101-3 R	3,41	5,54	6,87	3,81	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	32,74	2,08	0,82	0,00	93,83	JUST
5	5	CHJ-121	3,41	3,21	6,87	0,00	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	23,99	2,08	0,00	0,00	88,38	JUST
6	6	CHJ-121 R	3,41	5,54	6,87	3,81	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	32,74	2,08	0,82	0,00	93,83	JUST
7	7	CHJ-151	3,41	3,21	6,87	0,00	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	23,99	2,08	0,00	0,00	88,38	JUST
8	8	CHJ-151 R	3,41	5,54	6,87	3,81	3,28	0,39	1,24	4,22	3,08	2,96	8,45	0,00	32,74	2,08	0,82	0,00	93,83	JUST
9	9	CHJ-181	3,41	3,21	6,87	0,00	3,28	0,39	4,10	6,74	3,08	2,96	5,64	15,50	33,04	2,08	0,00	0,00	91,49	JUST
10	10	CHJ-181 R	3,41	5,54	6,87	3,81	3,28	0,39	4,10	6,74	3,08	2,96	5,64	15,50	41,39	2,08	0,82	0,00	96,94	JUST
11	11	CHJ-211	3,41	3,21	6,87	0,00	3,28	0,39	4,10	6,74	3,08	2,96	5,64	15,50	33,04	2,08	0,00	0,00	91,49	JUST
12	12	CHJ-211 R	3,41	5,54	6,87	3,81	3,28	0,39	4,10	6,74	3,08	2,96	5,64	15,50	41,39	2,08	0,82	0,00	96,94	JUST
13	13	CVJ-151	3,78	1,11	7,06	0,00	3,28	0,39	1,24	4,22	3,08	4,61	8,15	0,00	23,99	3,88	0,00	0,00	93,48	JUST
14	14	CVJ-151 R	3,78	1,11	7,06	3,81	3,28	0,39	1,24	4,22	3,08	4,61	8,15	0,00	32,74	3,88	0,00	0,00	99,31	JUST
15	15	CVJ-181	3,78	1,11	7,06	0,00	3,28	0,39	4,10	6,74	3,08	4,61	2,69	15,50	33,04	3,88	0,00	0,00	96,09	JUST
16	16	CVJ-181 R	3,78	1,11	7,06	3,81	3,28	0,39	4,10	6,74	3,08	4,61	2,69	15,50	41,39	3,88	0,00	0,00	101,92	JUST
17	17	CVJ-211	3,78	1,11	7,06	0,00	3,28	0,39	4,10	6,74	3,08	4,61	2,69	15,50	33,04	3,88	0,00	0,00	96,09	JUST
18	18	CVJ-211 R	3,78	1,11	7,06	3,81	3,28	0,39	4,10	6,74	3,08	4,61	2,69	15,50	41,39	3,88	0,00	0,00	101,92	JUST

Fig. 8.31 Process map – Group A (part I)

19	19	EHJ-101	3,11	3,47	4,39	0,00	1,53	0,00	1,24	4,22	0,00	2,46	8,45	0,00	15,87	1,14	0,82	0,00	43,30	HIGHER
20	20	EHJ-121	3,11	3,47	4,39	0,00	1,53	0,00	1,24	4,22	0,00	2,46	8,45	0,00	15,87	1,14	0,82	0,00	43,30	HIGHER
21	21	EHJ-151	3,11	3,47	4,39	0,00	1,53	0,00	1,24	4,22	0,00	2,46	8,45	0,00	15,87	1,14	0,82	0,00	43,30	HIGHER
22	22	EHJ-181	3,11	3,47	4,39	0,00	1,53	0,00	4,10	6,74	0,00	2,46	8,45	0,00	15,87	1,14	0,82	0,00	43,30	HIGHER
23	23	EHJ-211	3,11	3,47	4,39	0,00	1,53	0,00	4,10	6,74	0,00	2,46	8,45	0,00	15,87	1,14	0,82	0,00	43,30	HIGHER
24	24	EVJ-151	4,63	1,18	14,93	0,00	1,53	0,00	1,24	4,22	0,00	5,16	8,45	0,00	15,87	2,13	0,00	0,00	49,25	HIGHER
25	25	EVJ-181	4,63	1,18	14,93	0,00	1,53	0,00	4,10	4,22	0,00	5,16	8,45	0,00	15,87	2,13	0,00	0,00	49,25	HIGHER
26	26	EVJ-211	4,63	1,18	14,93	0,00	1,53	0,00	4,10	4,22	0,00	5,16	8,45	0,00	15,87	2,13	0,00	0,00	49,25	HIGHER
27	27	AHU-101-1	6,52	4,39	11,26	0,00	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00	91,00	JUST
28	28	AHU-101-3	6,52	4,39	11,26	0,00	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00	91,00	JUST
29	29	AHU-101-1 R	6,52	4,39	11,26	3,81	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00	110,50	JUST
30	30	AHU-101-3 R	6,52	4,39	11,26	3,81	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00	110,50	JUST
31	31	AHU-121	6,52	4,39	11,26	0,00	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00	91,00	JUST
32	32	AHU-121 R	6,52	4,39	11,26	3,81	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00	110,50	JUST
33	33	AHU-151	6,52	4,39	11,26	0,00	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00	91,00	JUST
34	34	AHU-151 R	6,52	4,39	11,26	3,81	1,90	0,39	0,74	8,44	3,08	5,42	16,90	0,00	40,00	3,22	0,00	0,00	110,50	JUST
35	35	AHU-181	6,52	4,39	11,26	0,00	1,90	0,39	4,40	13,48	3,08	5,42	14,09	15,50	40,00	3,22	0,00	0,00	109,00	JUST
36	36	AHU-181 R	6,52	4,39	11,26	3,81	1,90	0,39	4,40	13,48	3,08	5,42	14,09	15,50	40,00	3,22	0,00	0,00	112,50	JUST
37	37	AHU-211	6,52	4,39	11,26	0,00	1,90	0,39	4,40	13,48	3,08	5,42	14,09	15,50	40,00	3,22	0,00	0,00	109,00	JUST
38	38	AHU-211 R	6,52	4,39	11,26	3,81	1,90	0,39	4,40	13,48	3,08	5,42	14,09	15,50	40,00	3,22	0,00	0,00	112,50	JUST
39	39	DN 205 H	3,33	0,00	2,80	3,80	0,59	0,74	18,67	0,00	1,20	7,54	0,00	0,00	26,27	0,00	0,00	2,98	80,40	JUST
40	40	DN 255 H	3,33	0,00	2,80	3,80	0,59	0,74	18,67	0,00	1,20	7,54	0,00	0,00	26,27	0,00	0,00	2,98	80,40	JUST
41	41	DN 305 H	3,33	0,00	2,80	3,80	0,59	0,74	18,67	0,00	1,20	7,54	0,00	0,00	26,92	0,00	0,00	2,98	80,40	JUST
		Σ Dc	22,88	6,97	22,88	17,70	22,88	19,64	22,88	6,97	19,64	22,88	6,97	1,54	22,88	6,97	1,39	15,91	22,88	
		Takt	16,73	54,94	16,73	21,62	16,73	19,49	16,73	54,94	19,49	16,73	54,94	248,42	16,73	54,94	276,12	24,06	16,73	
		Actual time(Atw)	3,72	2,69	5,08	3,80	1,05	0,67	13,76	6,18	1,56	6,62	9,68	15,50	26,51	2,55	0,82	2,98	78,85	
		Operations	0,22	0,05	0,30	0,18	0,06	0,03	0,82	0,11	0,08	0,40	0,18	0,06	1,58	0,05	0,00	0,12	4,71	

Fig. 8.32 Process map – Group A (part II)

a lean flow environment, because of physical synchronization, a priori sub-assembly production is not a necessity since these are produced for just on time consumption by the flow line. In this way planning and execution of sub-assembly production is eliminated. This leads to the elimination of the need for maintaining

			Back Preparation	Preparation of Condenser tank	Preparation of panels Ventilation	Preparation of inversion valve	Tube Aspiration	Tubing Supression	Preparation of liquid circuit	Preparation of Capillarytube	Pressure plugs	Preparation of valves panels	Valves preparation	Motor preparation	Preparation of electric box	Dressing preparation	Coil bending	Partition	Final assembly	Indexing
No	Sequence	PRODUCT	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18	1	Atw
																				113.77
1	43	EVJ-301	7.32	1.66	8.62	0.00	6.06	0.00	2.48	8.44	0.00	2.48	5.05	11.19	0.00	1.47	0.00		66.22	HIGHER
2	44	EVJ-361	7.32	1.66	8.62	0.00	6.06	0.00	8.20	13.48	0.00	2.48	5.05	11.19	0.00	1.47	0.00		66.22	HIGHER
3	45	EVJ-421	7.32	1.66	8.62	0.00	6.06	0.00	8.20	13.48	0.00	2.48	5.05	11.19	0.00	1.47	0.00		66.22	HIGHER
4	46	EVJ-451	7.32	1.66	8.62	0.00	6.06	0.00	8.20	15.00	0.00	2.48	5.05	11.19	0.00	1.47			71.50	HIGHER
5	47	EVJ-561	7.32	1.66	8.62	0.00	6.06	0.00	8.20	15.00	0.00	2.48	5.05	11.19	0.00	1.47			71.50	HIGHER
6	41	EVJ-301-S	7.32	1.66	8.62	0.00	7.19	0.00	3.86	8.44	0.00	2.48	5.05	11.19	0.00	1.47	0.00		81.74	HIGHER
7	42	EVJ-361-S	7.32	1.66	8.62	0.00	7.19	0.00	5.94	8.44	0.00	2.48	5.05	11.19	0.00	1.47	0.00		81.74	HIGHER
8	19	CVJ-301-S	5.71	1.53	9.90	0.00	3.28	0.00	3.86	8.44	3.08	11.44	2.95	15.50	40.14	4.66	0.00		105.20	JUST
9	21	CVJ-301	5.71	1.53	9.90	0.00	6.86	0.78	2.48	8.44	6.16	11.44	2.95	15.50	47.04	4.66	0.00		105.20	JUST
10	23	CVJ-361-S	5.71	1.53	9.90	0.00	3.28	0.00	5.94	13.48	3.08	11.44	2.95	15.50	40.14	4.66	0.00		105.20	JUST
11	20	CVJ-301-S R	5.71	1.53	9.90	3.81	3.28	0.00	3.86	8.44	3.08	11.44	2.95	15.50	46.92	4.66	0.00		111.93	JUST
12	24	CVJ-361-S R	5.71	1.53	9.90	7.62	3.28	0.00	5.94	13.48	3.08	11.44	2.95	15.50	46.92	4.66	0.00		111.93	JUST
13	66	RM 105	7.07	0.00	0.00	6.46	1.09	0.66	15.31	0.00	2.44	6.98	2.94	3.05	29.70	5.49	2.68	4.81	117.04	JUST
14	67	RM 125	7.07	0.00	0.00	6.46	1.09	0.66	16.03	0.00	2.44	6.98	4.05	3.05	29.70	5.49	2.81	4.81	124.63	JUST
15	68	RM 155	7.07	0.00	0.00	6.46	1.09	0.66	16.03	0.00	2.44	6.98	4.05	3.05	29.70	5.49	2.81	4.81	124.63	JUST
16	69	RM 185	7.07	0.00	0.00	6.46	1.09	0.66	16.03	0.00	2.44	6.98	4.05	3.05	29.70	5.49	2.81	4.81	124.63	JUST
17	70	RM 235	7.07	0.00	0.00	6.46	1.09	0.66	16.03	0.00	2.44	6.98	4.05	3.05	36.93	5.49	2.77	4.81	127.14	JUST
18	71	RM 255	7.07	0.00	0.00	6.46	1.09	0.66	16.03	0.00	2.44	6.98	4.05	3.05	36.93	5.49	2.77	4.81	127.14	JUST
19	72	RM 305	7.07	0.00	0.00	6.46	1.09	0.66	16.03	0.00	2.44	6.98	4.05	3.05	36.93	5.49	2.77	4.81	127.14	JUST
20	25	CVJ-361	5.71	1.53	9.90	0.00	3.28	0.78	8.20	13.48	6.16	11.44	2.95	15.50	47.04	4.66	0.00		153.09	JUST
21	27	CVJ-421	5.71	1.53	9.90	0.00	3.28	0.78	8.20	13.48	6.16	11.44	2.95	15.50	47.04	4.66	0.00		153.09	JUST
22	63	DN 405 H	7.90	0.00	4.80	7.60	1.18	1.48	38.74	0.00	2.40	17.15	0.00	0.00	33.07	0.00	32.49		155.06	JUST
23	64	DN 505 H	7.90	0.00	4.80	7.60	1.18	1.48	38.74	0.00	2.40	17.15	0.00	0.00	33.07	0.00	32.49		155.06	JUST
24	65	DN 605 H	7.90	0.00	4.80	7.60	1.18	1.48	38.74	0.00	2.40	17.15	0.00	0.00	33.07	0.00	32.49		155.06	JUST
25	22	CVJ-301 R	5.71	1.53	9.90	7.62	6.86	0.78	2.48	8.44	6.16	11.44	2.95	15.50	56.82	4.66	0.00		160.12	JUST
26	26	CVJ-361 R	5.71	1.53	9.90	7.62	3.28	0.78	8.20	13.48	6.16	11.44	2.95	15.50	55.82	4.66	0.00		160.12	JUST
27	28	CVJ-421 R	5.71	1.53	9.90	7.62	3.28	0.78	8.20	13.48	6.16	11.44	2.95	15.50	55.82	4.66	0.00		160.12	JUST
28	29	CVJ-451	5.71	1.53	9.90	0.00	6.86	0.78	8.20	15.00	6.16	11.44	2.95	11.50	47.04	4.66			160.74	JUST
29	31	CVJ-561	5.71	1.53	9.90	0.00	6.86	0.78	8.20	15.00	6.16	11.44	2.95	11.50	47.04	4.66			160.74	JUST
30	30	CVJ-451 R	5.71	1.53	9.90	7.62	6.86	0.78	8.20	15.00	6.16	11.44	2.95	11.50	55.82	4.66			168.12	LOWER
31	32	CVJ-561 R	5.71	1.53	9.90	7.62	6.86	0.78	8.20	15.00	6.16	11.44	2.95	11.50	55.82	4.66			168.12	LOWER
		Σ Dc	14.34	7.89	10.94	7.70	14.34	8.07	14.34	7.89	9.11	14.34	11.29	11.29	9.11	11.29	6.45	3.40	14.34	
		TAKT	26.70	48.51	35.00	49.68	26.70	47.42	26.70	48.51	42.02	26.70	33.90	33.90	42.02	33.90	59.39	112.59	26.70	
		ΧΡΟΝΟΣ (Atw)	7.08	1.62	7.87	6.96	3.72	0.99	15.11	10.95	3.16	8.33	4.20	9.63	36.99	3.43	16.82	4.81	113.77	
		ΘΕΣΕΙΣ ΕΡΓΑΣΙΑΣ	0.27	0.03	0.22	0.14	0.14	0.02	0.57	0.23	0.08	0.31	0.12	0.28	0.88	0.10	0.28	0.04	4.26	7.71

Fig. 8.33 Process map – Group B

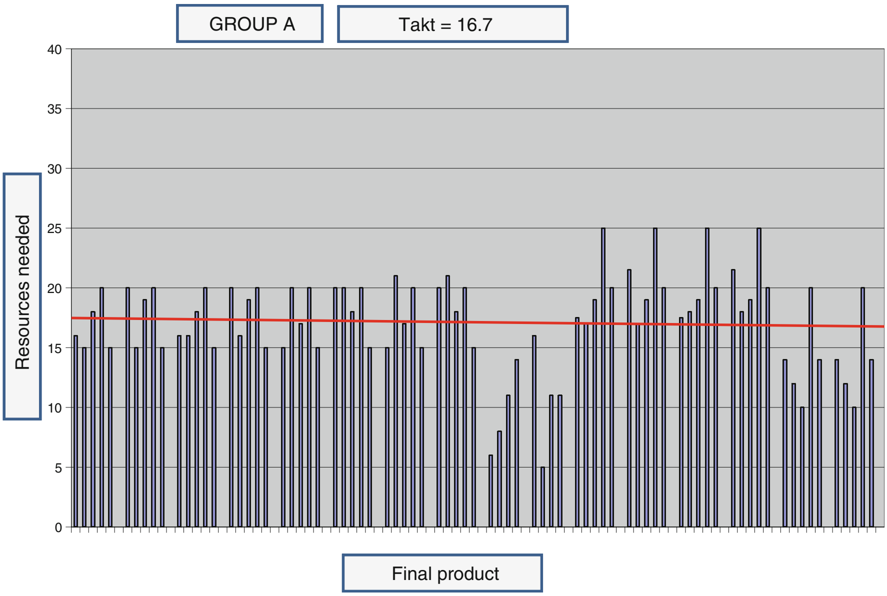

Fig. 8.34 Line balancing – Group A

multilevel BOM for part numbers of intermediate components or sub-assemblies From this rule part numbers for spare parts are excluded. In this case the spare part is viewed as a final product, the demand of which should be taken into account in the line design mentioned in part II. Consequently, a new flat BOM is advised so that its

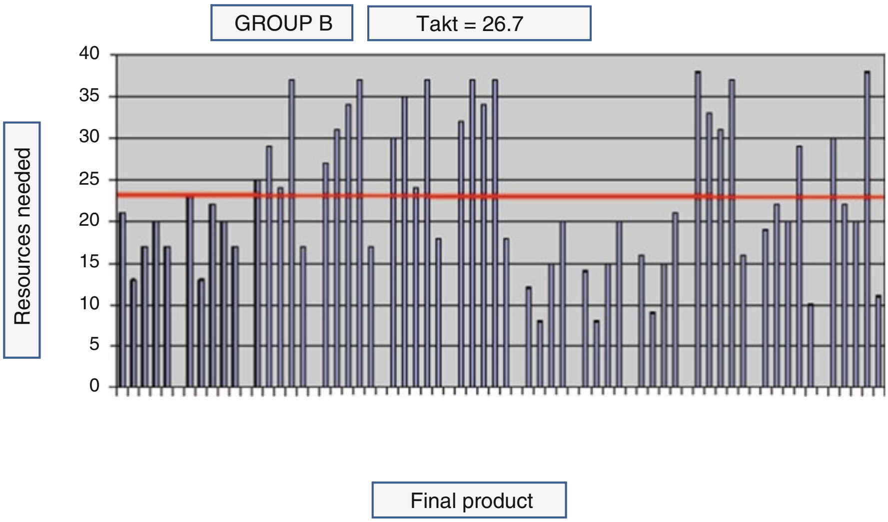

Fig. 8.35 Line balancing – Group B

Fig. 8.36 Brake press at the assembly line

management and Kanban sizing activities can be drastically simplified, however it is not a prerequisite for lean flow implementation. During redesign, it was decided to move two brake presses (Fig. 8.36), one for each line in order to produce exactly what the line needs, as well as two machines for bending coils (Fig. 8.37), one for each line. The machines were modified so that two different types of coils could be bent in flow without setup. In the following, pull sequences for big size sheet metal unpainted and painted parts, as well as tubing parts production are discussed.

On the particular coil bending machine (Fig. 8.37) the cylinder shown hanging on an axis is detached and is replaced by another one with a different bending

Fig. 8.37 Coils bending machine at the final assembly line

Fig. 8.38 Models of subassemblies

radius within less than a minute (single minute exchange of die – SMED). The total time for setting up the machine and bending the coil is less than TAKT. Furthermore, a very good way of avoiding systematic errors is to position sub-assembly models at points where mistakes often happen near to the assembly line (Fig. 8.38). Errors result from the insufficient training of seasonal workers who, proportionally,

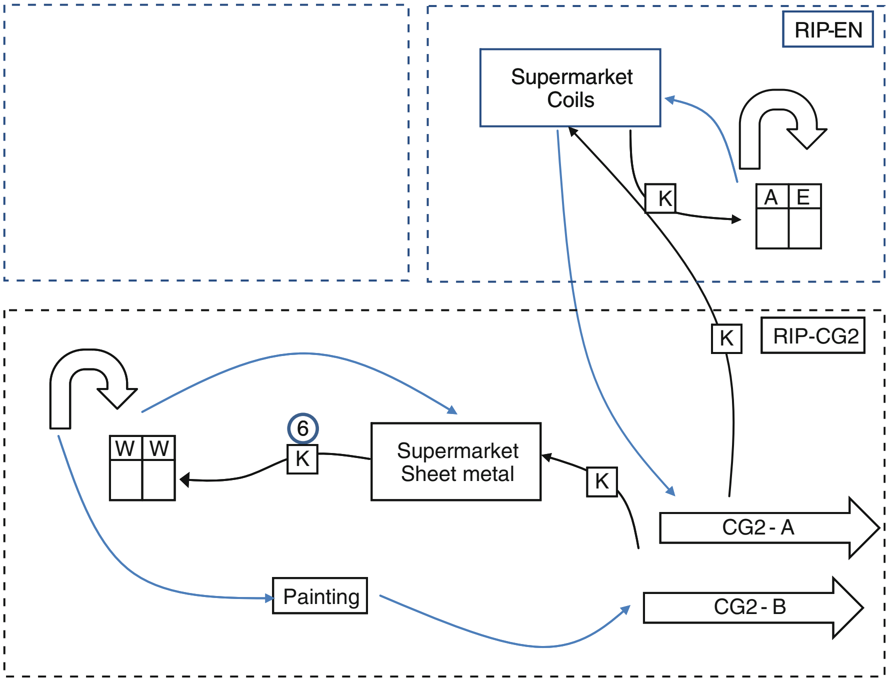

Fig. 8.39 Replenishment pull sequences for metal parts and coils

are many in the air conditioning industry. For example, it is mentioned that in the high season the total number of workers is almost doubled. The pressure on behalf of management to complete on the job training as quickly as possible, frequently led to more errors even though most of them worked in the high season every year in the company.

With respect to line replenishment with metal parts and coils, it was decided that two supermarkets would be created. The pull sequences flows are mapped in the diagram shown in Fig. 8.39. In the diagram, a separate RIP for the coils is illustrated. The coil production line also manufactured coils to demand for external customers and, thus, the corresponding department can be viewed as an individual value adding centre.

For sheet metal parts the calculation of Kanban quantities (Fig. 8.40) was based on the capacity of the sheet metal processing centre and concerned 321 part numbers. The flow of processes included three phases: drilling, cutting, and bending. Each machine had its own setup time. The calculation was performed on the basis of the theory described in Sect. 6.6.1.2 for a machine cell. As an initial strategy to determine the inventory at the supermarket, the implementation team together with management, had chosen to set the replenishment time (R) to fifteen (15) days, mainly because the long setup times led to high inventory, outside the limit of five (5) days, resulting in a large number of non replenishable parts Kanban.

COMPONENT	Description	PKG SIZE (pkgs)	Kc (Max) 1	Kc (PKGS) 2	Kc (Tot Pcs) 6	Total Produce cards 6a	R TIME (hrs) 7	MOVE TIME (hrs) (Est) 8	SAFETY FACTOR 4	KB POUR Pieces 9	KB POUR QTY Conteneurs 10	TOTAL QTY (CARDS) 11	MAX DAYS OF INVENT. 12	KANBAN RECOM-MENDED 13	DUALKB CARDS 1 of ? 14	LINE REPLEN TIME (hrs) 3	LINE KANBAN QTY. Pieces 5	LINE KANBAN QTY. Conteneurs 5a
293628	ENS.PIEDS POUR MOTOVENTILATEUR	10	50,03	6	24	3	1,57	0	0%	1	1	4	8,1	DUAL	3	8	4	1
293632	JEUX PIEDS AT 15/15	10	50,03	6	12	2	0,97	0	0%	1	1	3	7,1	DUAL	2	8	2	1
293633	JEUX PIEDS AT 18/18	10	50,03	6	6	1	0,67	0	0%	1	1	2	19,3	SET QTY	1	8	1	1
293634	SUPPORT MOTEUR ET VISSERIE AT 12/12	10	50,03	6	36	4	2,17	0	0%	2	1	5	7,8	DUAL	4	8	6	1
293635	SUPPORT MOTEUR ET VISSERIE AT 15/15	10	50,03	6	12	2	0,97	0	0%	1	1	3	7,1	DUAL	2	8	2	1
293636	SUPPORT MOTEUR ET VISSERIE AT 18/18	10	50,03	6	6	1	0,67	0	0%	1	1	2	19,3	SET QTY	1	8	1	1
300268C-88	FOND EVJ 151/181/211 GRIS	8	50,03	7	21	3	1,42	0	0%	1	1	4	11,5	DUAL	3	8	3	1
300274C-88	FOND EVJ 301/301S/361/361S/421 GRIS	6	50,03	9	27	5	1,72	0	0%	1	1	6	12,4	DUAL	5	8	3	1
300280	FOND DN205/255 (2613120696)	10	50,03	6	78	8	4,27	0	0%	7	1	10	7,2	DUAL	8	8	13	2
300280	FOND DN205/255 (2613120696)	10	50,03	6	78	8	4,27	0	0%	7	1	10	7,2	DUAL	8	8	13	2
300281	FOND DN305 (2613120691)	10	50,03	6	24	3	1,57	0	0%	1	1	4	8,8	DUAL	3	8	4	1
300281	FOND DN305 (2613120691)	10	50,03	6	24	3	1,57	0	0%	1	1	4	8,8	DUAL	3	8	4	1
300284C-88	FOND RM105H GRIS (2613022161)	10	50,03	6	6	1	0,67	0	0%	1	1	2	13,4	DUAL	1	8	1	1
300285C-88	FOND RM125/155/185/235H GRIS (26130	10	50,03	6	18	2	1,27	0	0%	1	1	3	8,9	DUAL	2	8	3	1
300286C-88	FOND RM255/305H/305C GRIS (26130221	10	50,03	6	6	1	0,67	0	0%	1	1	2	13,4	DUAL	1	8	1	1
300288C-88	FOND DN405/505/605 GRIS (2613120469	10	50,03	6	24	3	1,57	0	0%	1	1	4	9,2	DUAL	3	8	4	1
300289	BAC EVAPORATEUR RM105H (2613022167)	10	50,03	6	6	1	0,67	0	0%	1	1	2	13,4	DUAL	1	8	1	1
300290	BAC EVAPORATEUR RM125/155/185/235H	10	50,03	6	18	2	1,27	0	0%	1	1	3	8,9	DUAL	2	8	3	1
300291	BAC EVAPORATEUR RM255H/305H/305C (2	10	50,03	6	6	1	0,67	0	0%	1	1	2	13,4	DUAL	1	8	1	1
302235	DEFLECTEUR EHJ 101/121	12	50,03	5	5	1	0,62	0	0%	1	1	2	6,8	DUAL	1	8	1	1
302236	DEFLECTEUR EHJ 151/181/211	12	50,03	5	15	2	1,12	0	0%	1	1	3	6,0	DUAL	2	8	3	1
302237	DEFLECTEUR CHJ 151/181/211	6	50,03	9	27	5	1,72	0	0%	1	1	6	14,0	DUAL	5	8	3	1
302238	DEFLECTEUR CHJ 101/121	8	50,03	7	14	2	1,07	0	0%	1	1	3	9,8	DUAL	2	8	2	1
304135	BOITIER ELECTRIQUE EVJ 151/181/211	4	50,03	13	13	4	1,02	0	0%	1	1	5	15,7	SET QTY	4	8	1	1
304136	BOITIER ELECTRIQUE CVJ 151/181/211	4	50,03	13	26	7	1,67	0	0%	1	1	8	27,5	SET QTY	7	8	2	1
306266C-88	CLOISON CONDENSEUR RM105H GRIS (261	10	50,03	6	6	1	0,67	0	0%	1	1	2	13,4	DUAL	1	8	1	1
306267C-88	CLOISON COMPRESSEUR RM105H GRIS (26	10	50,03	6	6	1	0,67	0	0%	1	1	2	13,4	DUAL	1	8	1	1
306268C-88	CLOISON CONDENSEUR RM125H/155H/185H	10	50,03	6	12	2	0,97	0	0%	1	1	3	7,2	DUAL	2	8	2	1
306269C-88	CLOISON COMPRESSEUR RM125H/155H/185	10	50,03	6	12	2	0,97	0	0%	1	1	3	7,2	DUAL	2	8	2	1
306270C-88	CLOISON CONDENSEUR RM235H GRIS (261	10	50,03	6	6	1	0,67	0	0%	1	1	2	16,7	SET QTY	1	8	1	1

Fig. 8.40 Kanban sizing for metal parts (partly)

Table 8.6 Overview of Kanban calculations for metal parts

Available production time	6.5 h	One card (K)	5 1.56%
Replenishment time	8.0 h	Multiple cards (K)	267 83.18%
Max inventory filter	15.0 days	Non-replenishable (K)	49 15.26%
		Total	321 parts
Process	Drilling	Cutting	Endforming
Number of shifts	3	3	2
TAKT	1.20 min	1.20 min	1.60 min
Number of resources	1	1	2
Actual work content time	1.00 min	1.00 min	1.00 min
Setup time	10.00 min	0 min	15.00 min

With a limit of fifteen (15) days, the number of non replenishable parts had fallen to 49 (15.2% of the total number of parts) which is acceptable. For the calculations, it was considered that it would be needed to set up all the machines at the same time each time a part was manufactured (Table 8.6). The machines, although they form a cell, are not in reality coupled and therefore it is possible while one produces, to individually set up the downstream machines. In this way there is no time loss during the shift. The days of inventory at the supermarket can be further reduced if products are made in a specific sequencing order to achieve reduction in the number of setups. After implementing these two steps, the days of inventory were reduced to ten (10) which was found satisfactory. Due to the large size of the table, only a portion of the results is presented in Fig. 8.40 Kanban sizing for metal parts (partly).

At the assembly line, space for one Kanban container was provided containing the related pieces per part number. Furthermore, replenishment of coils was signalled from the corresponding supermarket and it was decided to introduce a Kanban card at the appropriate level of the on the pallet stacked coils corresponding to the calculated Kanban quantity. In this way consuming coils from the assembly line, the card will be uncovered. At that particular point in time, the material handler responsible for line replenishment should be informed about resupplying

Fig. 8.41 Supermarket for sheet metal parts

Fig. 8.42 Kanban containers at the assembly line

coils from the appropriate supermarket. In Figs. 8.41 and 8.42 Kanban containers used for the painted sheet metal parts are shown. Every container carried a special Kanban card.

To present the cards consumed at the assembly lines, a board was used like the one illustrated in Fig. 8.43.

For unpainted sheet metal parts, a supermarket was created using pallets and shelves for transportation and positioning respectively. Figure 8.44 clearly depicts the process of carrying and signalling information.

Moreover, it is interesting to describe the way small parts, such as for example, screws, washers etc. were managed, which the company used in cooperation with a supplier and operates the system as a service provision (Figs. 8.45, 8.46 and 8.47).

Fig. 8.43 Kanban board for small sheet metal parts

Fig. 8.44 Supermarket of unpainted sheet metal parts

These figures do not need comments. However, it is important to mention that the containers are placed on electrical scales and when the reorder point is reached a replenishment signal is released to the supplier.

For managing tube sub-assemblies production, a fixed routine was implemented for producing a product very near to the point in time that this product is to be consumed by the line. Therefore, it was decided to produce all types of tube sub-assemblies one (1) day before, based on the production plan of the next day. In order to make this feasible, it is necessary to have all required tubes available of various lengths. In Fig. 8.48 the diagram of tubing production pull sequences is illustrated and commented on.

The method of lean flow was used, in order to design a flow line for producing the subassemblies. Based upon the method, the number of operations was

Fig. 8.45 Supermarket for small parts – overview

Fig. 8.46 Supermarket for small parts – in detail

calculated and the layout line was studied. Furthermore, special machinery and tools had to be arranged to the line for facilitating production. The processes involved are consecutively: *bending, expanding, soldering*. The tubes were supplied by the suppliers directly to the supermarket.

8.4.2 The Secrets of Managing Demand and Supply

Studying and sorting through material collected all these years of wandering in the amazing world of manufacturing, I discovered that the problems and the challenges 10 years ago are practically similar today, despite a quantum leap achieved in knowledge and in technology especially in information systems. The cause, in my opinion, lies in the traditional way of thinking in managing companies and in the

Fig. 8.47 Containers on electrical scale

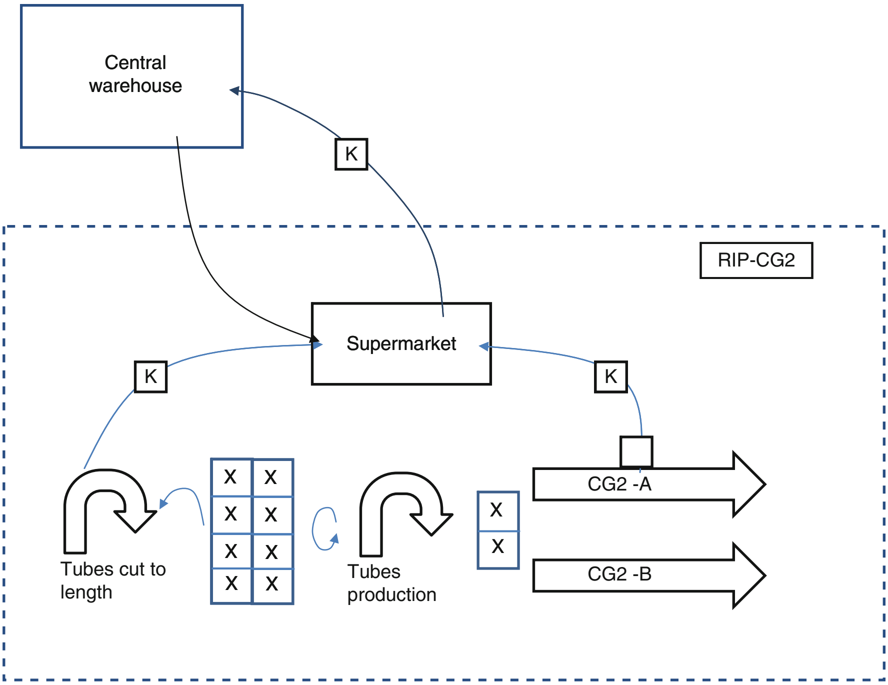

Fig. 8.48 Production pull sequences for tube subassemblies

denial of managers to rethink management primarily due to insecurity and crystallized practices as opposed to adopt best practices or to try something new and innovative. It is difficult to change habits and practices created and tested in the real world, especially if modern management practices are not taught as a way of life in Universities insisting on conserving past outdated knowledge. While lean production has revolutionized the way of managing and executing operations leading to slashed lead times and vastly reduced production costs especially in overheads in the last decade, nevertheless, customer response times are not in harmony with market needs. Furthermore, the supply of materials has been viewed by many companies as independent from demand, causing an inability to deliver on time due to materials shortages. Companies, instead of investing their working capital in raw materials and components, tie it up in finished products produced through forecast.

When producing to forecast there is the danger that the mix and volume produced does not match the mix and volume ordered by the customer. Therefore, availability of working capital is turned from investment into cost, not only of the capital that a company would borrow, but moreover to losses due to wrong investment. The current economic circumstances are directly down to, in my opinion, the choices made a decade ago, especially in Europe and the United States. In the topology of enterprises, implementation of lean production and similar concepts and philosophies are mainly aimed at solely reducing the cost of direct work though increasing productivity. However, increases in productivity led many companies to fill their supply chains with products on the basis of mass production and economies of scale to further lessen the cost. The results were good regarding productivity, became worse with respect to the cost of working capital, due to the fact that improvements in productivity were financed through bank loans. No special knowledge of economics is required for a sensible person to realize that this is exactly the recipe for disaster which was not late to come. One of the few, since around 1984, who spoke and wrote about the basic cause of market extinction for thousands, even giant companies worldwide was John Constanza. Constanza claimed that although these companies had products that the market wanted, the major cause for this extinction was lack of working capital and not the cost of production.

To prove the above mentioned, the results of a survey conducted from 24.01 to 03.02.2000 on behalf of a group of companies related to the level of inventories of finished products in their daughter companies in Europe are presented. The target was to reduce the level of finished goods inventories at the group level. A summary of the final report about the findings of the survey to managing director of the group is presented below. Based on these findings, a green light was given by management to develop best practices aiming at reducing finished goods inventories using quantitative methods compatible with lean flow in the supply chain. The results are presented hereafter.

A modern global enterprise needs adequate tools for exchanging, processing and decision making near real time information. Today the marketing organizations of the group in Europe are far from this status. The European holding company does not own resources for an independent and rash implementation of an Information System and are dependent on the budget and time table of the factory in France for implementing an information system. It is imperative to raise funds, and not wait for 1 or 2 years for implementation. Operation and maintenance of such a system can be outsourced. A significant finding during this visit was that people do not inform each other. Aid and assistance of downstream or upstream operations is a necessity, particularly when it affects late deliveries or product modification.

Concerning production flexibility, the feedback received from nearly every marketing company visited was that all factories had almost 1 month for ex-factory availability on every order. We have a similar response for the factory in France. This contradicts the possibilities of production capable to produce on average every order between 3 and 5 days. Therefore lack of reliability in promised delivery dates leads to the necessity of keeping more inventory in their warehouses, in order to build buffers for possible delivery delays. The objective for a marketing organisation is not to lose any sale.

Lean flow is actually well established in all assembly production departments. However, in order to build any model, every day to customer demand the necessary materials are needed. Most of the problems leading to delays are often due to lack of materials. Kanban techniques should be rapidly applied upstream to suppliers. The number of suppliers should also be reduced for better management and quality monitoring and control. Expand the concept of partnering with key suppliers as much possible. This increases reliability and quality of delivery.

It is imperative that a balance between materials inventory and finished products should be established. Simultaneous lowering in stock levels of both materials and finished products should be avoided. Highest priority should be given to on-time deliveries and to the decrease in finished goods stock levels. Once this has been attained, reductions in raw materials stock will come automatically and should be pursued. A tool should be developed to help marketing companies manage and control safety stocks. A common tool will also establish a common language between the marketing organisation and production sites.

Product modifications are often reported first by the end-customer to the marketing organisation. This is a major quality handicap from the perspective of the customer and needs to be addressed more rigorously. Frequent marketing modifications during the R&D cycle extend the design-to-market cycle and there is a danger of losing sales due to this fact. Long delays in delivering to the market damages the company's profile and puts sales in danger.

Frequent product modifications due to purchasing decisions may also lead to problems in production of the modified product. A purchasing decision taken on the basis of the component price alone may and frequently does lead to increased production costs and delivery delay to the final destination. The objective should be to reduce the total cost of ownership of this component under consideration of the supply channel quality and on-time delivery. Production of spare parts should be part of the lean flow implementation program. Until today, this sector of business has been excluded from the program. Today, almost all marketing organizations are faced with lack of spare parts when needed. This increases the cost of sales and service in the field.

Finally, unless factories can provide an adequate level of reliability for on-time production, it will be very difficult, if not impossible, to attain the stock levels projected and signed up by Management. On the contrary, if these inventory levels are kept, there is a danger of outplaying a major competitive advantage in building any product any day to customer demand.

The next step was the development of a procedure and an algorithm for the calculation of maximum allowed quantities ordered by the group of factories for

MANUF' / CUSTOMER	FACT 1			FACT 2			FACT 3			FACT 4			FACT 5		
	OH	TR	TOT	OH	TR	TOT	OH	TR	TOT	OH	TR	TOT	OH	TR	TOT
CUS 1	1	0	1	1	0	1	3	1	4	4	3	7	0	0	0
CUS 2	3	2	5	3	2	5	1	0	1	4	4	8	0	0	0
CUS 3	3	2	5	3	2	5	1	1	2	4	4	8	0	0	0
CUS 4	3	2	5	3	2	5	1	1	2	4	4	8	0	0	0
CUS 5	3	2	5	3	2	5	1	1	2	4	4	8	0	0	0
CUS 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CUS 7	4	4	8	4	4	8	4	5	9	4	4	8	0	0	0

Fig. 8.49 Current state for customer orders

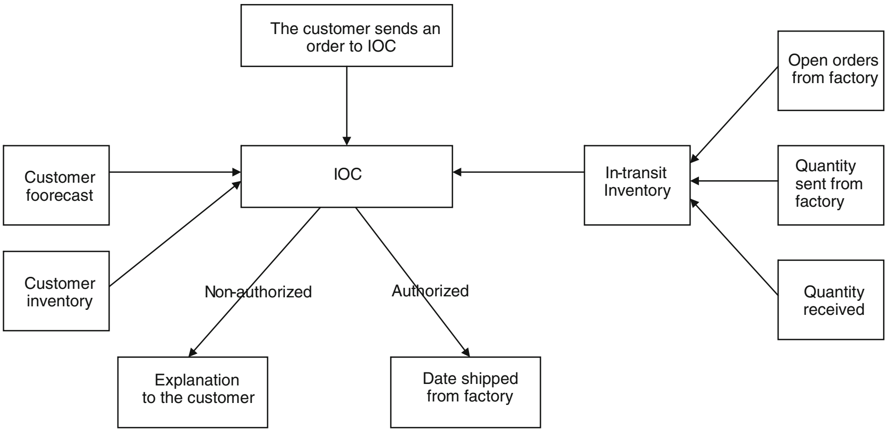

Fig. 8.50 Basic operations of IOC

each company and SKU (stock keeping unit). For this reason, the international ordering centre (IOC) was established, its purpose to receive orders from marketing organizations and distribute them to the factories. The IOC has the right to limit order quantities which lay outside the rules established for carrying inventory.

Below, the basic characteristics of the IOC operations are described, as well as the algorithm developed in collaboration with marketing and the supply chain executives of the companies. The algorithm was implemented in the ERP system of the group. IOC operations start with the current state for customer orders shown in Fig. 8.49.

In Fig. 8.50, the basic operations of IOC are illustrated

The key to success in achieving the desired inventory levels are the accuracy and availability of the following information:

- Every customer, member of the group sends a weekly report on the available inventory and the source of production
- Every production site will provide immediate information of what has been produced to meet which order and when is it shipped, by sending a copy of the documents to the IOC and to the customer

- Every customer will immediately notify the IOC with every receipt of the finished product
- The IOC checks open production orders before approving a new incoming production order

The following procedure has been developed for controlling safety stocks in daughter companies. The following data were provided for conducting the necessary analysis:

- Forecast based on budget
- Purchased Orders, dates and quantities
- Delivery Orders, dates and quantities
- Net Stock on Hand

The company basically develops two types of forecasts:

1. The annual budget that should reflect the sales profile across the year as seen from the beginning of the year
2. The rolling forecast that reflects the short term forecasting with a horizon up to 3 months. This forecast is updated on a monthly basis

It was necessary to establish a common definition concerning safety stock. The terminology was augmented with two more terms: Stock-out and Service level. Looking at the literature:

- Safety stock is the buffer added to on hand inventory during lead-time
- Stock-out is an inventory shortage
- Service level is the probability that the inventory available during lead time will meet demand

Definition of Safety Stock in the group is measured in terms of weeks of future stock, based on the rolling forecast as mentioned above. This leads to the following challenges:

- The rule of three (3) weeks of future stock can be undermined if the rolling forecast is changed without limitations. As an example we refer to the product of the marketing organization in Spain in which the budget for March 2001 is given at *535 units* and the actual PO (purchase order) is given at *2700 units*!! It means that the three (3) weeks inventory can represent practically any quantity, never mind safety stock.
- It destabilises the inventory control system that is difficult to stabilise again.
- The receiving manufacturing site suddenly receives a very big order that needs to be fulfilled within a relatively short period of time. This situation can disturb the lean flow mixed model lines put in place to satisfy many clients every day.
- Lot production will probably delay order fulfilment for other customers.
- It will also challenge the planning and replenishment of materials in the factory and in the supply chain.

Analysing the situation, the following facts were observed:

1. One of the basic rules that inter-company procedures determine is that the rolling forecast cannot exhibit a greater difference of +/−10% of the budget at any point in time. This rule is not respected. Not only is it not respected, but quite often it also exceeds 10 times the forecasted quantity for the period of the lead-time of 6 weeks. This fact makes the process for the calculation of safety stock meaningless.

2. The stock level in the low season was higher than the stock level in the high season. This was observed in both products. This is not normal and it should be avoided.
3. The On Hand stock is poorly managed. It was expected to see a profile that exhibits regular receptions and issues from Stock. Its profile exhibits very abrupt changes, dropping every time to almost "0" in order to be refilled again.
4. Reordering from one of the marketing companies was not regular. Although the agreement is to place one PO weekly, the data show an irregular pattern of placing POs.
5. The order quantities do not follow the rules of a periodic inventory system with random demand.
6. Lean flow rules of demand based agility fronts are not applied nor even considered.

Analysis of the data shows strong indications that marketing organizations do not follow a reordering process that is repeatable and predictable. In addition, this process, uses to a great extent, subjective criteria as opposed to some sort of control algorithm that takes into account known parameters. Processes that are neither repeatable nor predictable are very likely to produce uncontrollable results. As a consequence, any effort on the side of the IOC to control fixed inventory levels in marketing organizations and also to calculate realistic and accurate safety stocks based on the demand coming from these organizations is very difficult, if not impossible. Any predictions regarding safety stocks will not reflect reality since initial data used to calculate these safety stocks are not respected. One of the downsides of this approach is to have high stocks at the end of the year.

The purpose of holding safety stock as an extra buffer to on hand inventory is to account for demand fluctuations during lead-time. The higher the demand fluctuations during lead-time the higher the safety stock needed for a certain service level. At the moment, this fact is not taken into account by marketing organizations. Safety stock protects against possible stockouts during lead time, due to uncertainties in demand rate and in lead time. The fact that demand is seasonal and random should be seriously taken into account. A reordering process and an algorithm is defined to calculate reorder quantities for a periodic inventory system that is based on the following parameters:

1. The supply lead time
2. The demand fluctuations during lead time
3. The average demand rate in the lead time
4. The fixed time between orders
5. The on-hand inventory
6. The service level

Service level can be defined as the probability that demand will not exceed supply during lead time. Thus a service level of 90% implies a probability that demand will not exceed supply during lead time. The formula that combines all these factors is given below:

$$\mathrm{Q} = \mathrm{D}(\mathrm{P} + \mathrm{R}) + \mathrm{z}\sigma\ \sqrt{P + R} \tag{8.1}$$

Table 8.7 Definitions

Order quantity	=>	Q
Average demand over lead time	=>	D(P + R)
Safety stock	=>	$z\sigma\sqrt{P+R}$
Stock	=	On hand inventory
	+	In transit inventory
Stock target	=	Average demand over lead time
	+	Safety stock

Table 8.8 The algorithm

Order (t_i)	=	Stock target (ti + R)
	−	Stock (ti + R)
Stock (ti + R)	=	On hand inventory(ti)
	+	In transit inventory (ti + R)
Average demand over lead-time (ti,ti + P + R)	=	D(ti, ti + P + R) (P + R)
Safety stock (ti,ti + P + R)	=	z σ D (ti,ti + P + R) $*\sqrt{P+R}$
Stock target (ti + R)	=	Average demand over lead-time (ti,ti + P + R)
	+	Safety stock (ti,ti + P + R)

Where

D = average demand rate over lead time per time unit

P = fixed time between orders => 1/number of orders per week

R = lead time

σ = standard deviation of demand rate during lead time

z = standard normal variable expressed as service level % (Svc Level) and can be calculated with the Excel function of NORMSINV(Svc Level)

i => current week

t => point in time

The algorithm is presented in Table 8.8.

Requirements for running simulation for validation purposes:

1. Prepare a test database with test data emulating weekly forecast.
2. Define agility factor as a % of budget data – it should be modifiable.
3. Define service level (z) as a % number.
4. Allow the possibility to randomly modify this database for achieving rolling forecasts. The randomly generated data should be compared to the data than can be achieved if maximum allowed agility defined in point 2 is implemented.
5. Every time that the forecast changes, the algorithm should be activated in order to calculate recommended order quantities.
6. Allow on line execution of the above process as an interactive procedure.

Implementation of the same reordering process and the same algorithm from every participant in the group of companies network assures that a repeatable and predictable process that starts from the point of consumption passes through IOC to the supplier. Every effort should be made to standardize the process and the algorithm across the group and for every marketing organization. This process and the algorithm should become part of inter-company procedures. Furthermore, the process of developing a rolling forecast should also be revised. Deviations from the budget should also be defined and respected as should deviations between successive monthly forecasts for the same period of time. This cannot be left to the individual purchaser to decide. It is suggested that the process be designed so that changes can be accommodated as needed. This also suggests that the budgeting process should also be revised to provide a more realistic view of the market situation. Experience with the group teaches that particularly this very important factor for business success does not attract the necessary attention. Especially now that products have been moved to China, the budgeting process should be redesigned to meet the increased demand for budget accuracy. An alternative strategy would be if the IOC were upgraded to a real Orders Dispatching Centre from the status of Orders Relay Centre being today. It will be the IOC that will create the PO using the process and the algorithm stated above. The marketing organizations will simply pass the rolling forecast to the IOC. The IOC has to know the stock on hand at the point in time of reordering in every marketing organization. The procedure and the algorithm was accepted with small modifications and implemented in all marketing companies of the group in Europe with success.

Cautious management should permanently look for opportunities to reduce working capital needs, certainly not through delaying accounts payable and speeding up accounts receivable. This model of financial management can bring short-term cash benefits, but in the medium-term it is not a sane decision and leads with mathematical precision to a halt in economic activity sooner or later. There are no universal recipes valid for all enterprises. However, there are important principles which can be viewed as fixed values. This is what my experience taught me, throughout the years, and they are stated below as nourishment for critical thinking.

1. Sales and marketing are responsible for the level of stocks which they believe are needed.
2. Sales management is held responsible to the degree they influence working capital level.
3. The bonus paid to sales representatives is tied to the difference of the turnover and the value of stock at the end of every fiscal year.
4. Forecasting is part of the duties of those responsible for stock level.
5. Forecasting must be facilitated through restructuring the BOM, in order to follow as much as possible the rule:

   final product = basic model + obligatory options + optional options

The existence of thousands of individual BOM in many implementations is a common phenomenon. In such an environment, forecasting at the level of the individual part number is impossible and it is natural that production can suffer

Table 8.9 BOM – obligatory options

Obligatory options		Option
Option 1	A	
Option 2	B	
Option 3	C	X
Option 4	D	

Table 8.10 BOM – optional options

Optional options		Option
Option 1	F	
Option 2	G	X
Option 3	H	
Option 4	J	

under the complexity the products present. It is doubtful that in such environments sales representatives are aware of all their products. However, restructuring the BOM as mentioned above, will lead to successful forecasting of the basic model, based on the so-called planning BOM, with a significant reduction in the degree of error. With respect to options, these can be estimated according to the percentage related to the totality of the demand. Reduced effort and increased visibility in the procedure of developing the demand plan, an inextricable part of which is forecasting, would be significant. In order to achieve this, tough decisions should be taken at management level as the issue concerns marketing, product development, production, purchasing and accounting. It involves, in other words, the whole company. In such an approach, the connecting point is the customer order. At the end of production, the sales order number should be declared, in order to update the information system which manages materials inventory. An example of the BOM structure is provided, as this may be developed when a new customer order is received. Let a customer order of a basic model including options be mapped as follows.

Let a sales order (SO) be SO = 31071951

Let the part number of the basic model be BM – 0A15

The BOM of the obligatory options is shown in Table 8.9

The BOM of the optional options is shown in Table 8.10

Based on the above data, the final BOM for the ordered product is created (Fig. 8.51).

This will be the BOM to be declared to the information system concerned in order to update inventories and handover the product to shipping. Nowadays, through the dynamic appearance and establishment of mass customization and personalization in the market, the procedure of forecasting gradually loses its sense, as long as it is not possible to forecast something that does not exist a priori. The demand in such environments is allocated in a different way, an issue we deal with in a future volume of this book.

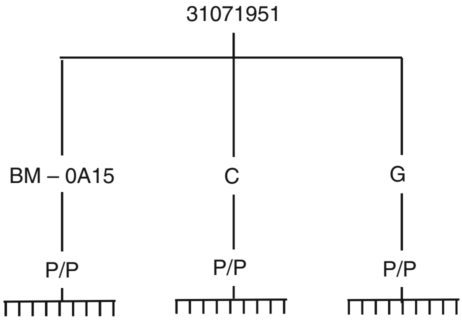

Fig. 8.51 Final BOM

Fig. 8.52 Production in Russia (2008)

After 1 year of production in a lean environment, the factory manager said: *something big has happened in this factory*. *We now know something we did not know 1 year ago*. I believe that no further comments are needed, except only to mention that, we should stop seeing in our factories that what is illustrated in Figs. 8.52 and 8.53 also without comment.

8.4.3 Constraints on the Full Exploitation of Lean Flow

1. Lean flow provides the environment for flexibility, but this ability is limited today by *excessive internal complexity*
2. Internal complexity exists due to lack of standardisation of parts, modules, tooling and processes
3. Current R&D and Purchasing methods and policies create internal complexity that drive overhead cost expressed as cost of variety
4. Working Capital is tied-up in the cost of variety

Fig. 8.53 Production in the Czech Republic (2007)

8.4.4 How *Not* to Achieve Low Cost

1. Low-cost products do *not* come from volume exclusively. Design of flexible operations are the key to making mass customized products at low cost *independent* of volume.
2. Low cost products do *not* come from cheap parts. On the contrary, these multiply other costs such as quality, service, operations and other overhead costs.
3. Low cost products do *not* come from cost reduction efforts, because it will not come due to competitive priorities.
4. Low-cost products do *not* result from manufacturing misconceptions like purchasing policies based on low-bidder or offshore manufacturing to lower labour costs, which often raise many other overhead costs and lengthen delivery times.
5. Cost is very difficult to remove after a product is designed. Eighty percent of the cost is designed into the product and it is very difficult to remove later.
6. Shaving cost off reported costs (such as parts) might balloon other costs such as quality. Changing the design might force other changes.

8.4.5 Lessons Learned

It is noticeable that companies do not learn from their lessons and do not observe the displacements happening over time. Economic crises are provoked by us, directly or indirectly. The year 2000 was a good era for the world economy. Nowadays, more than 10 years later, the choices of that time led to sovereign over-indebtedness of all developed countries and not only. Many enterprises which provided then acted and made good choices, exist and prosper today, others have disappeared from the map. The reason is simple: correct and timely decisions.

The way is simple: quick understanding of what is happening and displacement capability in the market(s). The means are known: up to date knowledge which uncovers and not misleads, based on the embodiment of practice and theory, supported by the use of modern applications of lean informatics. The target is the decoupling to a great extent from bank loans for working capital and to this will help largely the right strategy in the design and operation of supply demand and supply networks respectively. Chains and supply networks must be supported by new evidence. The strategy model which proposes and suggests central production in low cost countries and shipping products to markets with high standard of living is breaking up speedily, basically for two reasons nowadays: reduction in demand and overconsumption in many European countries on the micro level and due to the increase in the cost of production in countries like China primarily and India secondly on the macro level.

8.5 Cooling Units

The company is well established and active in the market with residence in Cyprus. The contact was made by an Israeli supplier, who was informed about the significant benefits the Israeli group had achieved. At the end of 2001, I visited the factory to conduct an audit and a short while later the project was given the green light. The company was established in 1979 and had significant exports primarily to the Arab countries and Greece. In the internal market, they collaborate with large companies such as Coca-Cola, providing coolers for soft drinks in Cyprus. The factory relatively small exhibited similar problems to large factories, though on a smaller scale. Because of limited resources, the work for designing lean flow in the factory was performed by me. The implementation included the whole factory and was completed in about 6 months.

The results of the audit are presented in Fig. 8.54. We do not comment in detail here because there is a similar analysis of the structure and the purpose of the audit in Sect. 8.3. From the financial analysis, a significant reduction in working capital of about 40% is shown. Based on my experience and the experience of other lean production professionals, implementation of lean flow leads often to a reduction in working capital needs by 20%, 40% and even 50% in many cases.

The company had two assembly lines for the production of soft drink cabin coolers and water coolers respectively. The production procedure is the same for both product families. Moreover, for the production of sheet metal parts, the company had a very well equipped department with modern machines and one robot designed by one of the owners responsible for marketing, product design and manufacturing. Water coolers were designed according to customer specifications. Marketing approached the customer, proposed an idea and together the new product was shaped and specified. The customers were mostly commercial companies buying products in relatively large numbers and selling locally in their countries of origin. Furthermore, for each new product there was an agreement attached to a large sales order. Only then could a product enter the process of design and

Benefit Area		Pre Lean	Post Lean	Savings	Improvement
	2000	2000			
COGS		CYP 1.800.000			
Material (MCOGS) in CYP (WC+	60%	CYP 1.080.000			
Labour	17%	CYP 306.000			
Overhead	23%	CYP 414.000			
Total	100%	CYP 1.800.000			
Inventory					
Raw material average	50%	CYP 692.000	CYP 403.319,50	CYP 288.680,50	42%
WIP average	20%	CYP 138.400	CYP 22.406,64	CYP 115.993,36	84%
FGI average	30%	CYP 207.600	CYP 22.406,64	CYP 185.193,36	89%
Total Inventory (only material)		CYP 1.038.000	CYP 448.132,78	CYP 589.867,22	57%
Inventory Carrying Costs	20%	CYP 207.600	CYP 89.626,56	CYP 117.973,44	57%
Total Inventory Turns		1,04	2,41		43%
Response					
Raw material	1,56	154,4 days	90 days	3 turns	72%
WIP	7,80	30,9 days	5,0 days	48 turns	518%
FGI (for local + export)	5,20	46,3 days	5 days	48 turns	827%
Working Capital					
Sales		CYP 2.400.000	CYP 2.400.000		
A/R		CYP 575.000	CYP 575.000		
A/P		CYP 230.000	CYP 230.000		
Total Inventory		CYP 1.038.000	CYP 448.133		
Working Capital		CYP 1.383.000	CYP 793.133		
Percentage of Working Capital/$ of Sales		58%	33%		
Working Capital reduction				CYP 589.867	43%
Quality					
Total Cost of Quality					
warranties	CYP 4.333,00	CYP 4.333		CYP 0,00	0%
rework	CYP 1.652,00	CYP 1.652		CYP 495,60	30%
Total	CYP 5.985,00	CYP 5.985		CYP 495,60	8%
Floorspace		1,70			
Store Area	700 sqm	CYP 1.190	630 sqm	70 sqm	10%
Production Area	3.300 sqm	CYP 5.610	3.135 sqm	165 sqm	5%
Total Floorspace	4.000 sqm	CYP 6.800	3.765 sqm	235 sqm	5%

Fig. 8.54 Audit results

production. Because of the significant accumulated experience of the company in the market, the proposals for new products often found mature ground for large orders.

The factory, although of small scale, was divided into seven (7) departments.

1. Final assembly
2. Tank welding
3. Manufacturing of sheet metal parts
4. Presses
5. Cooling sub-assembly
6. Packaging
7. Shipping – Stores

Each department was driven by a separate production plan. This led to production flow interruptions at the borders of departments. In Fig. 8.55 the assembly layout before redesign is illustrated.

Practice shows that every company uses their own terminology when characterizing inventory. Therefore, semi-finished products were all those products regarding cooling sub-assemblies installed into cabin coolers and water coolers.

Every other part was viewed as WIP, which constituted the biggest problem with respect to factory space. It was evaluated that the WIP quantity covered about 3 months of the needs of production. The existing work fragmentation into many departments and the classical production planning procedure, based on keeping safety stocks everywhere, sustained the need for high space demand next to working capital needs. Furthermore, because of the lack of a material handler to support assembly lines, workers were obliged to search for the necessary parts, wasting valuable production time. Work allocation to subcontractors was performed in the form of lots, forcing the factory to make even more space available for products. Moreover, although the company produced to order, it carried a large number of finished goods inventory. Frequently, in anticipation of a large order, production operated on sales forecast for immediate response to potential incoming orders. However, on many occasions, the order either did not come or it did not come in sufficient quantities, resulting in finished products piling up in stores. Below, the factory redesign phases are described in detail. Our intention is, as authentically as possible, to transfer the dynamics of displacement of the company from the non lean to the lean topos.

Required elements for all lean flow implementations

The basic activity for the redesign of the production lines and the final layout is the collection of all necessary data. The data elements necessary are the following:

1. Models of cabin and water coolers
2. Production quantities per cooler model for the last 2 years
3. Sales quantities per cooler model for the last 2 years
4. Sales forecast for the following year
5. Stock level evolution of finished products of the last year
6. Production times of the 20% of all products usually corresponding to the 80% of sales turnover (Pareto rule)
7. Number of new products introduced per year
8. Number of products withdrawn per year
9. Number of parts purchased and number of parts produced per model
10. Number of big size parts

The data elements were provided and the work started. The first step in the design phase is the development of the mixed model product synchronization flow illustrated in Fig. 8.56 for the water coolers and in Fig. 8.57 for the cabin coolers respectively.

From the two mixed model cooler synchronization, it can be seen that the processes concerning cooling sub-assembly positioning is the same. The second step in the design phase is the development of SOE in order to register the work content time per process and product. Figure 8.58, illustrates the SOE indicatively for the assembly of cabin coolers as an example.

In the same way, all other SOE were developed. The next step towards line design is the development of the process map to calculate resources requirements. The first process map (Figs. 8.59 and 8.60) includes all water coolers (65 models) and the second process map (Fig. 8.61) includes all cabin coolers (19 models). In the last line of every process map, the resources per process are calculated taking into account TAKT and the weighted average time per process.

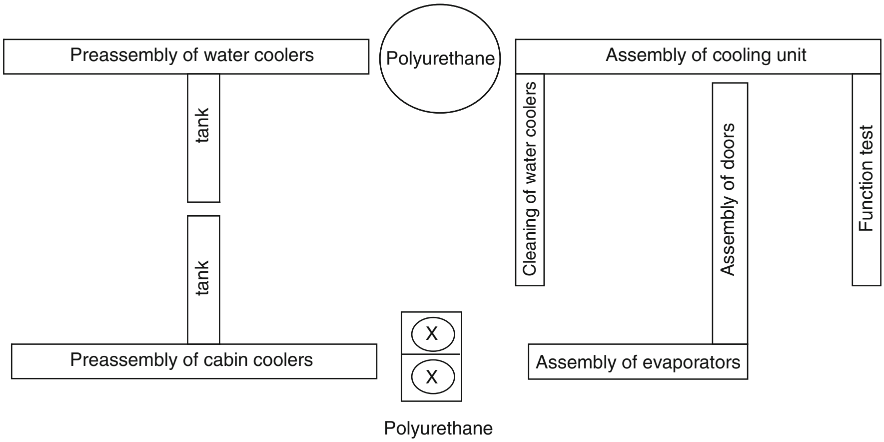

Fig. 8.55 Assembly layout before redesign

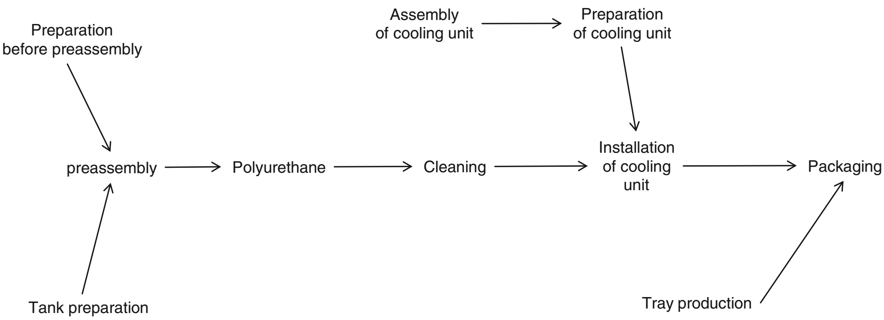

Fig. 8.56 Mixed model water cooler synchronization flow

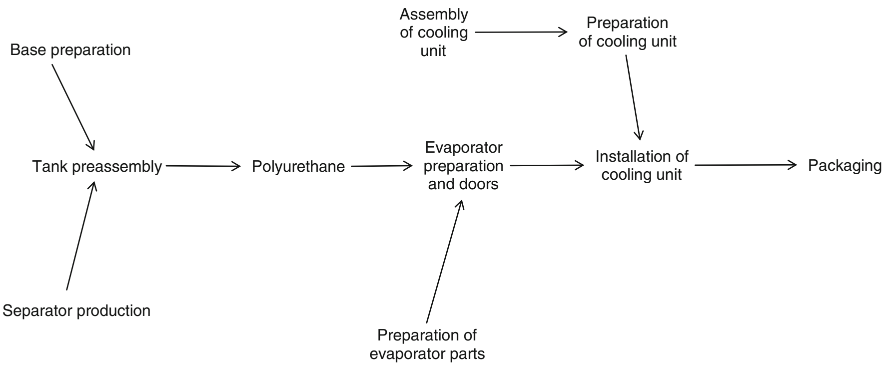

Fig. 8.57 Mixed model cabin cooler synchronization flow

Product	EU 0A15 DD								Tank assembly
			Preparation		Work		Transfer		
No of step	Step description	NVA	Machine	Labour	Machine	Labour	Machine	Labour	Quality control
10	Fix internal right side panel and left side panel to the roof and the floor					4			
20	Fix internal back plane								
30	Seal holes with paper tape in order to avoid leakage of polyurethane	X		2					Check holes
40	Seal seams with plastic tape at the corners	X		2					Check seams
50	Fix the upper side on the galvanized part					5			
60	Fix the base subassembly								
70	Install the armaflex and the plastic tube for the protection of the copper tube. Fix with plastic tape.					6			Attention the tube should not be right behind the holes used for inserting screws in order avoid injury of the tube
80	Install the sheet metal strip at the left outer side panel								
90	Repeat step 80 for the right side panel								
100	Seal seams with silicon and plastic tape at the corners	X		1					Check seams
110	Στερέωση της βάσης πάνω στις δύο εξωτερικές πλευρές					4			
120	Rotate tank by 180 degrees	X		0,2					
130	Install and fix with plastic tape of the capillary tube with the buffer of the return flow copper tube					2			
140	Fix the outer back panel					3			Use fixation adaptor for appropriate installation
150	Seal holes with paper tape and plastic tape in order to avoid leakage of polyurethane	X		2					Check holes
	Part sum	7,2		7,2	0	24	0	0	
							Sum	31,2	min

Fig. 8.58 SOE for cabin coolers

No	Group	Product	Dc	Tank preparation	Special preparation before assembly	Preassembly	Polyurathane	Cleaning and Finishing	Preparation of cooling unit	Cable preparation	Installation of cooling unit	Electric acoustic, optical test	Vacuum	Function Test
			220											
1	1	YEN15/2	8,43	27,58		12	8	27	8	1	7	2	20	30
2	1	YEN15/1	5,80	27,58		11	8	27	8	1	7	2	20	30
3	1	YEN30SS HI	2,92	29,58	4	12	10	33	8	1	7	2	20	30
4	1	YEN20SS HI	0,91	27,58	4	12	8	27	8	1	7	2	20	30
5	1	YEN50SS	0,44	41,75	4	12	10	33	8	1	7	2	20	30
6	1	YEN20SS	0,91	27,58	4	12	10	27	8	1	7	2	20	30
7	1	YEN25SS	0,00	27,58	4	12	10	27	8	1	7	2	20	30
8	1	YEN30SS	0,00	29,58	4	12	10	33	8	1	7	2	20	30
9	1	YEN35SS	0,00	33,90	4	12	10	33	8	1	7	2	20	30
10	1	YEN110SS	0,15	55,42	4	30	10	33	8	1	7	2	20	30
11	2	SG25SS	4,41	27,58		19	10	27	8	1	7	2	20	30
12	2	SG50SS	3,44	41,75		25	10	33	8	1	7	2	20	30
13	2	SG60SS	3,05	58,75		25	10	33	8	1	7	2	20	30
14	2	SG20SS	2,48	27,38		17	8	27	8	1	7	2	20	30
15	2	SG32SS	1,60	29,58		20	10	33	8	1	7	2	20	30
16	2	SG15SS	0,95	26,42		15	8	27	8	1	7	2	20	30
17	2	SG90SS	1,36	60,42		30	10	33	8	1	7	2	20	30
18	2	SG40SS	0,23	33,90		20	10	33	8	1	7	2	20	30
19	3	T20SS	4,75	27,38		12	10	27	8	1	7	2	20	30
20	3	T30SS	1,59	29,58		12	10	33	8	1	7	2	20	30
21	3	T40SS	0,11	33,90		12	10	33	8	1	7	2	20	30
22	4	SG20B	2,86	27,38		17	8	27	8	1	7	2	20	30
23	4	SG25B	1,13	27,38		19	10	27	8	1	7	2	20	30
24	4	SG40B	0,25	33,90		20	10	33	8	1	7	2	20	30
25	4	SG15B	0,00	27,38		15	8	27	8	1	7	2	20	30
26	4	SG32B	0,00	29,58		20	10	33	8	1	7	2	20	30
27	4	SG50B	0,00	41,75		25	10	33	8	1	7	2	20	30
28	4	SG60B	0,00	58,75		25	10	33	8	1	7	2	20	30
29	4	SG90B	0,00	60,42		30	10	33	8	1	7	2	20	30
30	5	AZ40S	0,74	8,00		40	10	33	8	1	7	2	20	30
31	5	SGAZ50S	0,39	41,75		25	10	33	8	1	7	2	20	30
32	5	SGAZ15S	0,34	27,38		15	8	27	8	1	7	2	20	30
33	5	SGAZ20S	0,23	27,38		17	8	27	8	1	7	2	20	30
34	5	SGAZ25S	0,23	27,38		19	8	27	8	1	7	2	20	30
35	5	SGAZ90S	0,07	60,42		30	10	33	8	1	7	2	20	30
36	5	SGAZ40S	0,05	33,90		20	10	33	8	1	7	2	20	30
37	5	SGAZ32S	0,00	29,58		20	10	33	8	1	7	2	20	30
38	5	SGAZ60S	0,00	53,75		25	10	33	8	1	7	2	20	30

Fig. 8.59 Process map for water coolers (part 1/2–38 models)

The next step in the design phase is line balancing based on the TAKT per process and grouping resources so that each operation has work content time which can be performed by one person close to TAKT, but not surpassing it. The work content time is called *operational cycle time*. Once this activity is completed, all data needed for line design are available.

For finalizing the layout design, what is still missing is the design of the pull mechanism, including Kanban sizing and Supermarkets for the replenishment of materials. When the issue of materials was discussed, it was identified that they did not use the MRP system for the calculation of materials requirements and the BOM had a flat structure, a fact that facilitated the calculation of Kanban quantities. The

39	6	WP30	1,81	27,38		19	10	33	8	1	7	2	20	30
40	6	WP35	0,00	29,58		20	10	33	8	1	7	2	20	30
41	6	WP50	0,00	33,90		25	10	33	8	1	7	2	20	30
42	6	WP60	0,00	0,00		25	10	33	8	1	7	2	20	30
43	6	WP85	0,00	0,00		25	10	33	8	1	7	2	20	30
44	6	WP100	0,00	0,00		30	10	33	8	1	7	2	20	30
45	7	MW25SS	0,47	21,38		12	10	33	8	1	7	2	20	30
46	8	MSK100	0,25	0,00		22	10	33	8	1	7	2	20	30
47	9	JC25SS	0,15	0,00		22	10	33	8	1	7	2	20	30
48	10	EMS70	0,10	0,00					8	1	7	2	20	30
49	10	EM50SS	0,00	0,00					8	1	7	2	20	30
50	10	EMS()	0,00	0,00					8	1	7	2	20	30
51	10	EBC30	0,00	0,00					8	1	7	2	20	30
52	11	SOL 100	0,10	0,00		19	10	33	8	1	7	2	20	30
53	12	AS20	0,00	22,42					8	1	7	2	20	30
54	12	AS30	0,00	23,83					8	1	7	2	20	30
55	12	AS40	0,00	0,00					8	1	7	2	20	30
56	12	AS65	0,00	0,00					8	1	7	2	20	30
57	12	AS100	0,00	0,00					8	1	7	2	20	30
58	13	SGAZ15B	0,00	21,38					8	1	7	2	20	30
59	13	SGAZ20B	0,00	21,38					8	1	7	2	20	30
60	13	SGAZ25B	0,00	21,38					8	1	7	2	20	30
61	13	SGAZ32B	0,00	21,58					8	1	7	2	20	30
62	13	SGAZ40B	0,00	25,90					8	1	7	2	20	30
63	13	SGAZ50B	0,00	31,75					8	1	7	2	20	30
64	13	SGAZ60B	0,00	43,75					8	1	7	2	20	30
65	13	SGAZ90B	0,00	45,42					8	1	7	2	20	30
		ΣDc =	53	52	5	53	53	53	53	53	53	53	53	53
		TAKT =	7,6	7,7	75,0	7,6	7,6	7,6	7,6	7,6	7,6	7,6	7,6	7,6
		Aw =	154,3	31,10	0,40	16,52	9,14	29,13	8,00	1,00	7,00	2,00	20,00	30,00
		ПОРОІ =	20,3	4,11	0,01	2,18	1,20	3,84	1,06	0,13	0,92	0,26	2,64	3,96
		H=	6,65	6,65	6,65	6,65	6,65	6,65	6,65	6,65	6,65	6,65	6,65	6,65

Fig. 8.60 Process map for water coolers (part 2/2–27 models)

Product	Dc	Tank preassembly	Separator preparation	Base preparation	Polyurethane	Evaporator and Doors	Evaporator parts preparation	Doors preparation	Preparation of rest parts	Preparation Fan Motor	Preparation cooling unit	Motor prepararion	Preparation ACCU	Cable preparation	Installation of cooling unit	Electric acoustic, optical test	Vacuum	Function test
	160,00																	
EUC1000DD	4,10	27	4	8	15	45,5	11	8	1	2	5	2	7	1	20	2	20	30
EUC2000DD	2,88	27	4	8	15	45,5	11	8	1	2	5	2	7	1	20	2	20	30
EUC2200DD	0,00	38	6	8	15		11	8	1	2	5	2	7	1	20	2	20	30
EUC800D	1,56	27	4	8	15	45,5	11	8	1	2	5	2	7	1	20	2	20	30
EUC7200	1,25	27	4	8	15	45,5	11	8	1	2	5	2	7	1	20	2	20	30
EUC1900DD	0,63	27	4	8	15	45,5	11	8	1	2	5	2	7	1	20	2	20	30
EUC8200	0,31	27	4	8	15	45,5	11	8	1	2	5	2	7	1	20	2	20	30
EUC8400	0,14	27	4	8	15	45,5	11	8	1	2	5	2	7	1	20	2	20	30
EUC120	0,28	13	4	8	15	15	2	4	1	2	5	2	7	1	20	2	20	30
EUC2400DD	0,00	27	4	8	15	45	11	8	1	2	5	2	7	1	20	2	20	30
EUC450	3,76	15	4	8	15	35	5	4	1	2	5	2	7	1	20	2	20	30
EUC501	1,75	15	4	8	15	35	5	4	1	2	5	2	7	1	20	2	20	30
EUC500	1,56	15	4	8	15	35	5	4	1	2	5	2	7	1	20	2	20	30
EUC300	0,45	15	4	8	15	25	5	4	1	2	5	2	7	1	20	2	20	30
EUC300C	0,22	15	4	8	15	25	5	4	1	2	5	2	7	1	20	2	20	30
EUC95	0,01	15	4	8	15	25	5	4	1	2	5	2	7	1	20	2	20	30
EUC300SD	0,00	15	4	8	15	25	5	4	1	2	5	2	7	1	20	2	20	30
EUC700	0,00	15	4	8		25	5	4	1	2	5	2	7	1	20	2	20	30
EUC2100SL	0,94	23	4	8	15	25	5	8	1	2	5	2	7	1	20	2	20	30
ΣDc =	19,83	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
TAKT =		19,79	19,79	19,79	19,79	19,79	19,79	19,79	19,79	19,79	19,79	19,79	19,79	19,79	19,79	19,79	19,79	19,79
Aw =		21,92	4,00	8,00	15,00	39,66	8,24	6,38	1,00	2,00	5,00	2,00	7,00	1,00	20,00	2,00	20,00	30,00

Fig. 8.61 Process map for cabin coolers (19 models)

use of Kanban would regulate materials consumption in the factory and purchased orders to the suppliers. Furthermore, they would have the ability to know at any time exactly the level of inventory in production, impossible before without conducting frequent physical inventory, a resource and time consuming activity thus increasing overhead costs. For supermarket design in the assembly area, the situation was relatively easy, almost routine once inventory policies were defined, due to the fact that the majority of the parts concerned were purchased parts. However, pulling sheet metal parts through production, especially water coolers parts, to the assembly line was not a trivial task and the process had to be slightly modified. The cause of the differentiation was the fact that, although these products had a high degree of standardization, customers frequently asked for changes affecting the number and placement of holes on certain sheet metal parts. This activity occurred at the very first process in production thus becoming the point of interaction with the customer. The phenomenon is quite frequent in many factories, where in most cases, when a part must be modified a new part number is created. However, it depends on the number and the modifications frequency, but the way of creating new part numbers, some of which may even never appear again, creates progressively a high amount of dead part numbers and dead stock if these parts are produced just in case they will be needed. In lean flow, the way of dealing with the situation is as follows. The part is characterized by three qualities: *fit, form and function*. If all three remain constant, then the part number does not change (rule of constancy). The number of holes, in this case, does not violate the rule of constancy.

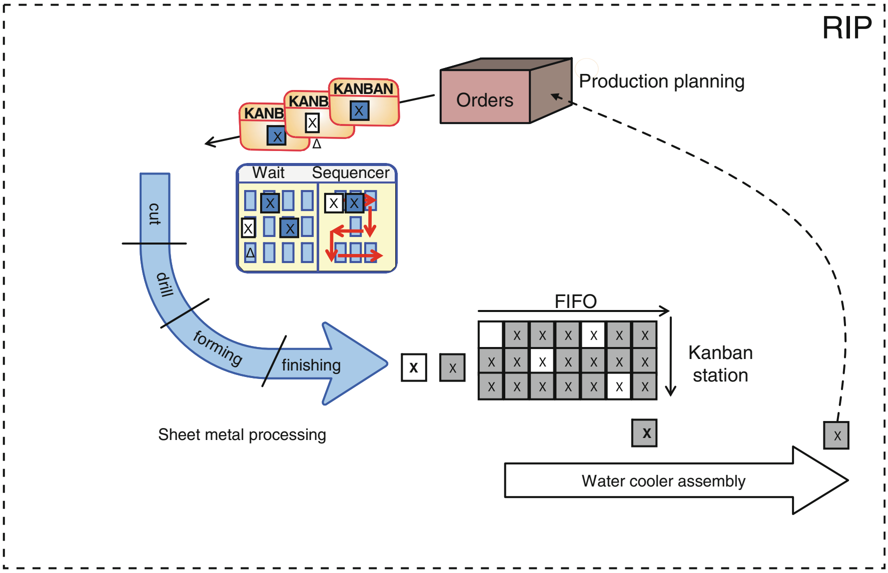

Fig. 8.62 Production Kanban pull sequences for sheet metal parts

What changes is the use of the part which influences its relations, namely interactions with other parts of the product and therefore its behaviour. However, the change in the behaviour of a part does not signal a different part. Consequently, the part number should not change. However, how should the change in behaviour of the part be signalled? The way chosen in facing this issue was the following. Since the part number remains the same, the use of the pull mechanism Kanban is advised as these parts are used quite often and in satisfactory quantities. In this case a new element is introduced. The element concerns the modifications to be effected on the part with respect to the positioning of the holes. Based on the customer order, the necessary modification information is created and accompanies the Kanban card for producing the modified part. On the Kanban card, a yellow sticker is attached (Fig. 8.62, light grey) to signal to the machine operator that an individuated modification of a standard part is requested. When the part is delivered to the assembly line, the Kanban card is returned to the production planning department in order to be reused. Production planning is responsible for setting up the product mix and sequence in the execution of customer orders respecting the line balancing rules. In Fig. 8.62 the lean flow pull sequences designed for this purpose are illustrated.

The new assembly layout, based on the design calculations performed, is shown in Fig. 8.63. The assembly line and installation of the cooling unit is common for the two product families and the right mix for line balancing is 3:1, namely three (3) water coolers for one (1) cabin cooler, because the total number of water coolers is 65 while that of cabin coolers is 19. Furthermore, it was decided to create flow for water cooler production after the polyurethane process, so that products continue towards cleaning and finishing without pause. Moreover, for facilitating common

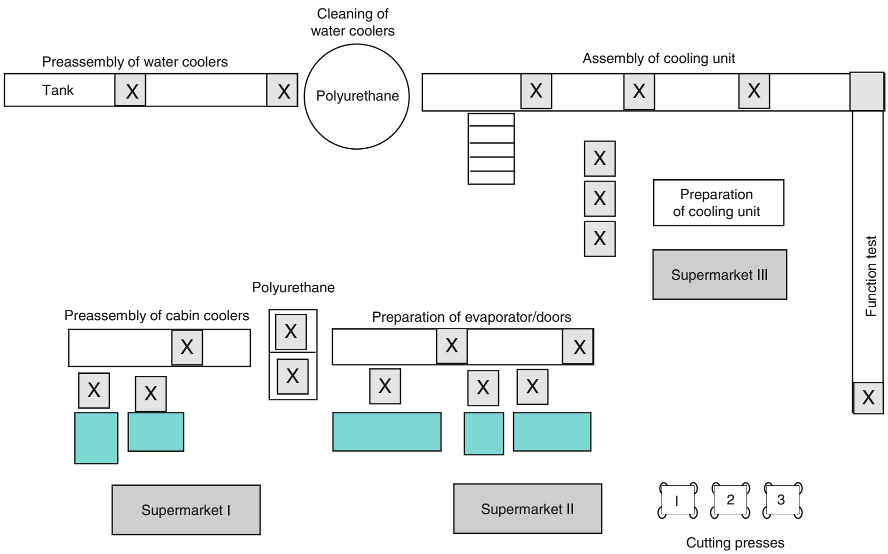

Fig. 8.63 Assembly layout after redesign

assembly of water coolers and cabin coolers a ramp with a lift was designed and constructed so the cabin cooler coming from the polyurethane process may have immediate access to the preparation and assembly line of the cooling unit.

In Fig. 8.64 VSM for water coolers and cabin coolers is illustrated.

The implementation of lean flow in the factory brought many benefits. The main benefit for the owners of the company was that all persons involved in production increased their contribution to the value created. This led to visible production cost reduction and the reduction of the number of errors in production that reduced the cost of quality. Based on the way of calculating standard product cost in an environment of lean flow, the cost of cabin coolers was calculated and results were compared to the cost before the change (Fig. 8.66). In Fig. 8.65 the comparison is graphically illustrated. The difference is more apparent in the biggest cabin models. The way of determining product cost in an environment of lean flow is a management accounting tool. Tying cost accounting to improvements in the production process is strongly recommended. A comparison between the two ways of cost accounting, based on the example of the cabin coolers is presented below. For the calculation of the standard product cost, the following formulas were used.

Conventional flow in costing (8.2)

standard product cost	=	actual cost of work
	+	actual overhead
	+	actual material cost

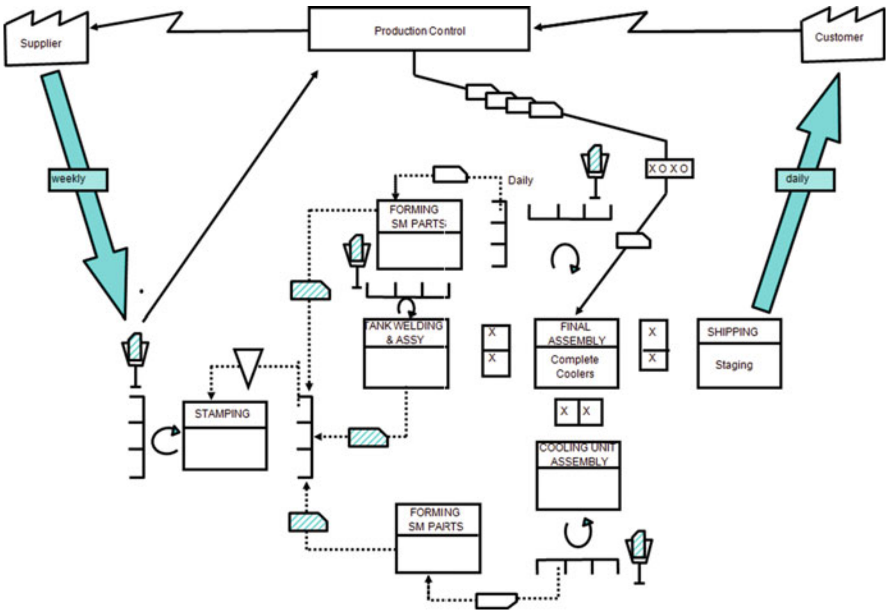

Fig. 8.64 VSM for water coolers and cabin coolers

The company determined the actual cost of work as a percentage (%) of the cost of materials for each product model varying in this case study between 15% and 42% depending on the product model. The actual overhead (OH) is calculated as a percentage of 37% of the cost of materials. As seen by the example, the company takes the cost of material as the basis for calculating the cost of work and the overhead to be absorbed by the product.

Lean flow in costing (8.3)

standard product cost	=	total overhead
	+	standard material cost

Where,

- Total overhead = (HOH/Gross TPct) × TPct + VOH
  1. HOH = OH + cost of work for the quantity Pv of production
     1. OH = > % of COGS (Cost Of Goods Sold)
     2. Cost of work = mixed work hours × average wage
        1. Mixed work hours = Σ (Pvi × AT) i = 1,. . .,n
        2. Average wage = w
  2. Gross TPct = Σ (Pv × TPct) i = 1,. . .,n
  3. TPct per product (from the process map)
  4. Add to Total OH variable overhead (VOH)

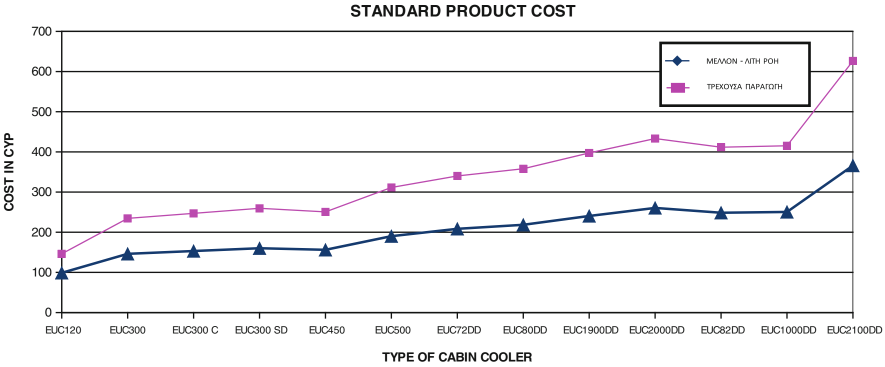

Fig. 8.65 Comparison of the standard product cost before and after the change

no	Products	Total production time (ΣAT) (min)	Total production time (ΣAT) (hours)	Number of resources	TP ct (min)	Gross Tpct (Pv * TPct) (hours)	Mixed production time (Pv * ΣAT) (hours)	Total OH per product (CYP)	Total current OH per product CYP)	Material cost (CYP)	Current production cost (CYP)	Standard product cost in lean flow (CYP)	Standard product cost (CYP)
1	EUC1000DD	223,5	3,7	7,24	180	1.963	2.444	18,5	85,8	232,0	97,4	250,5	415,3
2	EUC2000DD	223,5	3,7	7,24	180	1.376	1.714	18,5	89,5	242,0	101,6	260,5	433,2
3	EUC80DD	223,5	3,7	7,24	180	748	931	18,5	74,0	200,0	84,0	218,5	358,0
4	EUC72DD	223,5	3,7	7,24	180	598	745	18,5	70,3	190,0	79,8	208,5	340,1
5	EUC1900DD	223,5	3,7	7,24	180	299	373	18,5	82,1	222,0	93,2	240,5	397,4
6	EUC82DD	223,5	3,7	7,24	180	150	186	18,5	85,1	230,0	96,6	248,5	411,7
7	EUC120	166	2,8	4,62	135	99	122	13,9	31,5	85,0	29,8	98,9	146,2
8	EUC450	191	3,2	5,76	157	1.575	1.916	16,2	51,8	140,0	58,8	156,2	250,6
9	EUC500	191	3,2	5,76	157	654	796	16,2	64,4	174,0	73,1	190,2	311,5
10	EUC300	181	3,0	5,30	147	176	217	15,1	48,5	131,0	55,0	146,1	234,5
11	EUC300C	181	3,0	5,30	147	86	106	15,1	51,1	138,0	58,0	153,1	247,0
12	EUC300SD	181	3,0	5,30	147	0	0	15,1	53,7	145,0	60,9	160,1	259,6
13	EUC2100SL	193	3,2	5,85	155	388	483	16,0	129,5	350,0	147,0	366,0	626,5
					Total =	8.112	10.031						
					CYP 5,00	/hour	CYP 50.156,58						
					OH as % of COGS		CYP 0,00						
					HOH		CYP 50.156,58						
					HOH/Gross TPct		CYP 6,18						

Fig. 8.66 Calculation of standard product cost

- Standard material cost = cost of material + cost of acquisition[1] + cost of carry[2]

Implementation of the above formulas gave the corresponding results presented in Fig. 8.66 and graphically in Fig. 8.65.

In comparing the results of the two cost accounting methods, a growing difference appears, which progressively increases with the complexity of the product. The reasons for differentiation are the following.

1. The different way of calculating cost of work. In lean flow the cost of work is calculated by the number of working hours multiplied by the average wage.

[1] A business term referring to the expense required to attain materials. In setting a purchasing strategy, a company must decide what the maximum cost of acquisition will be, which effectively determines the highest amount the company is willing to spend to attain each part.

[2] Costs incurred as a result of an inventory position. These costs can include financial costs, such as the interest costs on loans used to purchase materials, and economic costs, such as the opportunity costs associated with taking the initial position.

In non lean production the cost of work is calculated as a percentage (%) of the cost of materials (15–42%), i.e. material is taken as the basis for absorbing work.

2. The different way of calculating overhead. In lean flow, overhead is calculated as a percentage (%) of the cost of goods sold. In non lean flow, overhead is calculated with a factor of 37% of the cost of materials for each product separately, i.e. material is taken as the basis for absorbing overhead.

The choice of material cost as a basis for absorbing cost of work and cost of overhead may be justified, nevertheless it deprives the company of tying cost reduction to improvements on the shop floor. Cost reduction may only occur if material cost is reduced. In a lean environment, cost determination should reflect the lean way of operation. In any case, the two graphs should be overlaid and be reconciled in order to determine a single starting graph. The starting point must be common for both methods of cost accounting. For this purpose the somewhat arbitrary way of setting the overhead factor (37%) as well as the corresponding range of factors for calculating the cost of work (15–42%) should be reviewed. A starting graph is defined as a graph where non lean costing and lean costing graphs coincide or exhibit very small or zero deviation from each other. After the identification of the common point, the official beginning of lean accounting in an environment of lean flow can be declared.

8.6 Furniture

The company Neoset, the leader in furniture manufacturing in Greece, had already made its first steps in lean manufacturing before I got involved, but the results achieved were not satisfactory for the factory manager. Even with the results achieved, the factory manager confirmed that if the company had not implemented lean, the factory would not have survived the difficult economic climate, especially for the furniture industry, which has suffered a strong blow in sales for three consecutive years. The lean application described hereafter concerns lean flow implementation in the kitchen area under my supervision (Margaritis 2008).

What characterized production around 2006 was the huge amount of WIP. There were two reasons for this common phenomenon in many factories. The first reason is linked to the production of big lots in the cutting process lines and the second reason is linked to the fact that the company had a policy of sustaining inventory, a situation that has changed in recent years. For better understanding of the improvements made thereafter, the production process is briefly described. Production activity is executed as follows. Initially, melamine sheets coming from suppliers enter the raw material warehouse. After grouping customer orders on a weekly basis (it changed after the introduction of the Kanban pull mechanism), a cutting order is released to the cutting machine. Following cutting, band adhesion to the sides of the melamine pieces takes place and finally the pieces are drilled by special drilling machines in lots. A flow runner follows the lot from process step to process step up to lot storage in a designated WIP area. The information stored on the runner carries the production routing for each product. The company applies a different inventory policy for every brand name (Fig. 8.67).

Fig. 8.67 WIP between cutting and band adhesion processes

Table 8.11 Factors influencing inventory levels (Margaritis 2008)

Demand	Inventory	WIP
Historical data	Availability	Demand
Forecast	Cost of capital	Many parts
Uncertainty	Cost of elimination	Store space
Bill of materials	Store space	Process cycle time
Many parts	Lead time	
Lage variation	Unpredictable factors	
Low demand in some parts	Delivery time	

Although the company products are highly standardized, with many parts shared among many products, a problem is created mainly from the fact that internal logistics, combined with the machine layout, was highly complex. This event obliged production planning to plan for WIP inventory for the same part in various points on the factory floor.

In the last 2 years (2009 and 2010) in production a great effort was undertaken to reduce the quantity of the parts with the gradual introduction of the pull sequence and the creation of a supermarket, which practically replaced stores. This made the activity of planning to WIP stores based on forecasting redundant. The aim was to change the way of planning for a mix of products to order with respect to those produced to stock. The reasons were obvious. On the one hand, reduction in consumption and on the other, the frequent introduction of new products made this change almost obligatory. Moreover, through the reduction of semi-finished products until their complete avoidance, a high amount of scrap will be eliminated leading to the release of valuable floor space, which the company recognizes as one of the biggest challenges next to the release of important working capital. The factors influencing inventory levels are many and are illustrated in Table 8.11.

The company achieved a major reduction in WIP inventory, leading to the reduction in working capital by €400,000 as declared by the company in two phases. In the first phase, they abolished the parts stores and the related production planning and introduced the pull mechanism Kanban for all parts. Designing and implementing a single supermarket for hosting all parts, the need for separate programming was abandoned as well. This way of managing parts led to an essential cost reduction of internal logistics, due to the fact that there would exist only one place for supplying and consuming parts in predetermined Kanban quantities. In the second phase, the factory layout was reorganized, involving the relocation of machines and work operations to simplify internal logistics and eliminate unnecessary transportation on the production floor. The large reduction in scrap anticipated before the actual implementation was confirmed after reorganization. The two phases are described below.

8.6.1 Kanban Implementation

The scenario studied, designed and implemented was the following:

1. For parts exhibiting high demand and relatively low variation, a supermarket was designed to supply all consuming processes. It was placed close to the assembly-packaging area to supply the lines using the 2-Bin Kanban method based on the daily shipping plan. Replenishment of material in the supermarket is effected through automatically created Kanban cards. When consumed, the Kanban cards return to the cutting process planning department, where they are reproduced based on the shipping program with a planning horizon of 2 weeks, while simultaneously optimizing for cutting melamine sheet for scrap minimization.
2. For parts exhibiting low and sporadic demand, production is effected based on the Min-Max rule. Furthermore, for the parts with almost zero demand, these are produced only to order by a machine cell, called Lean Factory. The machine cell combines three processes, cutting, band attachment and drilling. The cell was specifically designed by the manufacturer in cooperation with the company for producing products in one piece flow fashion.
3. Design and implementation of the mixed model flow line for the assembly of all modules of the kitchen (frames, drawers and angle pieces of furniture) according to order, needed to arrive assembled at the site of the customer for final assembly.
4. During analysis of the kitchen assembly area (Fig. 8.69) and the way the kitchen was produced, it was proposed and implemented the integration of packaging of the modular frames with high demand to the existing manual packaging line for all other modules. Under the current production process the frames concerned were kitted to stock through a highly automatic packaging machine (LCR) in the fashion of mass production. Redesign of the packaging process brought a large increase in the efficiency of the personnel on the one hand. On the other hand, inventory on frames was immensely reduced, because production changed from package to stock, to package to order.

Category		A Value	A Number of parts	B Value	B Number of parts	C Value	C Number of parts	Sums Value	Sums Number of parts	Sums Value %	Sums Number of parts %
C / X	Suitable for Kanban	1.174.932	13	19.618	2	10.665	2	1.205.215	17	19,4%	6,1%
V / Y	Suitable for Kanban	3.492.241	51	500.611	37	140.654	55	4.133.506	143	66,5%	51,3%
S / Z	Suitable for Kanban	204.258	6	165.322	14	31.796	9	401.377	29	6,5%	10,4%
	No	88.680	2	250.181	19	134.334	69	473.194	90	7,6%	32,3%
Sums	Value	4.960.111	72	935.732	72	317.449	135	6.213.292	279	100,0%	
	%	79,8%	25,8%	15,1%	25,8%	5,1%	48,4%	100,0%			

Fig. 8.68 ABC/XYZ parts categorization

Fig. 8.69 Kitchen assembly and packaging before redesign

The LCR has been finally taken out of order and remains to be dismantled and removed from the factory. The cost of dismantling is considerable, and the company is trying to sell it. The area covered by the machine is about 1,000 m^2.

For the analysis of the data and the final categorization, the method ABC/XYZ has been used. The parts categorization is the basis for deciding on inventory policies for the supermarket design. An example of the analysis related to manufactured parts is shown in Fig. 8.68.

In Fig. 8.68, nine parts categories are identified and a different inventory policy may be assigned to each one of them.

For the comparison of the topoi before and after displacement to the lean state, the current (Fig. 8.70) and future (Fig. 8.71) value stream maps for kitchen production have been developed.

Based on the analysis, all kitchen furniture parts were found to be good candidates for the Kanban pull mechanism. Briefly, the kitchen products consist of 436 parts. Some of these parts are used only in certain products with very low

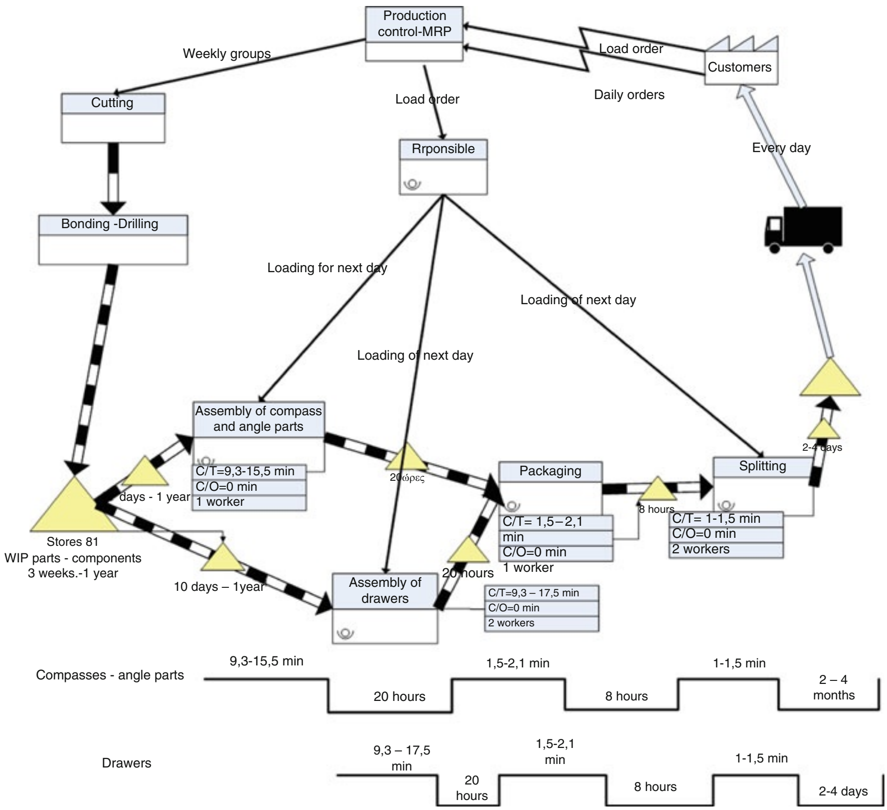

Fig. 8.70 Current VSM for kitchen modules assembly and packaging (Margaritis 2008)

demand. Moreover, it may even be possible that these parts exhibit high demand variation due to spot orders on the products concerned. Following the study and the calculation of the Kanban quantities, three categories of parts have been identified. The first category includes all parts, the demand of which lies between one (1) and fifteen (15) pieces, which continue to be produced to order based on production planning. Alternatively, these parts can be produced in the Lean Factory cell (Fig. 8.74), produced in one piece flow fashion. The second category includes parts the demand of which lies between sixteen (16) and fifty nine (59) pieces and are rounded up to sixty nine (69) which is the minimum lot quantity for cost minimization. For the remaining parts quantity remains unaffected (Fig. 8.72).

The results from implementing and operating the Kanban pull mechanism are:

- Release of about 700 m^2 in the central warehouse
- Drastic simplification of the production planning process – abolition of the use of MRP for WIP inventory planning
- Drastic inventory reduction – about 1 year of WIP inventory was kept in stores, while parts inventory in supermarkets amounts to about 10 days

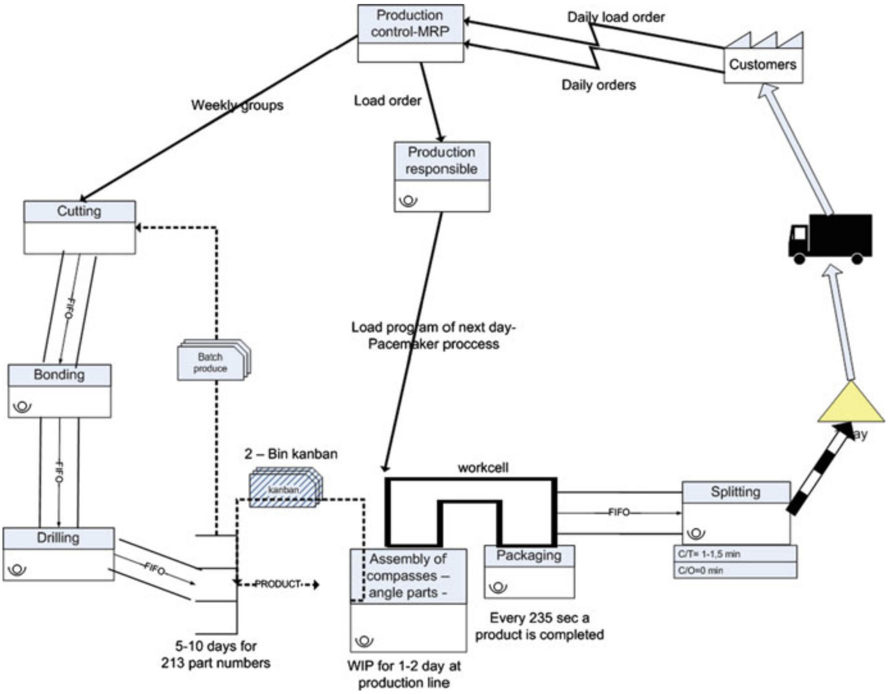

Fig. 8.71 Future VSM for kitchen modules assembly and packaging (Margaritis 2008)

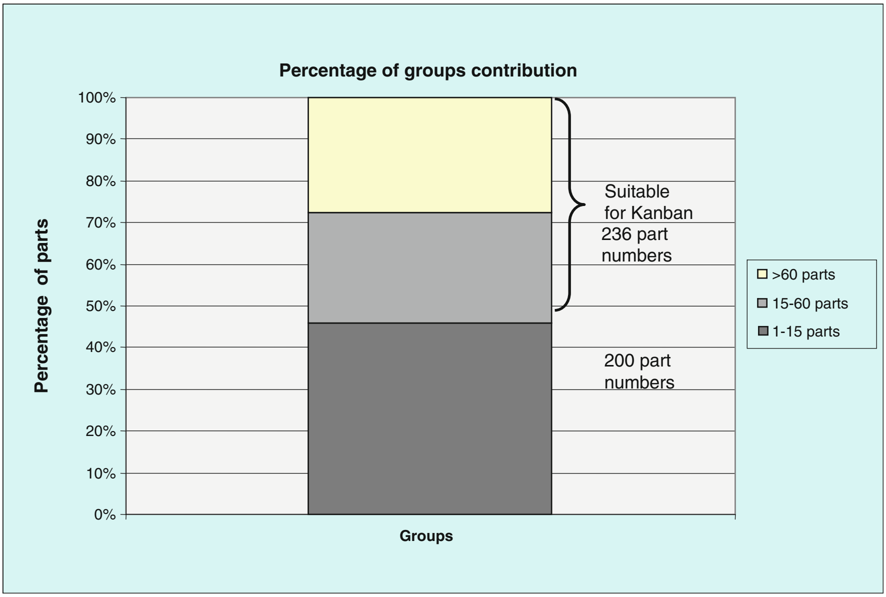

Fig. 8.72 Categorization of parts for kitchen assembly (Margaritis 2008)

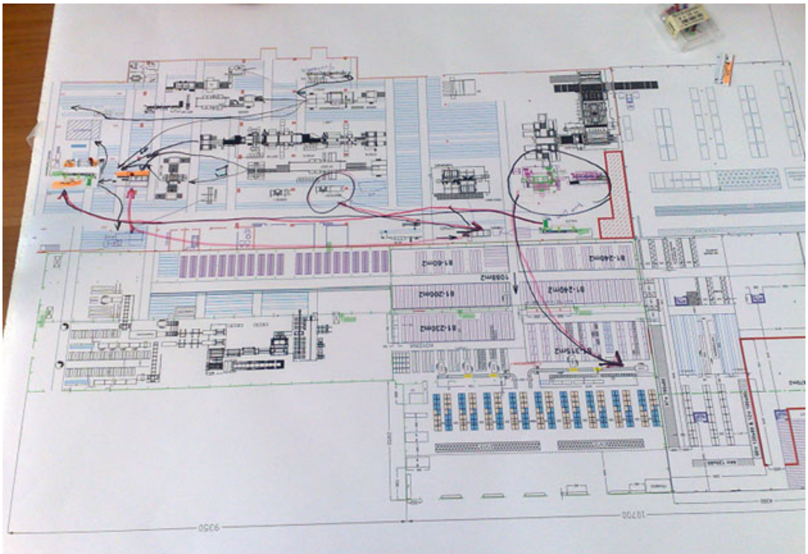

Fig. 8.73 Layout redesign

8.6.2 Layout Redesign

Layout redesign (Fig. 8.73) included machine and operations displacement and was performed to significantly simplify internal logistics. The frequent internal transportation and the remote rearrangement of resources created many problems with respect to quality, next to the loss of factory productivity. The displacement took place stepwise following a detailed lean flow design and implementation plan.

The redesign of the layout was accompanied by the design of a supermarket, its purpose to continually reduce WIP inventories and eliminate the need of MRP for all parts of the Neoset brand (Fig. 8.74).

8.6.3 Epilogue

Neoset has achieved remarkable improvements in performance through implementing lean flow. However, it should be stressed at this point that the company should move ahead with three bold, but necessary steps in the future. The first step is the implementation of lean flow to the supply chain, because the benefits achieved so far on the factory floor would vaporize over time if there is no continuation in pursuing improvements for turning them into cash. The second and serious issue is the adoption of lean accounting methods in order to account for the improvements achieved in the lean environment. The use of EBITDA (earnings before interest, taxes, depreciation, amortization) leads many companies to erroneous conclusions, mainly because it excludes obligations coming from loans for financing working capital needs (Slome 2010). This metric was created for bank executives at the beginning of the 90s in order to be able to evaluate companies for financing purposes and not a metric for management accounting of the company.

Fig. 8.74 Lean factory – one piece flow for produce to order

It is like someone wearing glasses for myopia, although suffering from presbyopia. The third step is the reduction in complexity and interconnections among the various information systems in order to support the lean environment with lean informatics. We bring this issue as an example, which is valid in almost every company we have worked for and with, where the introduction of lean flow methods strengthens the capability of the company to continuously and permanently reduce their needs for information. Information is a treasure only when it adds value. For more details, the interested reader may surf the Internet, looking for information on Lean Manufacturing Execution Systems (LMES). They are strongly recommended for speeding up and boosting lean performance.

8.7 Elevators

It is a dynamic Greek company with a German name. The name comes from Kleemannn Hubtechnik GmbH, a company that in 1857 sold the product rights to a Greek investor, who kept the brand name. The company resides in Kilkis, a city 50 km north of Thessaloniki and covers a space of around 70,000 m^2 of the industrial park. Around 45,000 m^2 belong to production (Fig. 8.75).

Activities of the company include the design, manufacture and distribution of integrated elevator systems. It is one of the largest enterprises of this branch in the European and international markets. They produce more that 12,000 elevator systems yearly or 3% of the world market (2010). Moreover, they enjoy a leading place in the continuously growing Greek market (about 70% in installed units and 47% in value). The company looks at the elevator not only as a product but also as a service, the root cause of which is the force of gravity. Their target is to offer to the market a complete proposition under the brand name of *Complete Lift*. In Fig. 8.76 the Complete Lift components are exhibited.

Fig. 8.75 Kleemann tower built in 2011

Lean flow implementation at Kleemann came at a time when the company was looking at ways to move to the next level of operations excellence. It was the end of 2009, when our proposal for implementing lean flow was accepted and thus the lean journey started. Aiming at rolling out the programme stepwise in all factories, the first step was taken in the hydraulic set and in the cabin assembly simultaneously. The implementation program started with training 35 executives from all the departments in lean flow method, a necessary initial step, followed by an audit of the production activity of the hydraulic set and the cabin assembly in both factories. The purpose of the audit was the evaluation of the benefits that could be achieved. After the presentation of the audit results, the decision was taken to start the lean flow program in the hydraulic tank. The tank line program was driven as a pilot program and was completed successfully. The next phase of the program started with redesigning the cabin assembly as well as redesigning the factory of elevator electronics.

Training in the lean flow method is a prerequisite for successful implementation, which has a mixed character and embodies practice and theory into a lean factory *topos*. During training, the participants work in groups to carry out a short line design and to present the results (Figs. 8.77 and 8.78). Evaluation and constructive criticism of the proposals is applied and moderated by the trainer.

The pillars supporting a successful lean flow implementation are, on the one hand, the commitment of management for supporting the implementation program and on the other hand the capability of the program coordinator in organizing, leading and inspiring the implementation teams operating in the various areas of the

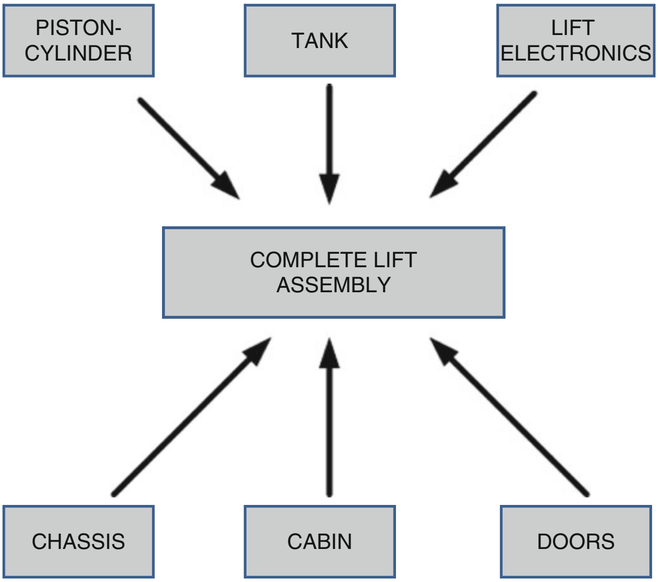

Fig. 8.76 Complete lift product synchronization

Fig. 8.77 Group training in lean flow

factory. In Kleemann these two pillars are strong. The role of external consultants is to provide know-how and experience, evaluate the progress steps during the program and propose adjustments to the implementation plan if needed.

The audit was performed on the followed subsystems.

- Hydraulic tank
- Piston and cylinder
- Chassis for hydraulic and mechanical elevator
- Elevator cabins

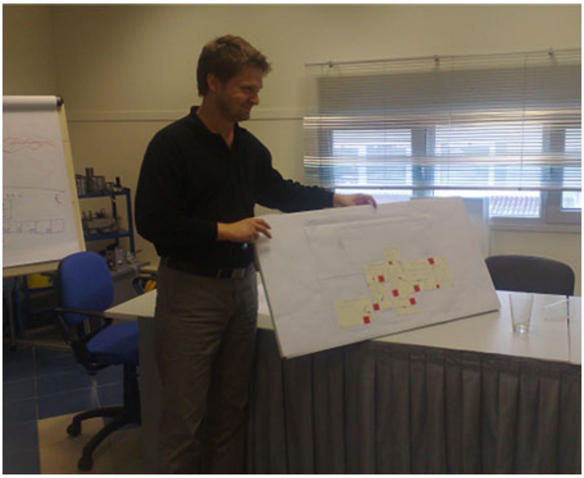

Fig. 8.78 Program coordinator at work

	Improvement area	Before	After	Improvement	Improvement %
1	Inventory reduction (WIP)	2.432.025 €	343.869 €	2.088.156 €	85,86%
2	Working capital reduction	73,29%	50,94%	22,35%	30,49%
3	Effectiveness improvement	87,40 €/hr	109,71 €/hr	22,31 €/hr	25,52%
4	Shoop floor needs reduction	15.205 sqm	6.206 sqm	8.999 sqm	59,18%
5	Shop floer needs reduction per person	101 sqm	41 sqm	59,9942	59,18%
6	Lead time reduction	15 – 20 days	5-10 days	10 days	50,00%
7	Productivity improvement (for equal production volume)	96.082 hrs	83.619 hrs	12462,6	25,00%

Fig. 8.79 Summary of projected improvements

The audit was based on the financial data provided by the company, as well as profound and purposeful observation on the shop floor through interviews with the production and technical department stakeholders. The method applied began with analysis of the current state. From this analysis and experience of similar implementations, a preliminary design, as well as the means of displacement to the future lean state, is proposed accompanied by a parallel projection of possible achievable benefits. In Fig. 8.79 a summary of projected results are presented.

The necessary condition for achieving the results stated above is the commitment of the company to perform significant changes in the layout concerning production resources and to use the method for driving a business strategy. Moreover, the creation and activation of such an activity embraces all the company and demands the direct involvement of all stakeholders in accepting the purpose and the achievement of set targets. It is essential to focus on the benefits of lean displacement, abandoning the focus of old concepts of mere cost and productivity. The following formulas were used for the analysis of financial data:

- Inventory turns (IT) = material cost/inventory cost
- Days of inventory = working days per year/IT
- Working capital = Total inventory + Accounts receivable + Accounts payable
- Value produced = Sales turnover – Material cost

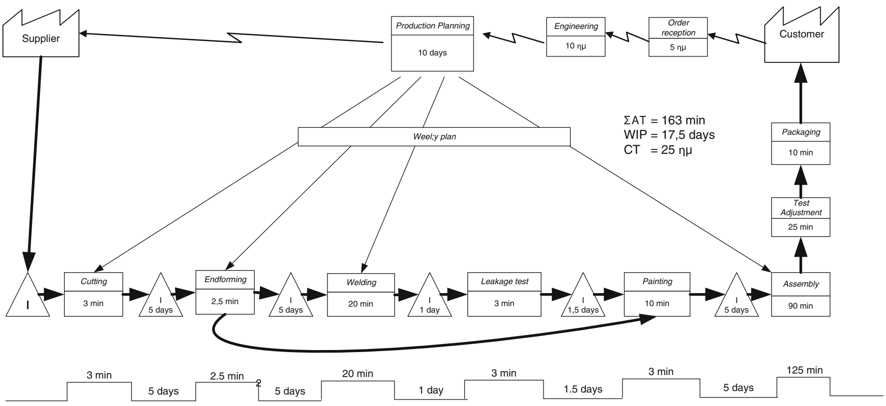

Fig. 8.80 Current value stream map in tank production

- Operations expenses = Cost of work + Overhead expenses
- Net profit = Value produced – Operations expenses
- Current assets = Total inventory + Accounts receivable
- Return on assets = Net profit/Current assets
- Company productivity = Net profit/Work load
- Average cost of work = Sum of wages/Number of hours worked

Note 1: Because accounts receivable and account payable could not be analysed per subsystem, the following allocation was used.
Accounts per subsystem (receivable or payable) = (Sales turnover per subsystem/Total sales turnover) × Sum of accounts

Note 2: Because the total amount of purchased material (raw material and components) could not be analysed per subsystem, the following allocation was performed.
Purchased material per subsystem = (Sales turnover per subsystem/Total sales turnover) × Sum of purchased value

8.7.1 Hydraulic Tank Subsystem

The VSM was performed through direct observation on the shop floor. The representation includes the sequencing of processes and the intermediate buffers, where these exist in the work flow, as well as the estimated average waiting time. The purpose of using the tool is to make those points in the production activities visible during which value is added and activities during which no value is added. The target is the reorganization of production resources to drastically reduce the duration during which the product waits to be processed. In Figs. 8.80 and 8.81, current and future VSM is illustrated respectively.

The tank, the piston, and the chassis constitute the three basic parts of the hydraulic set of the elevator. The cabin and the doors complete the product.

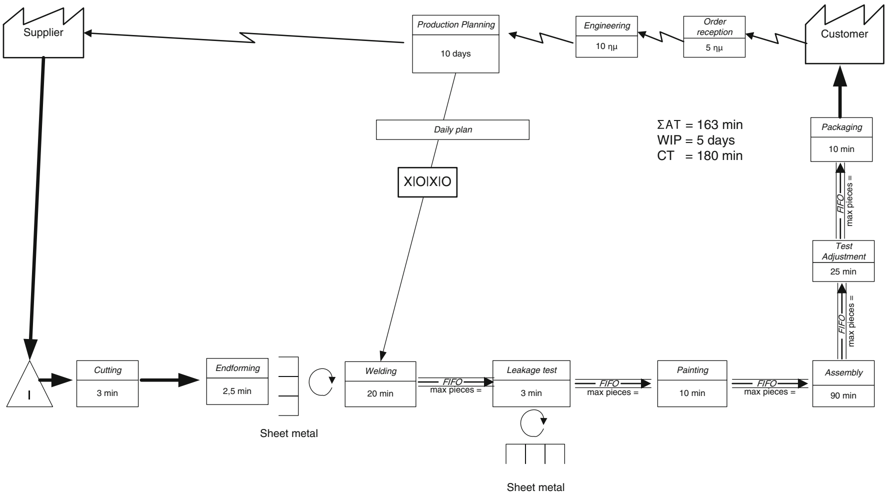

Fig. 8.81 Future value stream map in tank production

Fig. 8.82 Tank production before lean flow

Implementing lean flow in tank production was viewed as a pilot program to show the benefits of implementing lean flow. Concurrently with tank line design, a similar study for the line design of the piston was conducted. The basic elements of the study are presented hereafter. One piece flow in piston manufacturing will demand respective investment in equipment and major changes in the layout. Changes and investments are scheduled for the end of 2012 incorporating the final reorganization of the hydraulic set factory layout. The tank started being produced on a assembly flow line. Before lean flow, the tank was produced in lots of four (4) pieces concurrently by an equal number of workers (Fig. 8.82).

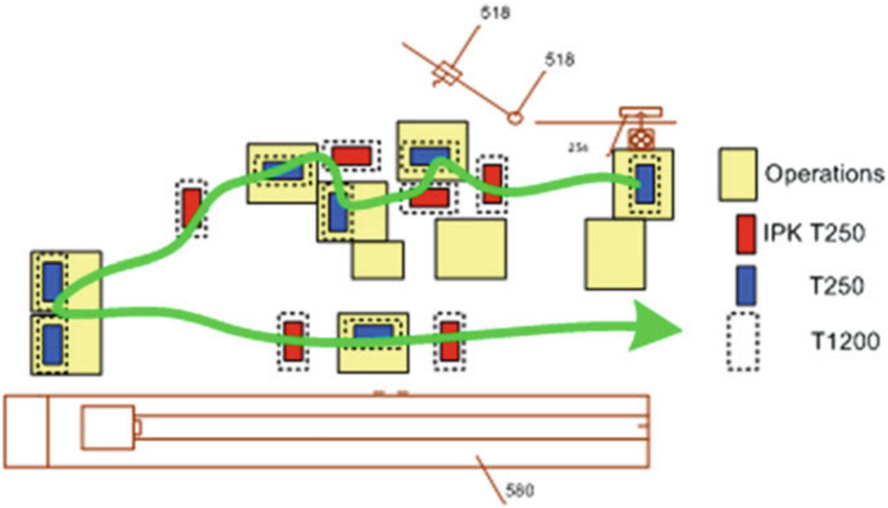

Fig. 8.83 Tank lean flow line layout

Fig. 8.84 Tanks in one piece flow line – work side

Tank line design faithfully followed the steps of lean flow method. The result was the proposal of a line producing in one piece flow fashion. The new layout proposal was discussed thoroughly with the line leader and the workers (Fig. 8.82). The new layout is presented in Fig. 8.83.

The line is illustrated in Figs. 8.84 and 8.85.

Fig. 8.85 Tanks in one piece flow line – supply side

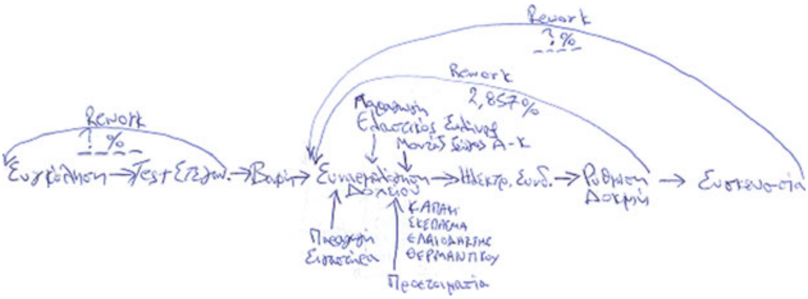

Fig. 8.86 Tank product synchronization flow (in Greek handwriting)

Below, the steps for flow line design are presented. The use of paper and pencil for the development of value stream maps and product synchronization flows is advised (Fig. 8.86), mainly because of frequent changes and improvements made to them before these reach their steady state. These are tools absolutely suited for use on the factory floor. Later, for documentation and presentations purposes the use of presentation software is suggested.

The process map follows, exhibiting forty-four (44) tank models with their respective process times from the corresponding SOE and the Dc per tank model.

From the process map (Fig. 8.87) it can be seen that for a mix of thirty-eight (38) tank models the number of ten (10) operations have been calculated. The calculation of operations was adopted fully for the designed line and realized. For material replenishment, the pull mechanism Kanban has been used. A supermarket has been

H	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450
SHIFTS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ΣDc	38,70	40,28	40,28	39,72	39,72	40,28	40,91	28,36	39,89	40,30	40,30	40,30	40,30	40,30	40,30	40,30
Atw	6,08	39,29	42,54	8,21	3,05	12,45	7,81	2,14	8,70	1,73	7,68	18,83	59,93	17,40	20,05	10,86
TAKT	11,6	11,2	11,2	11,3	11,3	11,2	11,0	15,9	11,3	11,2	11,2	11,2	11,2	11,2	11,2	11,2
#RES	0,5	3,5	3,8	0,7	0,3	1,1	0,7	0,1	0,8	0,2	0,7	1,7	5,4	1,6	1,8	1,0

Fig. 8.87 Tank process map

Fig. 8.88 Area before supermarket operation

Fig. 8.89 Area after supermarket operation

designed and installed near to the tank flow line. Figures 8.88 and 8.89 show how the space was before and after supermarket operation respectively.

Assembly line operation in one piece flow made possible the application of one piece flow to the welding operation as well. The tanks were painted at the central

Table 8.12 Program milestones (Mitsas)

Start of the project	13/01/2010
Operation of the Kanban system in tank assembly	12/10/2010
Heijunka sequencing with smoothing based on quantity and mix	15/10/2010
Lean flow line live operation of the tank assembly	06/12/2010
Kanban pull mechanism operation in the piston assembly	15/02/2011
Relocation of the silencers	15/03/2011
Tank welding based upon daily production plan (JIT)	23/05/2011

Table 8.13 Program status (Mitsas)

Area	Implementation	Status
Tank assembly	One piece flow – JIT	Implemented
	Kanban pull mechanism	Implemented
Tank welding	JIT	Implemented
	Kanban pull mechanism	Under implementation
Pistons production	One piece flow	Not yet impelemented
	Kanban pull mechanism	Implemented

painting booth half a day before the tanks are needed by the assembly line. The milestones, the programme status and results of the pilot program evaluated by the program coordinator, are summarized in Tables 8.12, 8.13 and 8.14 respectively.

8.7.1.1 Further Improvements

- Smoothing of orders in painting line for multicolour tank applications and in-time updating of the painting process
- Production orders with *on order* materials are planned only if these materials have been transferred to the line (no missing components event)
- So called express orders are not sensed as such from production, because they are absorbed during the production planning phase. Changes in planning order are not visible at the line
- Issue requests to stores were eliminated, the Kanban cards function as requests
- No ERP or other software application registrations for intra-transportation are needed, the integrated bar code of the Kanban card is used to automatically register the pull sequence of material
- About 100 m^2 of additional floor space has been liberated from the transfer of the silencers assembly to the tank assembly line. The line was around 300 m away from the point of consumption at the tank assembly line

8.7.1.2 Problems That Delayed Implementation

- No experience in applying lean manufacturing (learning curve)
- Significant delays due to resource involvement in other programs

Table 8.14 Program targets and degree of fulfilment (Mitsas)

Improvement area	Before	Target (%)	After	Improvement (%)	Target achievenet (%)
Time reduction					
Start-end time of tank assembly	4 h	50	2.5	37.5	75
Inventory reduction at tank production					
Raw materials ([a])	1,387	68	1,803	−8	−12
Work in process	61,824	37	50,584	18	49
Finished products	323,296	76	229,977	32	42
(Finshed products in production)	(14,931)	76	0,941	94	124
Semifinished	98,228	37	95,888	2.4	6.5
(Semifinished in production)	(83,932)	(37)	(79,253)	(5.6)	(15)
Total inventory ([a])	1,878	67	1,879	0	0
Space reduction ([b])					
Tank assembly	525 m^2	55	417 m^2	21	38
Tank welding (+ silencers)	470 m^2	55	470 m^2	0	0
Total tank line (+ silencers)	995 m^2	55	887 m^2	11	20

[a]The increased values are due to the following reasons:
There is increased inventory in six blocks valves, value of surplus inventory around €60,000, due to commercial agreement
In the inventory management data, the inventory existing in the tanks supermarket is not taken into account. Value estimation of the total surplus inventory is approximately €150,000
For both issues the responsible persons have been notified. If these two factors could be eliminated, it is estimated that the improvement percentage for raw material and parts would be 6.8% and for the total inventory 11.2%
However, in order to achieve significant reductions in the levels of the inventory of raw material and parts the application of lean methods related to inventory management and in general related to issues of external supply chain should be intensified (i.e. implementation of the full Kanban pull mechanism towards the suppliers)
[b]The reduction in shop floor surface needs in the assembly area was limited due to the existence of the test cabin

- Sourcing and purchase of necessary *lean* equipment
- Delays in the delivery of the necessary equipment
- Gaps were located to a greater extent than anticipated and were corrected, e.g. out of date technical specifications, codification of parts, etc.

8.7.1.3 Conclusions from the Pilot Program

The effectiveness of the adoption of lean philosophy and the application of tools and methods has been confirmed in the production reality from many companies worldwide. From a pilot lean implementation, what is essentially requested is the

Fig. 8.90 Piston subsystem production

confirmation, if the philosophy fits the company, if the company is capable of implementing, and if it has measurable short-term benefits further and beyond the expected midterm benefits. The effort of the pilot implementation showed, that despite the significant delays with respect to the original plan, the company was in the position to implement lean flow in the factory. Moreover, it was discovered that the planning of the next steps must take into account the availability of the necessary resources. Finally, the displacement of key performance indicators achieved in this short time of the pilot operation, assures that implementation of lean flow can have immediate results, although the real benefit of the philosophy is the achievement of midterm to long-term and sustainable benefits. Further and beyond accountable benefits, also the impacts should be stressed in the way the company operates and which are impressive. Indicatively the following issues would not have been resolved without the implementation of lean philosophy:

1. Feasibility study for drastically reducing valve variety
2. Definition of selection rules for selecting pump types
3. Development of software application for smoothing production (Heijunka)
4. Review and correction of tank specifications
5. Define packaging quantities and the packaging way of various suppliers

8.7.2 Piston Subsystem

The pair piston-cylinder subsystem is called piston subsystem for simplification purposes (Fig. 8.90). In piston manufacturing, although the value stream is simple as illustrated in Fig. 8.92, current for the subsystem piston-cylinder real flow in manufacturing is sufficiently complex as presented in Fig. 8.91.

This is due to the fact that the current layout does not support one piece flow operation. Moreover, there are machines that are needed in more than one place in

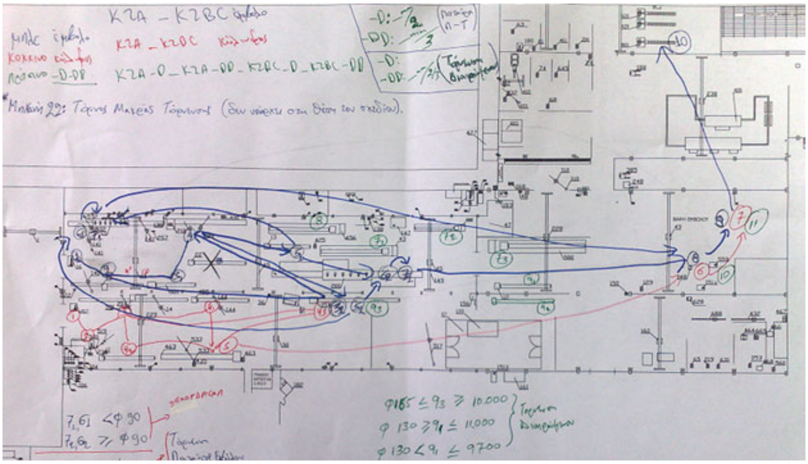

Fig. 8.91 Piston manufacturing flow (Chatzopoulos 2010)

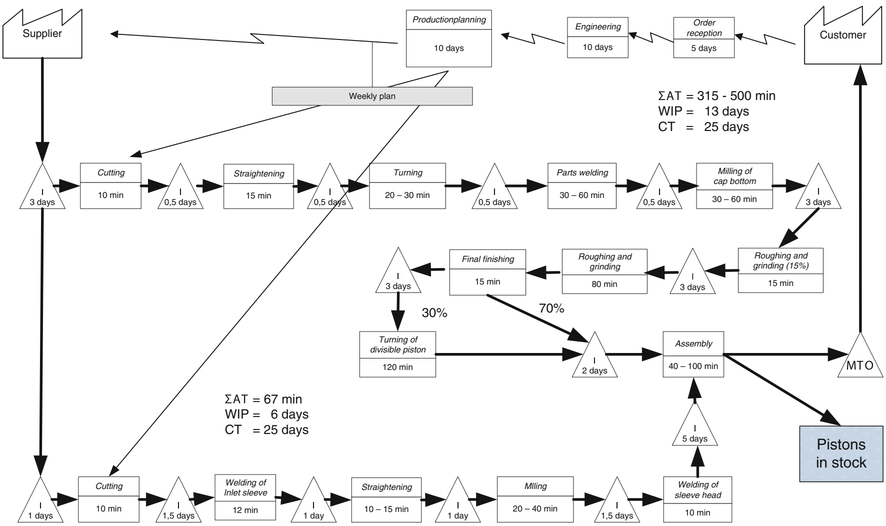

Fig. 8.92 Current value stream map for the subsystem piston-cylinder

the process flow and consequently there is often movements against the flow, interrupting flow continuity. Production operates in a job shop fashion. Furthermore, the setups are not negligible and hamper production in achieving TAKT.

The lean line design study has been completed proposing a new layout and the replacement of three machines. The realization of the design study has been postponed until the final layout of the factory is developed. In Fig. 8.92 the current VSM and in Fig. 8.93 the future VSM is illustrated respectively.

There are 5 types and 89 part numbers of pistons and cylinders respectively, which with variations reach 103 part numbers. It is significant to achieve one piece

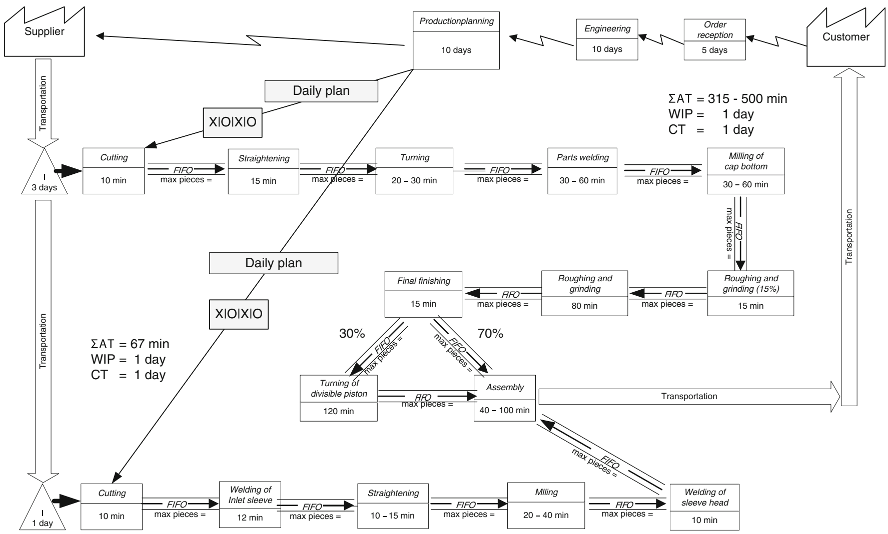

Fig. 8.93 Future value stream map of the subsystem piston-cylinder

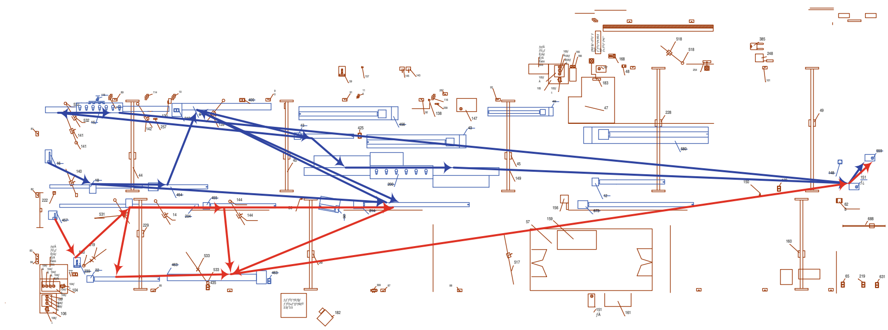

Fig. 8.94 Lean flow layout for cylinder manufacturing (Chatzopoulos)

flow and a reduction in lead times due to reduced intermediate inventory in production with the respective reduction in finished products inventory. The study has proposed alternative layouts, of which the most prevailing is presented in Fig. 8.94 using the existing machine equipment. The bold line illustrates piston flow, while the light line cylinder flow.

The resource calculation taken from the process map shows that for 40 pistons and its corresponding 40 cylinders, 43 work operations are needed for a production shift of 450 min. In piston manufacturing, a supermarket is already in operation using Kanban pull sequence for materials produced in the machining area using the principle of 2-bin, single card for covering 20 days of inventory. A dual card Kanban will be installed when the new factory layout and one piece flow in pistons become a reality.

The financial improvements projected to be achieved on the basis of the audit performed at the subsystems of pistons, the tanks as well as the chassis and the cabins before and after the displacement, is shown for better comparison in Figs. 8.95 and 8.96 respectively. It is estimated that through the implementation of the method, intermediate inventories will be reduced to 5 days, the final products inventories also to 5 days and raw material inventories to 20 days.

8.7.3 Subsystems of Hydraulic and Mechanical Chassis

The subsystems of hydraulic and mechanical chassis are the heart of the elevator because they are the carrying elements of the cabin. The word hydraulic means that the root cause of the movement is a force that is exerted by a piston, powered by a hydraulic pump. The mechanical chassis on the other hand, is moved by an electric motor and pulls the chassis by means of a winch instead of pushing it by means of a piston as happens in the case of the hydraulic chassis. The two types of chassis take up the lion's share on the workload including both manual and machine work. The production processes are all suitable for metal construction in different forms and dimensions. For this reason they occupy the largest portion of the shop floor.

The need for occupying excessive space and consuming time stems from the way contemporary manufacturing produces the parts. Although the elevator is produced to customer order, the parts are produced in lots for filling up WIP stores based on forecast (Fig. 8.97). The segments of the chassis (hydraulic or mechanical) are to a great extent standardized so that lot production may be a logical consequence in organizing and executing production. The basic reason why the company has decided to implement lean flow in this area is mainly to drastically reduce the volume (in space and quantity) of the chassis parts while at the same time a large portion of the shop floor and working capital will be released. The release of shop floor surface may lead to the displacement and housing of the cabin assembly in the same building with the chassis. Today the cabins occupy a separate building approximately 200 m away from the hydraulic and mechanical set factory. The synergies in mechanical equipment and human resources are obvious. In Figs. 8.98 and 8.99 the value stream maps of the current and future state for chassis (hydraulic and mechanical) manufacturing are illustrated respectively.

From Fig. 8.98 it is obvious that WIP covers 28 and 35 days of production for the hydraulic chassis and the mechanical chassis respectively. The initial target of designing a supermarket is the reduction to 10 days with a further reduction to 5 days once production is stabilized.

In Fig. 8.99 a mix of the two assembly lines is shown. This is possible because during the initial analysis phase, similarity of processes was detected. Differences with regard to manufacturing times and materials lead to different processing paths. Regarding materials, very low commonality exists between the two chassis and for this reason the final mix of the two lines must be agile. These necessary decisions will be taken during the design phase. Moreover, an issue that should be faced during design is the preparation process of the chassis, together with the accessories for customer order delivery. The way in which this work is performed today is

Benefit Area		6 months 2009	PISTON-CYLINDER		TANK		HYDRAULIC CHASSIS		MECHANICAL CHASSIS		CABINS	
COGS		20.260.227 €		2.649.927 €		4.024.392 €		3.093.195 €		1.191.552 €		3.248.819 €
Material (MCOGS)	66,22%	13.416.977 €	54,47%	1.443.315 €	84,11%	3.384.730 €	59,08%	1.827.327 €	59,35%	707.127 €	52,42%	1.703.052 €
Labour	20,59%	4.170.744 €	28,93%	766.521 €	9,21%	370.654 €	27,16%	840.185 €	23,72%	282.608 €	30,46%	989.530 €
Overhead (manufacturing overhead)	13,19%	2.672.517 €	16,61%	440.091 €	6,68%	269.008 €	13,76%	425.683 €	16,94%	201.818 €	17,12%	556.238 €
Total	100%	**20.260.227 €**		**2.649.927 €**		**4.024.392 €**		**3.093.195 €**		**1.191.552 €**		**3.248.819 €**
Inventory		100,00%		14,6%		26,3%		14,7%		4,1%		14,0%
Raw material	1,7 turns	7.927.298 €		1.161.008 €		2.087.076 €		1.168.809 €		327.885 €		1.113.330 €
WIP	5 turns	2.676.489 €		390.426 €		223.660 €		1.164.578 €		353.198 €		226.391 €
FGI	4 turns	3.126.502 €		912.315 €		585.236 €		426.567 €		133.005 €		333.155 €
Total Inventory (only material)	1,0 turns	13.730.289 €		2.463.750 €		2.895.973 €		2.759.954 €		814.089 €		1.672.877 €
Inventory Carrying Costs	6%	823.817 €		147.825 €		173.758 €		165.597 €		48.845 €		100.373 €
Inventory turns												
Raw material and components	1,7 turns	70,9 days	1,2 turns	96,5 days	1,6 turns	74,0 days	1,6 turns	76,8 days	2,2 turns	55,6 days	1,5 turns	78,4 days
Work in process (WIP)	5 turns	23,9 days	4 turns	32,5 days	15 turns	7,9 days	2 turns	76,5 days	2 turns	59,9 days	8 turns	16,0 days
Finished products	4 turns	28,0 days	3 turns	41,3 days	6 turns	20,7 days	7 turns	16,5 days	5 turns	22,6 days	5 turns	23,5 days
Working Capital												
Sales		28.658.244 €		4.197.199 €		7.545.060		4.225.401 €		1.185.353 €		4.024.838 €
COGS (Material, Labour, OH)		20.260.227 €		2.649.927 €		4.024.392		3.093.195 €		1.191.552 €		3.248.819 €
Accounts Receivable (A/R)		62.312.654 €		9.126.121 €		16.405.497		9.187.442 €		2.577.355 €		8.751.350 €
Account Payable (A/P)		5.754.310 €		842.759 €		1.514.978		848.421 €		238.008 €		808.150 €
Total Inventory		13.730.289 €		2.463.750 €		2.895.973		2.759.954 €		814.089 €		1.672.877 €
Working Capital		42.009.461 €		6.605.431 €		10.341.232 €		6.929.464 €		1.983.763 €		5.644.477 €
Percentage of Working Capital/$ of Sales		73%		79%		69%		82%		84%		70%
Working Capital reduction												
Return on Assets (ROA)												
Throughput		15.241.267 €		2.753.884 €		4.160.330 €		2.398.074 €		478.225 €		2.321.786 €
Operating Expenses (OE)		6.843.260 €		1.206.612 €		639.661 €		1.265.868 €		484.425 €		1.545.767 €
Net Profit (Throughput-OE)		8.398.006 €		1.547.272 €		3.520.668 €		1.132.207 €		-6.199 €		776.019 €
Current Assets (Total Inventory + A/R)		76.042.943 €		11.589.871 €		19.301.469 €		11.947.396 €		3.391.445 €		10.424.227 €
ROA = NP/Current Assets		11%		13%		18%		9%		0%		7%
Company Productivity (Net Profit/effort)		87,40 €/hr		46,84 €/hr		199,82 €/hr		47,05 €/hr		-0,67 €/hr		10,05 €/hr
Floorspace												
Production Area		11.230 sqm		2.843 sqm		900 sqm		987 sqm		356 sqm		5500
Store Area		3.975 sqm		600 sqm		168 sqm		1.041 sqm		640 sqm		1240
Total Floorspace		15.235 sqm		3.443 sqm		1.068 sqm		2.028 sqm		996 sqm		6.740 sqm
Ratio Stores floor to production floor		35,40%		21,10%		18,71%		105,49%		179,53%		22,55%
Efficiency												
Working days – six months		120		120		120		120		120		120
Number of employees (all organisations)		150		39		19		27		9		36
Number of working hours – six months		96.082 hrs		33.030 hrs		17.620 hrs		24.065 hrs		9.244 hrs		77.245 hrs
Total wages		1.305.030 hrs		488.507 €		230.822 €		309.692 €		122.253 €		966.093 €
Average cost of work		13,58 €/hr		14,79 €		13,10 €		12,87 €		13,22 €		12,51 €
Sales € per person		191.055 €		107.620 €		397.108 €		156.496 €		131.705 €		111.801 €
Average surface per person		101 sqm		88 sqm		56 sqm		75 sqm		111 sqm		187 sqm

Fig. 8.95 Financial data before lean displacement – first half year 2009

Benefit Area		6 months 2009	PISTON-CYLINDER		TANK		HYDRAULIC CHASSIS		MECHANICAL CHASSIS			CABINS
COGS		23.509.046 €		2.649.927 €		4.024.392		3.093.195		1.191.552		3.248.819
Material (MCOGS)	64,32%	15.120.029 €	54,47%	1.443.315 €	84,11%	3.384.730	59,08%	1.827.327	59,35%	707.127	52,42%	1.703.052
Labour	21,95%	5.160.274 €	28,93%	766.521 €	9,21%	370.654	27,16%	840.185	23,72%	282.608	30,46%	989.530
Overhead (manufacturing overhead)	13,73%	3.228.754 €	16,61%	440.091 €	6,68%	269.008	13,76%	425.683	16,94%	201.818	17,12%	556.238
Total	100%	**23.509.046 €**		**2.649.927 €**		**4.024.392**		**3.093.195**		**1.191.552**		**3.248.819**
Inventory				12,8%		23,1%		12,9%		3,6%		12,3%
Raw material	3,9 turns	3.918.174 €		441.654 €		670.732 €		515.532 €		198.592 €		541.470 €
WIP	24 turns	630.001 €		60.138 €		141.030 €		76.139 €		29.464 €		28.384 €
FGI	24 turns	630.001 €		60.138 €		141.030 €		76.139 €		29.464 €		28.384 €
Total Inventory (only material)	3,0 turns	5.021.442 €		561.931 €		952.793 €		667.810 €		257.519 €		598.238 €
Inventory Carrying Costs	6%	301.287 €		33.716 €		57.168 €		40.069 €		15.451 €		35.894 €
Inventory turns												
Raw material and components	3,9 turns	20,0 days	3,3 turns	20,0 days	5,0 turns	20,0 days	3,5 turns	20,0 days	3,6 turns	20,0 days	3,1 turns	20,0 days
Work in process (WIP)	24 turns	5,0 days	24 turns	5,0 days	24 turns	5,0 days	24 turns	5,0 days	24 turns	5,0 days	60 turns	2,0 days
Finished products	24 turns	5,0 days	44 turns	5,0 days	24 turns	5,0 days	41 turns	5,0 days	24 turns	5,0 days	60 turns	2,0 days
Working Capital												
Sales		32.683.081 €		4.197.199 €		7.545.060 €		4.225.401 €		1.185.353 €		4.024.838 €
COGS (Material, Labour, OH)		23.509.046 €		2.649.927 €		4.024.392 €		3.093.195 €		1.191.552 €		3.248.819 €
Accounts Receivable (A/R)		62.312.654 €		8.002.263 €		14.385.202 €		8.056.032 €		2.259.961 €		7.673.644 €
Account Payable (A/P)		5.754.310 €		738.975 €		1.328.413 €		743.941 €		208.698 €		708.629 €
Total Inventory		5.021.442 €		561.931 €		952.793 €		667.810 €		257.519 €		598.238 €
Working Capital		33.300.614 €		4.193.575 €		7.481.187 €		4.323.856 €		1.283.151 €		4.080.746 €
Percentage of Working Capital/$ of Sales		51%		50%		50%		51%		54%		51%
Working Capital reduction		22%		29%		32%		33%		23%		19%
Return on Assets (ROA)												
Throughput		17.563.052 €		2.753.884 €		4.160.330 €		2.398.074 €		478.226 €		2.321.786 €
Operating Expenses (OE)		8.389.028 €		1.206.612 €		639.661 €		1.265.868 €		484.425 €		1.545.767 €
Net Profit (Throughput-OE)		9.174.024 €		1.547.272 €		3.520.668 €		1.132.207 €		-6.199 €		776.019 €
Current Assets (Total Inventory + A/R)		67.334.096 €		8.564.194 €		15.337.995 €		8.723.842 €		2.517.480 €		8.271.882 €
ROA = NP/Current Assets		14%		18%		23%		13%		0%		9%
Company Productivity (Net Profit/effort)		109,71 €/hr		46,84 €/hr		199,82 €/hr		47,05 €/hr		-0,67 €/hr		10,05 €/hr
Floorspace	Μείωση κατά											
Production Area	50,00%	5.443 sqm	1.422 sqm	2.843 sqm	450 sqm	900 sqm	493 sqm	987 sqm	178 sqm	356 sqm	2.750 sqm	5500
Store Area	80,00%	764 sqm	120 sqm	600 sqm	34 sqm	168 sqm	208 sqm	1.041 sqm	128 sqm	640 sqm	248 sqm	1240
Total Floorspace		6.206 sqm	1.542 sqm	3.443 sqm	484 sqm	1.068 sqm	702 sqm	2.028 sqm	306 sqm	996 sqm	2.998 sqm	6.740 sqm
Ratio Stores floor to production floor		14,03%	8,44%	21,10%	7,48%	18,71%	42,20%	105,49%	71,97%	179,93%	9,02%	22,55%
Efficiency												
Working days – six months		120		120		120		120		120		120
Number of employees (all organisations)		150		35		14		30		9		58
Number of working hours – six months	25,00%	83.619 hrs	24.773 hrs	33.030 hrs	13.215 hrs	17.620 hrs	18.048 hrs	24.065 hrs	6.933 hrs	9.244 hrs	57.934 hrs	77.245 hrs
Total wages	25,00%	1.172.037 €	366.380 €	488.507 €	173.116 €	230.822 €	232.269 €	309.692 €	91.687 €	122.250 €	724.570 €	966.093 €
Average cost of work		14,02 €		14,79 €		13,10 €		12,87 €		13,22 €		12,51 €
			7,5	465.879 €	7,5	165.065 €	7,5	347.468 €	7,5	107.121,61 €	7,5	652.860 €
Sales € per person		217.887 €		119.920 €		538.933 €		140.847 €		131.706 €		69.394 €
Average surface per person		41 sqm	44 sqm	98 sqm	35 sqm	76 sqm	23 sqm	68 sqm	34 sqm	111 sqm	52 sqm	116 sqm

Fig. 8.96 Financial data projected after lean displacement

Fig. 8.97 Partial view of WIP stores area in chassis manufacturing

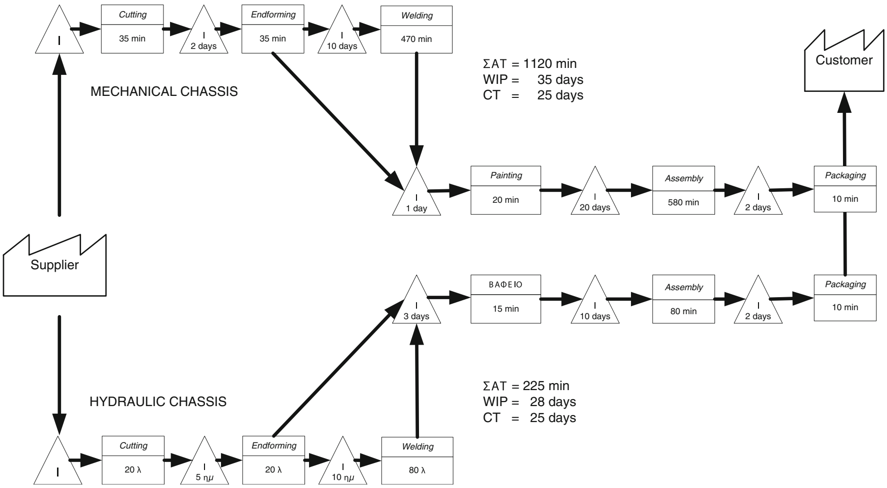

Fig. 8.98 Chassis value stream map – current state

similar to picking from stores shelves. The responsible material handler collects all modules and parts from WIP stores shelves in order to place them on wooden pallets, as shown in Fig. 8.100 preparing kits. The proposal is to design an assembly line for the preparation in flow of all kits based on customer order.

The loading site will be reorganized and operated only as staging and loading area. Today it functions partially as stock area for storing finished pistons inventory.

8.7.4 Cabin Subsystem

In the cabin manufacturing factory, the design activity was concentrated on cabin assembly as the point closest to the customer. Prior to customer order delivery,

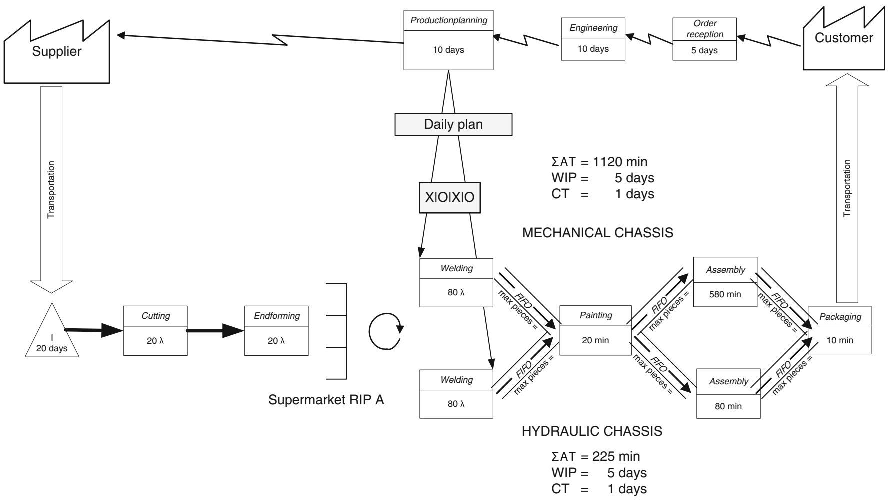

Fig. 8.99 Chassis value stream map – future state

Fig. 8.100 Kits preparation

cabins are assembled temporarily to ensure that the product is produced according to customer specifications. As possible improvement caused by implementing lean flow, the elimination of cabin final assembly and dis-assembly in the factory will be examined. Currently quality assurance places a veto on that perspective, because a number of parts are designed and manufactured based on customer specifications. One more reason is that some work concerning the final behaviour of parts at the site of use of the cabin is actually performed during the assembly process. The main parts of the cabin are metal parts constructed of formed metal sheet. Some parts related to interior finishing of the cabin can be manufactured only after the cabin is assembled. Currently, cabin production planning schedules all metal parts production and their transportation to a WIP storage area, before the order is given

Fig. 8.101 Cabin parts are placed on special cart before assembly (Danaktsi 2010)

for the final move to the assembly area in order to assemble the cabin. The actual way of assembling the cabin is similar to the way tanks are assembled today, namely parts of the cabin are transferred by a suitable vehicle to the assembly site and the cabin starts to be constructed by an assembly team in a fixed place (Fig. 8.101).

The cabins, in which the study was conducted, are made 100% to order. The customer initially gets in touch with a sales engineer. When the procedure of order reception is complete, the design department takes over. The study for the construction of the cabin takes up 1 day. After that, production of the components begins. The main parts of the cabin are constructed of sheet metal, cut and properly configured. At the carpentry sector, the internal finishing of the cabin is constructed. After completion, the main parts are placed on a cart (Fig. 8.101). Each filled cart is placed in a specific area until the instruction for its transfer to the assembly area is given. When this instruction is given, the cart corresponding to a specific order, is driven to the assembly station and one of the assembly teams takes over. During the assembly process, the placing and the assembly of the main parts of the cabin takes place. All cabins, regardless of their type, are managed in the same way. First, the platform, a robust structure at the bottom section of the cabin that bears the main loads, is placed at the special installation in the assembly area and the sides, the main casing of the cabin, are placed on the platform. Next, the placement of the roof, a robust structure that joins the sides, and the component which sets the height of the door and protects the customer from contacting the door's mechanism. The assembly of these specific parts of the cabin is temporary and done with special tools in order for the necessary work and controls to take place (Fig. 8.102). The final and permanent assembly is made at the customer's site.

Fig. 8.102 Work site for cabin assembly (Danaktsi 2010)

The cabin remains assembled until all necessary work takes place. During assembly, the opening of the necessary holes for permanent assembly and the placement of the rest of the cabin components takes place according to the type of the cabin. Furthermore, all the necessary procedures required for the proper configuration of the cabin take place, which might differ depending on the type of cabin or the order.

When all the events are completed, the cabin is disassembled. The removed parts are placed in a cart coloured differently from the previous one. The specific cart that corresponds to an order, once disassembly is completed, is placed in the specifically designated area where the carts remain until a signal is released to be transferred to the packaging area. Before packaging, the components of the cabin not included in the assembly (mirror, floor etc.) are placed in the corresponding order cart. The only exception is the roof, which is not placed immediately on the cart. The roof, after being removed from the cabin, is driven to the ceiling station, where some work is done, in order to be assembled with the ceiling. After that, the necessary electrical connections in the roof take place and all the work needed for the cabin lighting. Each cart is driven to the packaging area when the instruction is given. At the packaging station the wooden crate is also ready to accept the cabin for finalizing packaging (Fig. 8.103). The parts of the cabin are always placed in the same way in the wooden crate. The wooden crate, after being checked for completeness, closes in a way that protects the components of the cabin from the danger of being harmed. When the packaging is completed, the packaged cabin is taken to the consignment area, where it stays until it is loaded and sent to the customer.

The company had two immediate goals concerning component synchronization. The first goal is that after the completion of the assembly of the sides, the construction of the rest of the components needed for assembly should also be completed. The second goal is that, after the end of the disassembly, the rest of the parts of the cabin should also be ready. The application of lean manufacturing will

Fig. 8.103 Wait site for cabin packaging (Danaktsi 2010)

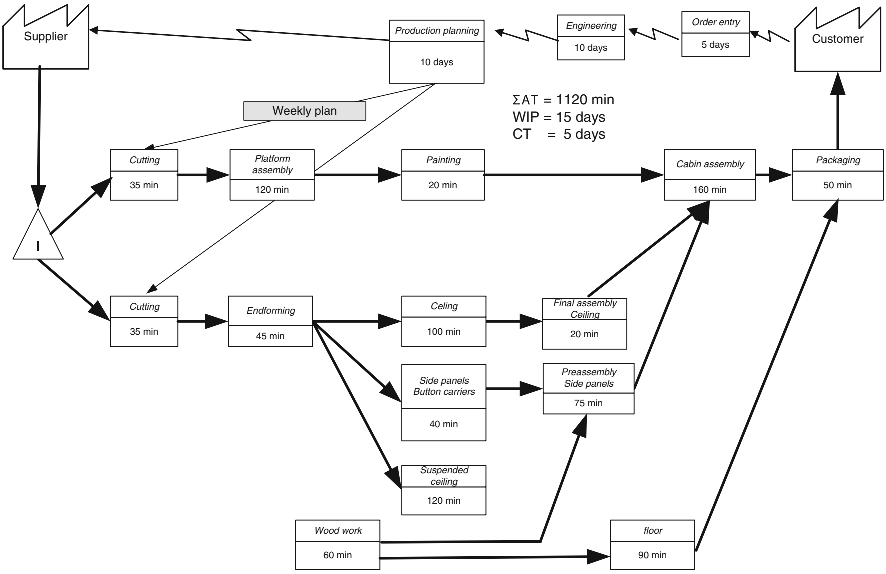

Fig. 8.104 Value stream map for cabin manufacturing – current state

have as an immediate result the synchronization of the products and thus, it will lead to the achievement of these goals.

In Fig. 8.104, the current state of the value stream for cabin manufacturing and assembly is presented.

The product synchronization flow for the cabin illustrated in Fig. 8.105, shows roughly how resources should be laid out for implementing lean flow in manufacturing, a piece of information not obvious from the value stream map. In addition, the value stream map tool does not explain how the displacement from current to future state of lean flow should take place. Product synchronization flow for the selected products of the target area should be created as the first step of the

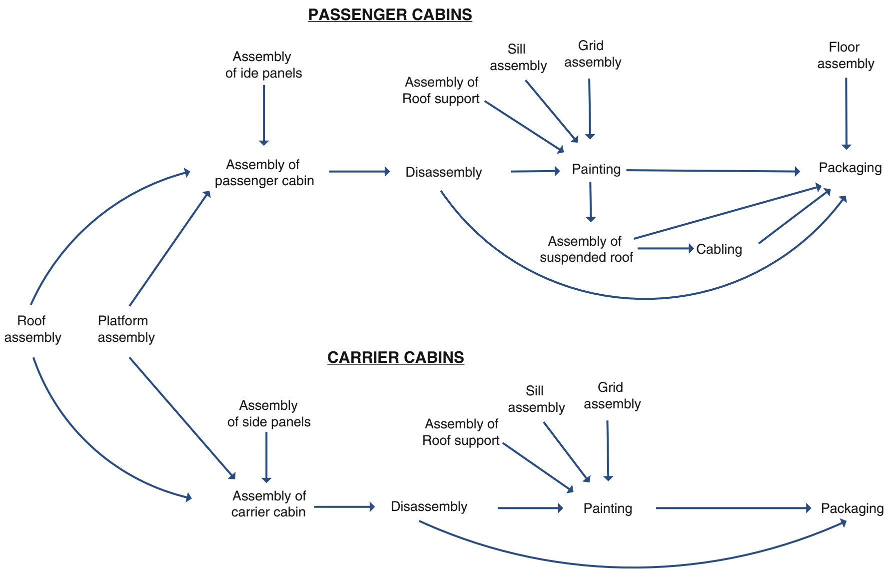

Fig. 8.105 Product synchronization flow – cabins (Danaktsi)

Table 8.15 Products categories (Danaktsi 2010)

Width	Length	Number of sides
<=1,500	<=1,500	3
>1,500	<=1,500	4
<=1,500	>1,500	5
>1,500	>1,500	6

method for implementing lean flow. It is a necessary and sufficient condition for arriving at the correct design of the future state, while the value stream map is, in our opinion, neither necessary nor sufficient for design purposes.

A smart way for categorizing the cabin products is according to their size which leads to a number of sides of the cabin (Table 8.15).

After the creation of product synchronization flow for the selected products and the study of the flow typology, before finalizing the line design, a future state value stream map can be developed, the practical necessity of which we do not really see. For lean flow design, the basic prerequisite is the allocation of the interaction point in production with the customer, which in this case it is not clearly defined.

The target of the company should be the creation of the conditions under which final assembly can be avoided, or at least to gradually reduce and finally eliminate the cause that make it necessary. The real reason why final assembly of the cabin is necessary is that customer order characterizes work in production from the cutting and forming of the metal sheet carried into and during assembly of the cabin. We need to find out if the wishes of the customer influence only the behaviour of the parts of the cabin as described in the case study for cooling equipment (Sect. 8.6), or

	CURRENT STATE	FUTURE STATE		DIRECT PACKAGING	
			% IMPROVEMENT		% IMPROVEMENT
TOTAL PROCESSING TIME (hours)	10.2 (average)	2.7 – 4.3 (relative to the required operations)	74% - 58%	2.1 – 3.8 (relative to the required operations)	79% - 63%
NEEDED SPACE	1350	414	69%	324	76%
TRANFER – TRANSPORTATION	Time consuming, high cost	minimum			
WAITING	maximum	minimum			

Fig. 8.106 Projected improvements in cabin assembly (Danaktsi 2010)

they change one or more of the three «f» (fit, form, or function). If the latter happens, then the interaction starts from the process that produces the part and the work concerned should be displaced from assembly to the process that produces the part, which is the cause of the process. If the former happens, then the work concerned is viewed as setup work or preparation work and in this case, an opportunity for improvement should be looked into for reducing the time and the quantity of parts that need such improvements. If the work is necessary, then instead of full assembly, it is possible to create tools for effecting the setup or the preparation, without the need to temporarily assemble the cabin.

Through this way of reasoning it can be concluded that the point of flow interaction is the point where the parts are characterized by the order. However, at the same time the activities are revealed, which should be evaluated looking for opportunities to reduce events that do not add value in the use cycle of the product. Based on lean flow design in the assembly, a cabin needs 2.5 h for assembly. The daily production of a cabin mix is 14 units. Based on this information, elimination of the assembly would mean 35 man hours less work per day. The saved man hours can be used for other activities. Independently of the fact whether elimination of the final assembly becomes reality, the use of lean methods projects among other benefits a drastic reduction of shop floor space as well. In Figs. 8.106 and 8.107 projected improvements and the layout before and after displacement to lean flow are illustrated (Danaktsi 2010). In the diagram on the left in Fig. 8.107 the framed parts taken up by the assembly are shown. In the diagram on the right the area needed by the assembly process after redesign is illustrated. The released area is about 1,000 m^2 and is shaded (light grey) for identification purposes.

In Fig. 8.108 the value stream map after redesign into lean flow is illustrated.

8.7.5 Electronics Subsystem

The most recent program relates to a lean flow redesign of the factory for the electronics. Electronics include the following sub-assemblies:

1. Elevator Car and Landing Operating Panels
2. Elevator Controllers
3. Elevator Pre-Wiring

The major problem in the factory is the issue of missing parts despite them being available in the warehouse. As a consequence, production is often delayed and valuable production time is lost. Moreover, the segmentation of production creates

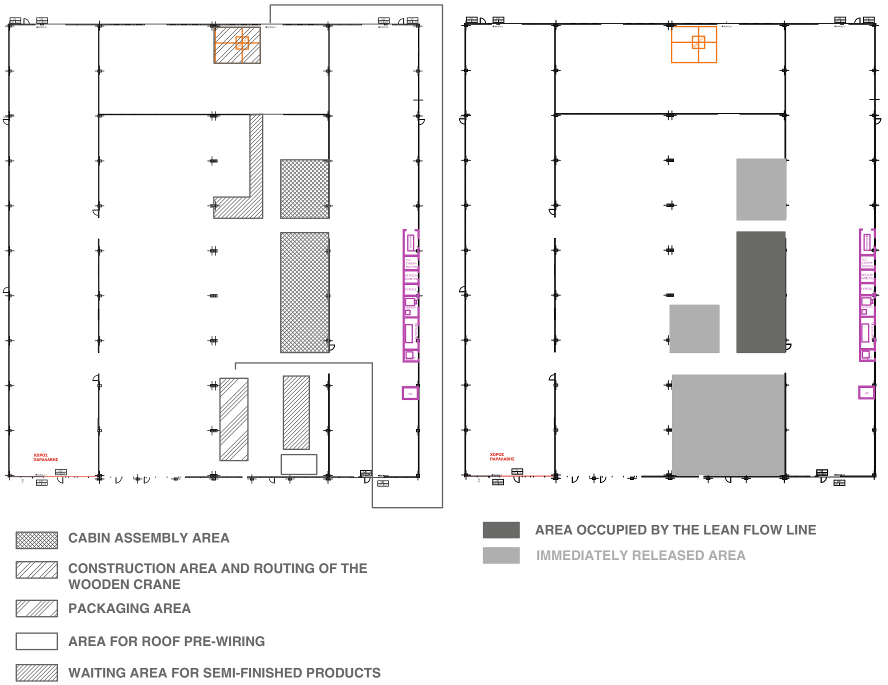

Fig. 8.107 Layout before and after displacement (Danaktsi 2010)

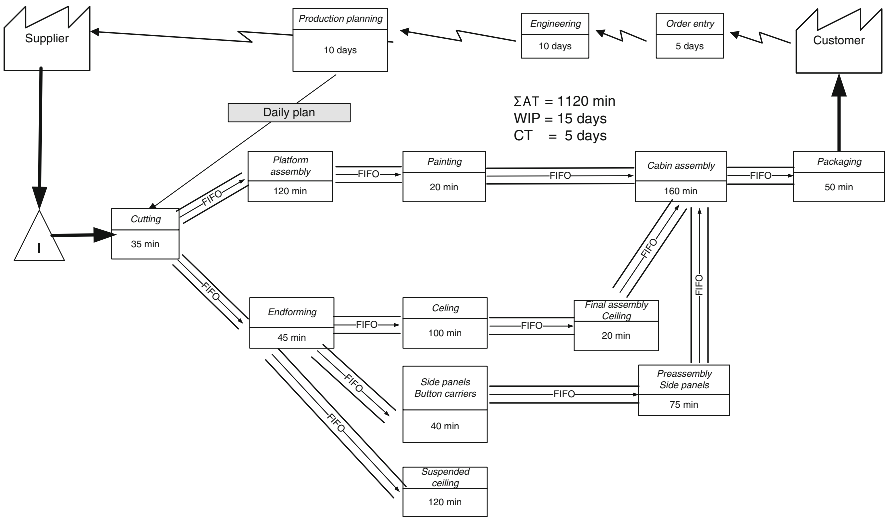

Fig. 8.108 Value stream map for cabin manufacturing – future state

synchronization problems in assembling customer orders. Implementation of the lean flow design study showed that efficiency will rise by about 40–50%. Installation and operation of the Kanban pull sequence in internal logistics will eliminate

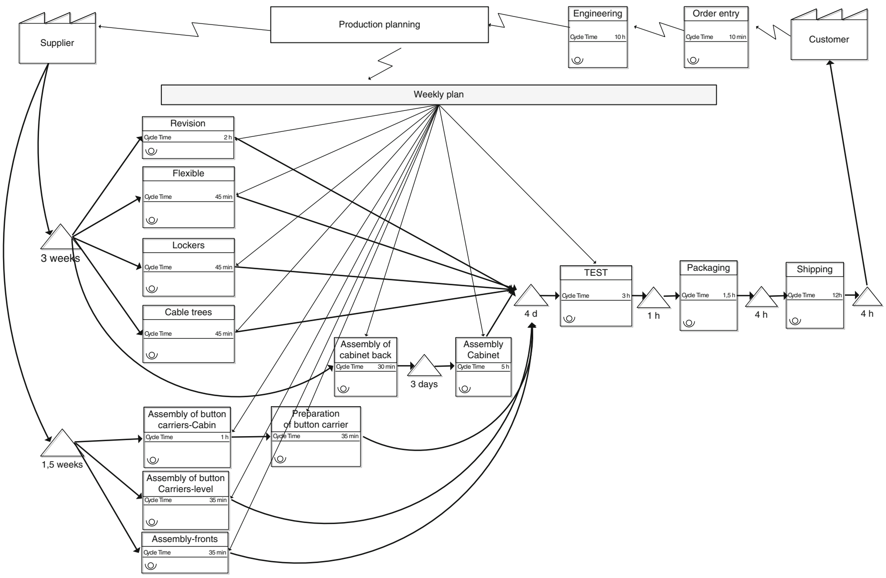

Fig. 8.109 Value stream map – current state (Danaktsi)

the problem of missing parts. A supermarket with an inventory coverage of 5 days will increase working capital efficiency by 50%. It is estimated that the working capital needs to support the new inventory policy in the supermarket is €650,000 instead of €2,000,000 in the old state. Rearrangement of the resources under lean flow, will lead to a reduction in floor space of about 500 m^2. In Figs. 8.109 and 8.110 the value stream maps for current and future states of the factory are presented respectively followed by the proposed layout of the factory for elevator electronics Fig. 8.111 in 2D and Fig. 8.112 in 3D.

8.7.6 Epilogue

Certainly, the Kleeman case has not been exhausted in these lines. As lean flow is stepwise implemented to all areas of the factories, it is a live case study still in progress. It concerns a leading player in the specific industry and its existence has many facets. The lean enterprise requires the commitment of all stakeholders including management, personnel, and suppliers. This is an on going effort in the company. The importance of lean flow has been recognized for the long-term viability and sustainability of the company, who have decided to apply lean flow also to its administration processes. We will risk a forecast. Kleemann will become the first Greek enterprise, which will belong to the top 10 companies worldwide who have implemented lean flow from wall to wall by 2015, The Lean Enterprise is alive.

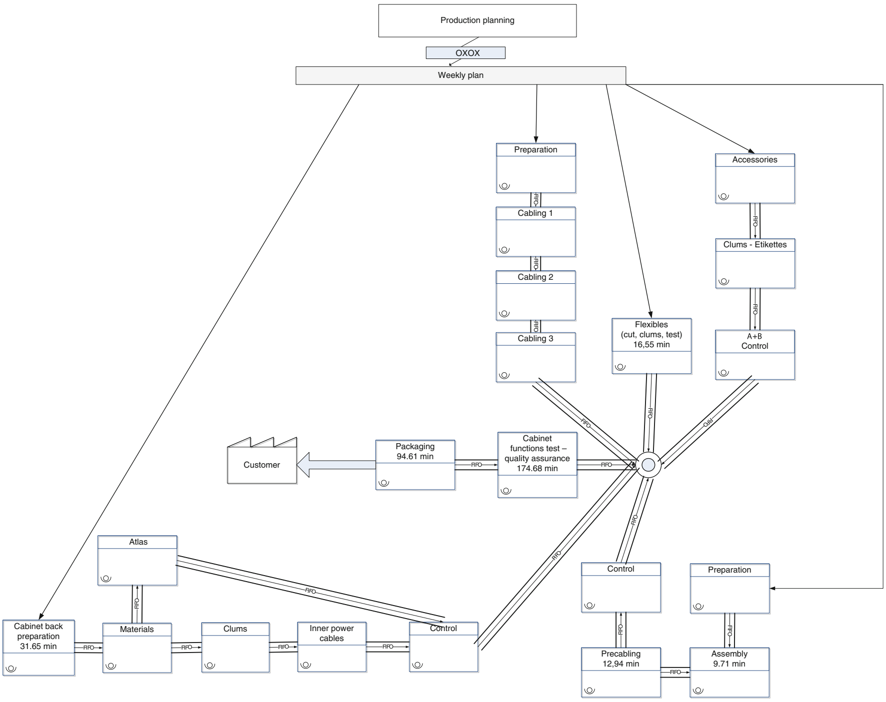

Fig. 8.110 Value stream map – future state (Danaktsi)

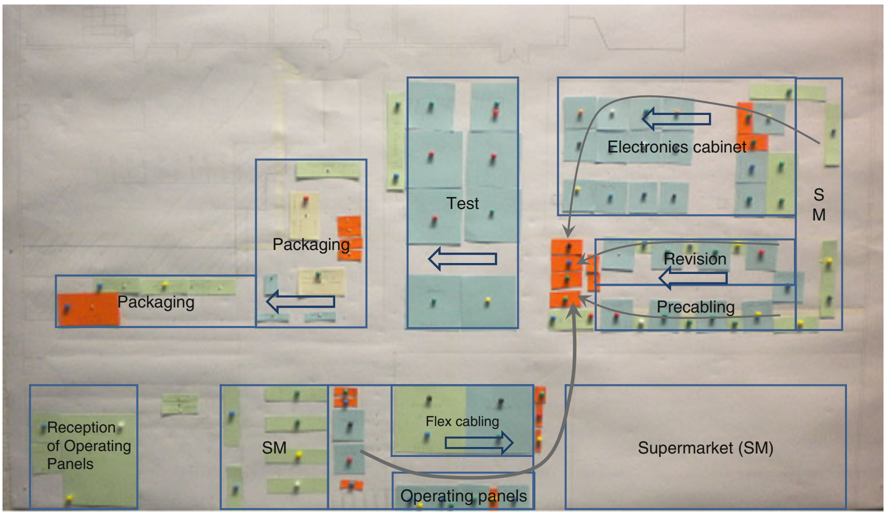

Fig. 8.111 Proposed layout of the factory for lift electronics – 2D (Mitsas)

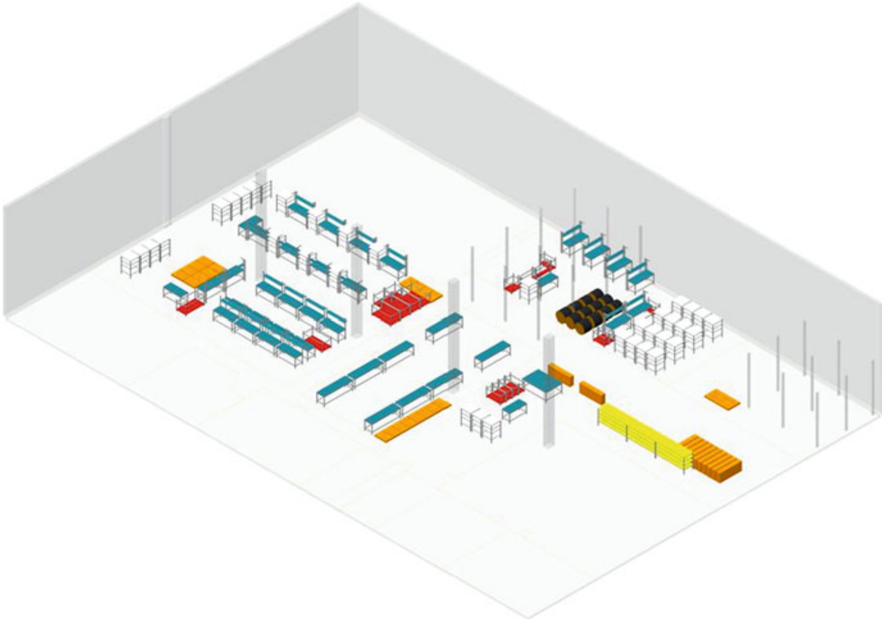

Fig. 8.112 Proposed layout of the factory floor for lift electronics – 3D (Kleemann R&D)

8.8 Electricity Supply

We close the implementation chapter, not with a further implementation, but with a vision of an implementation (Tsigkas 2011). Electricity goes lean. Traditional electricity supply (production and distribution) technologies were developed based on the mass production paradigm. Electricity end-use consumption differentiation in generating mix and volume of the year 2030 and beyond will be based on the mass customization and lean production paradigm. Restructuring electricity supply to fit mass customization, a lean production framework will enable the design and construction of power supply facilities that will exhibit higher sustainability performance at a much lower cost than in the paradigm of mass production. The main differences of these two paradigms are summarized in Table 8.16.

In liberalized markets, open sourcing is the main characteristic. Open sourcing is a synergy of stakeholders, achieved through the formation of Value Added Communities (VAC). Consequently, in liberalized electricity markets, Open Lean Electricity Supply Communities (OLESC) will operate as a Value Adding Community (VAC) with self-organized and self-regulated networks of distributed electricity supply sources offering on-demand electricity in mix and volume. OLESC operations require a quite different approach and marketing strategy, supported by modern Information and Communication Technology (ICT) and new economics based on differentiated use value. OLESC are entities which will

Table 8.16 Mass production versus lean production in electricity supply

Mass production	Lean production
Central generation	Distributed local generation
Central control	Distributed control
Long transportation distances	Short transportation distances
Mass outsourcing	Prosumer generation
Partial deregulation	Full deregulation
TSO, ISO based operation	Reduntant
Regulated logistics – unbundling	Open logistics
Mass produced – Just-in-case	Mass customized – Just-in-time
State monopolies → Private oligopolies	State monopolies → Open electricity
Technology driven	Marketing driven
Economy of scale	Economy of purpose
Electricityas a product (market of many)	Electricity as a service (markets of one)

invest in electricity generation mix portfolios that can be traded on future energy stock-exchanges worldwide.

In open and customized (differentiated) markets of this kind, OLESC will be formed to supply open electricity services (OES) for customers who wish to design new services that fit better their needs. The purpose is to fulfill a specific request from a customer or a range of customers or specific markets. Through appropriate ICT applications, OLESCs can be formed in response to a service request from a customer or a number of customers in the form of a cluster to provide a bid for electricity supply. Through e-Procurement applications, electronic auctions will be enabled on the web to supply electricity to the electricity markets worldwide. In this context, OLESC is an electricity supply community that enables interconnection of its members for managing and fulfilling customer requests. The major difference between OLESC and VPP (Virtual Power Plants) is that OLESC members may not necessarily be technically interconnected, while members of a VPP are connected through an electricity grid. An OLESC member may be a VPP in the classic sense.

In manufacturing product and service differentiation, responding to user individual needs is already a reality in many markets and provides a strong competitive advantage against product standardization. Differentiation in electricity supply, including its generation, delivery and consumption, already constitutes a strong leave-or-buy criterion due to economic and ecological reasons. Accordingly, electricity generation, which will support differentiation in the electricity supply chain, will require distribution through exploiting the opportunities offered by the local availability of renewable energy sources in order to fulfill demand for a mix of electricity end-use consumption.

Before proceeding to the next step, there is a need to introduce the important terms regarding electricity generation, used hereafter. Renewable energy is generated by natural power plants (NPP) through passive conversion of one form of

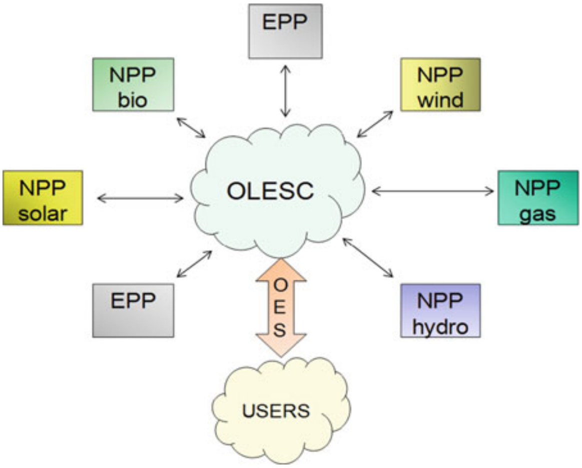

Fig. 8.113 Conceptual diagram for the formation of an OLESC as a VAC

energy into another using the sun, the wind, the earth or water as "raw" materials.[3] Active conversion of energy is generated through human intervention in engineered power plants (EPP). In these power plants, raw materials are either fossil fuels, for example coal, oil, gas and bio-fuels or refined fuels. The advantage of an NPP over an EPP is that there is no need for raw materials other than what nature directly provides. NPP does not need investment for producing the raw material or the "mass" needed for energy form conversion. This advantage is counterbalanced by the uncertainty in the sustainability of a constant "mass" duration and intensity for conversion purposes. The phenomenon is called intermittency and creates uncertainties on the supply side.

The conceptual architecture that will support OLESC is exhibited in Fig. 8.113. The diagram illustrates the fundamental entity of an OLESC that delivers Open Electricity Services (OES). Open mass customized markets will be served by various OLESCs. Operation of the OLESC is as follows: customers access through the internet the possibility to request OES from electricity markets. After a customer or a number of customers send a request for service, different OLESCs may respond with a bid to the request. Communication and exchange of information between potential OLESC members may take place through the use of mobile agent technology.

For speeding up the process of establishing collaboration among the OLESC members in order to respond quickly to various market requests, strong general bilateral agreements are necessary to exist upfront, which will be detailed for the specific bid. In practice, it is expected that the formation of OLESCs will consist of a core of participants which will be supplemented according to the case with local

[3] These four elements correspond to the primordial substances introduced by: Thales (water), Heraclitus (fire), the Pythagorean school (air and earth).

renewable electricity sources (RES), electricity producers (and maybe consumers) offering a competitive advantage over other formations (portfolios). Bidding may take place on the web through e-auction even running as cloud applications. Once, through the auction, a purchase agreement has been reached, fulfillment of the contract among the OLESC members must be managed.

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The Situation in Europe

9

Abstract
Ever since engineer Taiichi Ohno designed the famous Toyota Production System a great deal of time has elapsed for Europe, much later than Japan and the US, to *discover* that there is something to gain if similar techniques were implemented to European industry. Under the pressure of competition, companies are seeking ways to reduce operation costs in order to stay alive in a continuously globalized and competitive economy. The Lean approach has been adopted slowly but steadily by an increasing number of companies in Europe, nowadays at an accelerating pace, although some time ago many companies, some of which no longer exist, rejected the Lean approach as an approach that does not fit European culture. What has changed today for companies to, despite the cultural differences, embrace the Lean way?

9.1 Introduction

Since the time Taiichi Ohno designed the famous Toyota Production System (Ohno 1988), a great deal of time has elapsed for Europe, much later than Japan and the US, to *discover* that there is something to gain if similar techniques were implemented to European industry. Under the pressure of competition, companies are seeking ways to reduce operation costs in order to stay alive in a continuously globalized and competitive economy. The Lean approach has been adopted slowly but steadily by an increasing number of companies in Europe, nowadays at an accelerating pace, although some time ago many companies, some of which no longer exist, rejected the Lean approach as an approach that does not fit European culture. What has changed today for companies to, despite the cultural differences, embrace the Lean way?

In our view, nothing has changed. A more careful look at the way many companies implement *Lean* has very little to do with Lean. They observe practices

Whatever has not been invented by us, is rejected (German popular saying)

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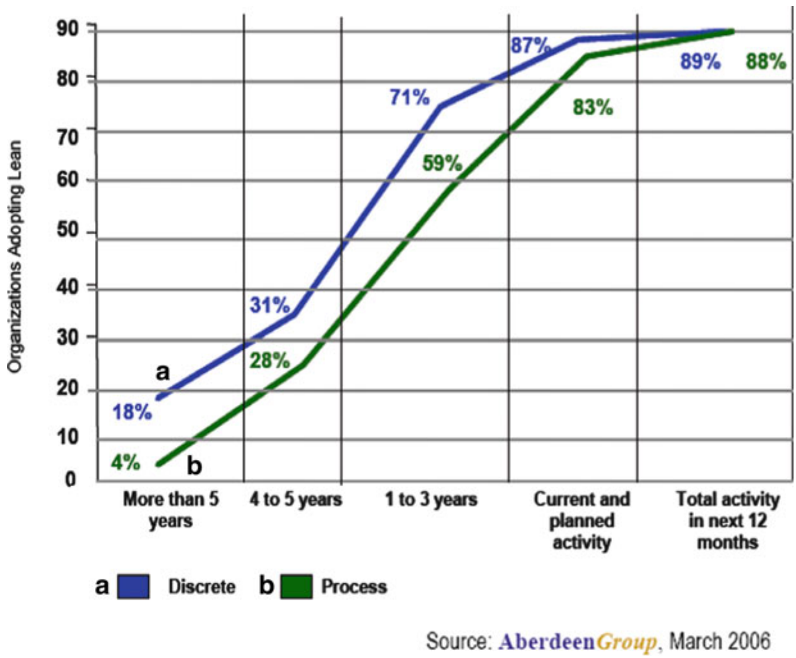

Fig. 9.1 Lean as mainstream philosophy

and merely implement lean methodologies. They do not view Lean as a different way of managing a company where the old industrial age attitude must vanish and be replaced with a completely new way of thinking, learning, measuring and acting. What they have in mind are mostly techniques for reorganizing resources in order to become more effective and efficient. Their focus, despite Lean, remains with short-term cost reduction throughout the company with no medium or long-term impact. The results have been significant in production especially in the first couple of years of implementation. However, as regards the medium to long term impact, benefits are really poor with little or no real improvement in the company's competitiveness.

A report published in 2006 by the Aberdeen Group shows that Lean Philosophy has become mainstream (Fig. 9.1). It revealed, however, that although nearly 90% of the respondents consider themselves lean, less than one-third can be considered to have mature lean deployments. Many think of Lean as supporting only key manufacturing functions, not broader, related functions. A closer look at the data shows that there is a wide gap between those companies that deploy some lean techniques and those that fully embrace lean culture.

According to the report, lean operational maturity is primarily focused on the use of lean tools and techniques used in production rather than the cultural aspects of Lean. One of the reasons for this is that *culturally, many of the leadership principles espoused in* The Toyota Way *are at odds with the managerial and facilitator skills taught on traditional MBA programs*. One of the major drawbacks in deploying Lean is the lack of integration of the supplier in the Lean program of their customers. Almost a third of respondents are challenged with integrating other parts of the company and all its suppliers into the Lean program. Meeting customer requirements for just-in-time deliveries requires the support and cooperation not only of finance and logistics, but also the suppliers who provide the raw materials, components, and assemblies used early in the manufacturing process. Expansion of Lean to the supply chain is therefore an imminent factor of success. Furthermore, taboos and prejudices have slowed down implementation decisions around the globe, especially in Europe. Nevertheless, since about 2008 there has been a boom in lean implementations across Europe at an accelerating pace especially in the extended enterprise. Through Lean comes Lea®ning as a permanent knowledge creation cycle (Tsigkas and Freund 2008).

9.2 Taboos and Prejudices

I remember 10 years ago while in Germany when lean implementations first started appearing and having their first impressive results. Taboos which viewed these techniques as of Japanese origin and therefore impossible to implement in Germany were common, but have since progressively declined. The syndrome of *whatever has not been invented by us is rejected*, was a typical refrain in many enterprises, which characterizes certain operational and business culture as a set of values. The phrase *we are different and therefore this cannot be implemented here*, has been used by many companies in the past, before going bankrupt under the burden of loans and debts. The strange thing is that many companies which went bankrupt had products that the market wanted. In Germany today, lean production is a modern and living reality for enterprises, a fact shown by many related jobs advertisements in the German market and the universities. The market is looking for specialists in this field as competition among consultant companies becomes fierce.

9.3 The Way Is Open and Certain

Pioneers in Lean Production started to implement lean practices 30 years ago. Today the conditions are ripe for adopting the Lean way and knowledge of the subject is rich. A search on the Internet is sufficient to determine that although the results of the search surpass 23 million items (depending on the search engine); however the essence hidden inside the vast volume of information is practically zero. Despite the over-information concerning the subject, if the interested reader wishes to retrieve data with respect to what actually has been achieved by the various companies which have implemented lean production programs, the results are poor. What is happening and why are the results not widely published in the era of over-information? Is it because lean production has itself fallen victim to what it tries to fight, namely to eliminate information that does not add value? The path is therefore open, a fact confirmed by thousands of companies who have already embarked on the Lean journey. Is the journey certain of success? The certainty

Fig. 9.2 The Lean Enterprise is strong and optimistic! Factory of Media Strom, Attica, Greece (unknown artist)

comes through knowledge becoming open in order to continue to create and uncover new knowledge. This is certainly the duty and obligation of academic professors, but it surely does not constitute an obligation on behalf of the enterprises that view such openness of knowledge as potentially damaging their economic situation. This is a perception from the 50s.

Our purpose in this book, due to our love of industrial production, is to contribute *mutatis mutandis* to critical thought in order to increase the degree of certainty in implementing lean flow across an enterprise through the knowledge and experience we have acquired over the years. Multidimensional knowledge is necessary. Single dimensional information does not exercise the brain in critical thinking. This is the duty of education inside and outside the universities. The condition is a healthy body, healthy mind (in Greek: *νους υγιής εν σώματι υγιή*) expressed through balancing the body and mind, through Aristotle *meanness* (in Greek: *μεσότητα*).

For those who doubt their ability to implement lean in their processes, I suggest thinking about the bee: the bee has a wing surface of 0.7 cm^2 with a body mass of about 1.2 gr. Based on the known laws of aerodynamics it is impossible for the bee to fly. Fortunately, the bee does not know this and continues to fly. Therefore, do as the bee does!

The Lean journey starts now. The Lean Enterprise is strong and optimistic (Fig. 9.2)

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