FACTA UNIVERSITATIS
Series: **Economics and Organization** Vol. 7, N° 3, 2010, pp. 319 - 334

LEAN PRODUCTION AND SIX SIGMA QUALITY IN LEAN SUPPLY CHAIN MANAGEMENT *

UDC 658.7

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Abstract. *Analyzing the difference between value and waste and value-added and non-value-added processes is crucial to understanding Lean. Sometimes it is not easy to discern the difference when looking at the entire supply chain. The best way is to look at the components of the supply chain and to apply Lean thinking in order to determine how to link the processes and reduce waste. In this paper special emphasis will be put on the coverage of methods and techniques and understanding of the philosophy of eliminating any wastes in the enterprise. Similarities between Six Sigma and Lean led to the connection of these concepts, so today there is Lean Sigma concept.*

Key Words: *Lean production, lean logistics, six sigma, supply chain, waste..*

INTRODUCTION

In today's highly competitive environment finding competitive edge is a critical success factor not only to expand business, but also to survive. Some companies tend to work on price, others on quality of service, but in the end they are all pursuing the same goal; increasing profit by acquiring, converting and retaining their most valuable asset: customers. Wholesalers, manufacturers, retailers, distributors, suppliers, third party service providers (3PLs) and every party involved in the supply chain are under pressure to reduce and balance their costs, time and inventories in order to continue to be profitable while still meeting their customers' demands. The best way for them to achieve this is to implement lean logistics. Lean logistics is focused on eliminating waste from the internal and external supply chains and this is achieved by reducing excessive inventories, replenishment times and unnecessary costs. Lean supply chains are designed to pull, not push, to replenish inventory levels.

Received November 15, 2010
* This paper is a part of the research project, Improving competitiveness of public and private sector by networking competences in the process of European integration of Serbia, number 179066, financed by the Ministry of Science and Technological Development of the Republic of Serbia.

The supply chain refers to the unique business processes without inter-company boundaries, which take place through a two-way flows of raw materials, finished goods, money and information, where each individual company is only one "link" in the chain. The supply chain includes all companies that directly or indirectly contribute to realization of the demands of consumers. The functions within each company are also involved in meeting consumer demands. Each company's logistics process, which is a member of the supply chain, is part of a larger process that takes place within the chain, logistics management. Therefore, each decision must be in accordance with the principles of specific management in the supply chain to which it belongs.

Partners in supply chain (see figure 1) need [1] to manage and have visibility of all inventory including inbound materials, raw materials stock, work in progress, finished goods, goods in transit and service parts and returns. This clearly requires full cooperation from all partners across this global supply chain, and this work need for full visibility of the whole supply chain [30, p. 23].

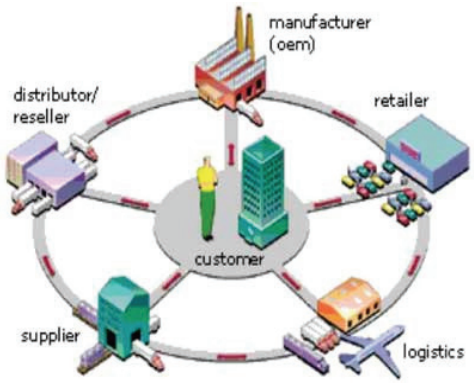

Fig. 1 Partners in Supply Chain [11]

Two very compelling reasons justify the emphasis on the entire supply chain. First, in some industries, especially consumer goods, suppliers are integrating, rather than interfacing, with their customers. There is no small difference between interfacing and integrating. Both parties must move away from coexistence with independent and oftentimes conflicting goals. In an integrated supply chain, customers and suppliers become mutually partners sharing information and focusing on common goals. The objective for all partners in the supply chain, not just an individual participant, is to increase market share through quick response to customers' needs. This can only happen when information, materials and products flow smoothly and quickly, in sync with demand.

The second reason is operational in nature and a prerequisite for establishing an integrated, mutually dependent relationship between company and selected customers. Customer and supplier operations must be streamlined for lean. This is best done by developing ways to quickly share relevant information to support synchronized material flow for quick response to customer needs. No matter what company is, its success in achieving these objectives may well determine its future. Many companies now recognize that an entire lean supply chain is critical to their success. The fact is that customers are going

to work more and more with "lean supply chains" that consistently and reliably meet their quick-response needs.

Dell Computer provides a good example of a successful lean supply chain strategy. Many are envious of how Dell's management team made the company into a short-cycle, configure-to-customer-demand product while improving all other significant measures of business performance at the same time. Dell Computer is one of few that have successfully tied the entire supply chain into short-cycle, synchronized flow of customer demand, material from suppliers to manufacturing and on to the customer, creating a truly lean supply chain.

1. IMPORTANCE OF LEAN LOGISTICS IN SUPPLY CHAIN MANAGEMENT

Supply Chain Management (SCM) encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, 3PLs, and customers. In essence, supply chain management integrates supply and demand management within and across companies [10]. Supply Chain Management has matured from a compelling method of deriving competitive advantage, to a "ticket to ride". It is now a baseline expectation for any company wishing to compete in the 21st century, and with that the professions and occupations comprising Supply Chain Management are now firmly entrenched in the armory of essential business executives [16].

Supply chains tend to accrue waste and non-value added activities for many reasons, both internal to the company and external. Regaining lean supply chain efficiencies may mean addressing many of the same issues that created the problems of extra and unnecessary time, inventory and costs.

Supply chain management, especially developing and implementing lean supply chain management, has challenges that must be acknowledged. These are in addition to the "usual" company issues with lean, such as lack of implementation know-how, resistance to change, lack of a crisis to create urgency, gaining resources and commitment, and back-sliding.

Lean has become a strategic method for gaining competitive advantage and even for survival, not just for manufacturers, but also for retailers and wholesalers. Adding value and removing waste are no longer options for companies. Non-lean practicing companies face competition from foreign made goods—competition which can have significant impacts on their business and industry. Even lean practitioners understand that the effort to be lean is ongoing.

When the focal firm, its suppliers, and its customers begin to work together to identify customer requirement, remove waste, reduce cost, and improve quality and customer service, it marks the beginning of lean supply chain relationships [35, pp. 226-227]. Lean supply chain management gained popularity in the manufacturing area as this is where significant improvement can be achieved. Manufacturing processes can be improved to reduce waste and resources while maintaining operational performance. Companies who have adopted lean supply chain practices have examined each of their routings, billed of materials and equipment to identify where improvements can be achieved.

Supply chain management is designed to take waste out of supply chains—waste as to excess inventory, time and cost. Supply chains are meant to pull, not push, inventory through the supply chain. This is exactly what lean logistics is also about—removing waste and variation from supply chains; it is what Kanban, Pull, is about with Lean Logistics.

Lean logistics [13] presents a business with several challenges due to the many different hand-offs that are involved when moving items along the supply chain. Lean logistics has many challenges for global-oriented companies which are operating in the global market with many different organizations. Some reports state that it requires the involvement of as many as 17 different organizations to deal with one single shipment. These organizations would be the suppliers, terminals, truckers, freight forwarders, customs brokers, railroads, air and ocean carriers, etc. So bringing lean logistics into such a large and extended multi transactional supply chain is not an easy task. It often means that some of those organizations involved are sometimes working together and at odds at the same time with each individual shipping transaction. This leads to additional non-value added activities being generated throughout the supply chain which creates waste (muda).

There are seven basic types of waste that were defined by Toyota managers. Such systematization can be applied in any company, for any process and it is the basis of LEAN concept – enterprise without waste. Over time, enterprises that practice LEAN concept systematized nine types of waste [8]:

- **Overproduction** - production that exceeds demand. Any product that is not immediately sold, or built into the final product, takes space, reduces the financial resources that a company has and disrupts the flow of production.
- **Defects** - (errors, malfunction) defects of the product itself which directly increase the cost of the product, are the only ones covered by this term. The term DEFECTS includes errors in documents, giving false information about the product, late delivery or making too much waste during processing.
- **Inventory** - cost occurs when there is an unnecessarily high level of raw materials, unfinished manufacturing or parts. All this increases the cost of storage as well as the percentage of defects in production.
- **Transportation** – any movement of materials that does not contribute to products value, such as transportation among working units. Ideal situation which the manufacturers are striving for is when a material is transferred to the next machine immediately after the processing was finished on the previous one.
- **Waiting** – waiting means idle machine time and workers who don't do anything until the part for processing arrives. This happens because of bottlenecks, bad compliance or delay in transportation.
- **Correction** – any errors in production that can lead to correcting the product should be avoided, because they increase the cost, impede the continuous flow of materials and increase the time of production. It is necessary to aim for 0% spoilage and implementation of total quality management.
- **Motion** - any unnecessary walking or unnecessary movements of workers which hinder workers while working. Also, poor workplace ergonomics or unprepared workplace affects preliminary-finishing time of machines, which reduces efficiency.

- **Over processing** – it is the processing of the product that does not contribute to its value and the buyer will not recognize it as a higher quality.
- **Incoherence of knowledge** – (also known as "waste of unused human talent") this happens when knowledge and information are not available when needed. This is usually related to the limitations of the procedures, or their inaccessibility and the result is often the production bottleneck or defects on products.

Fig. 2 Initial Seven Basic Types of Waste [19]

1.1 Lean production and Six Sigma

Lean production and Six Sigma initiatives support cost reductions and quality improvements. Although Lean and Six Sigma programs were initially separate initiatives in most organizations, today's firms see that Lean and Six Sigma do not compete with each other, but rather the two complement each other and provide for dovetailing of continuous improvement activities. Further we would like to stress the importance of lean production and Six Sigma for the lean supply chain management.

The focus of the 'lean" concept, as we noted, is to eliminate all waste i.e. all activities that do not add value, as we pointed. Waste can be measured in time, inventory and unnecessary costs. Value added activities are those that contribute to efficiently placing the final product at the customer. The supply chain and the inventory contained in the chain should flow. Any activity that stops the flow should create value. Any activity that touches inventory should create value. Lean concept can be easily applied in relatively stable and therefore predictable environment where the requirements (demands) of customers are similar. But when demand is in variable and when the requirements of their customers are very diverse, more important, is to quickly respond to changing customer demands rather than eliminate wastes. Supply chain agility is the chain that is able to respond to changing market demands and market [2, 106].

Lean supply chain management, we would like to stress gained popularity in the manufacturing area, where significant improvement can be achieved. Manufacturing

processes can be improved to reduce waste and resources while maintaining operational performance. Companies who have adopted lean supply chain practices have examined each of their routings, bill of materials and equipment to identify where improvements can be achieved [13].

Actually, the term lean production did not originate at Toyota. It was first used in a benchmarking study conduced by the International Motor Vehicle Program (IMVP) at the Massachusetts Institute of Technology in 1979. The IMVP conducted a global automobile quality and productivity benchmarking study which culminated in the book, *The Machine that Changed the World* wherein the elements of lean production and the benchmarking results were presented [36]. The IMVP is the oldest and largest international research consortium aimed at understanding the challenges facing the global IMVP researcher Matthias Holweg, right, discusses line innovations during a Nissan factory automotive industry. IMVP, founded, has mapped lean methodologies, established benchmarking standards, and probed the entire automotive value chain. The program's data-driven methods set the standard for industry research.

However, Toyota understood that they as an organization had a larger obligation than preserving the resources of Japan while building automobiles. Limiting the company's impact on Japan's resources, they were also obligated to the country to maximize the use of organizational resources to sustain the organization long-term. By doing so, Toyota became a leader in corporate citizenship by providing jobs to the Japanese and supporting the local community. Toyota achieved this through its value of social responsibility. Chang-Ran Kim on December 25, 2007 [17] writing for Reuters reported that Toyota Motor Corporation will charge further into emerging car markets to achieve another year of record sales in 2008, likely cementing its title as the world's biggest automaker ahead of General Motors Corporation.

Lean production [7, 38] is all about creating process and work area improvements to ensure the job is being done efficiently. One of the most important issues is the decision about how much effort and time the company is willing to spend in the area of lean improvements. The company must understand both its business needs and customer demands. Lean improvements can cause a slowdown in production if any reorganization of workstations or machinery is required. Overall, a business should not begin implementing lean improvements without first creating goals and objectives [12]. In a recent survey of manufacturing, distribution, and warehousing managers, respondents said the most important practices in manufacturing were continuous improvement and lean manufacturing, while the most important practices in warehousing were continuous improvement, value-added services, and lean inventories [6, p. 1].

Lean production is a set of methods and techniques that aim to reduce any waste that occur during the manufacturing process and all processes in the enterprise to the fullest. At the beginning, Lean terminology was connected exclusively to the production. After several years of attempting to bring Lean concept into the production processes of American car companies, there came the conclusion that such thing was impossible. It was necessary to adjust the entire company to the philosophy of continuous improvements of production processes and eliminating redundant costs in order to have the full effect of Lean. It is necessary that everyone, from top management to employees at the facility, knows the essence of Lean and is committed to its implementation [27].

Six Sigma [34] is a *business management strategy* originally developed by *Motorola*, USA in 1981. As of 2010, it is widely used in many sectors of industry, although its use is not without controversy. Maryland-based aeronautics firm Lockheed Marttin's Missiles and Fire Control Operation in Arkansas combine Lean and Six Sigma program was responsible for reducing the lead time for Patriot missiles from 18 down to 12 months and over a 5-year period, 91 Lean Six Sigma projects saved more than 23 million [26, p. 36].

Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability in manufacturing and business processes. It uses a set of quality management methods, including statistical methods, and creates a special infrastructure of people within the organization ("Black Belts", "Green Belts", etc.) who are experts in these methods. Each Six Sigma project carried out within an organization follows a defined sequence of steps and has quantified financial targets (cost reduction or profit increase). The term six sigma [7] originated from terminology associated with manufacturing, specifically terms associated with statistical modeling of manufacturing processes.

With Lean Six Sigma [34] your business will take a look at the way it is organized and how all the processes work together. Product development can save your company a lot of money if you spend enough time on it to do it right. With the product development phase you will take a look at the raw goods and all the other necessary supplies and equipment you need to produce and ship your products.

Similarities between Six Sigma and Lean led to the connection of these concepts, so today there is Lean Sigma concept. The idea is to fuse Lean production speed with elimination of variations by statistical and other methods and techniques from Six Sigma [7, 31]. When implementing Lean system in an enterprise, the main elements of Lean have priority, and then Six Sigma would run in parallel with other methods and techniques of Lean concept.

1.2 Principles and benefits of the lean production

To be able to explain all the methods and techniques which need to be implemented into Lean enterprise and which enable it to operate effectively, it is necessary to sublimate all the requirements and principles of Lean philosophy. Basic principles of Lean concept are [22, 25]:

- **Identification of losses** (WASTE) – The first step is to identify what has the value from the customer's point of view. Any material, process or product feature that does not lead to producing value from the customer's point of view means higher cost and should be eliminated,
- **Standardization of processes** – LEAN concept requires extremely accurate and detailed manufacturing procedures which at any time precisely define the state of material, time, sequel of operation and the result of an activity performed on the subject by an employee. This reduces variations in the sense that worker's errors in LEAN manufacturing were reduced to a minimum,
- **Continuous flow** – LEAN tends to implement the continuous flow and to free the manufacturing process from bottlenecks, waiting, stops and gaps,
- **Pull system** – the goal of this system is to manufacture only what is needed and when it is needed. The production gives signals to the workstation which stands

lower in the chain. Thus, every workstation manufactures only those parts that the station, standing next in sequence, needs,

- **Quality at the source** – the goal of LEAN concept is detection of errors in production at their very beginning. This is why workers have to examine the quality of components as a part of the processing,
- **Continuous improvement** – it can be explained as striving for perfection by constant removal of losses from production. This way, all the employees are involved in this continuous process.

By implementing Lean enterprise principles, you are able to incorporate [13]:

- A Continual improvement of processes company-wide;
- A Production schedules that are customer driven, not forecasted;
- A Pricing based on the market rather than cost, giving the organization a higher competitive advantage;
- A Lowered operating costs company-wide;
- A Higher employee morale.

When Lean principles are implemented enterprise-wide using the value stream maps that have been developed, waste is eliminated across all departments within an organization. It is important to remember that to be truly "Lean" and eliminate waste these principles must be implemented throughout the organization in order to experience lasting change. This requires focus on Lean principles from the product and service area, suppliers, distributors, customers and the various departments in the organization.

Effectively implementing Lean principles enterprise-wide requires your organization to combine leadership, change-management practices, and the computer systems/tools that all affect the transformation to lean principles throughout the organization. To accomplish the strategic business goals and objectives, every person throughout organization needs the tools that do the following [24]:

- Make it possible to establish lean principles and practices that are predictable and repeatable throughout the organization;
- Work together to not only integrate the value stream mapping and the components associated, such as analysis, implementation, etc., but also to enhance all facets of the value stream maps;
- To create a system that will make communicating easier and more efficient across your organization to make continuous improvements and aid in the changing of the culture due to implementation of lean principles; and
- Everyone to grow within the new systems of operation.

To truly experience the great benefits of a Lean organization and greater profits, organization must be completely committed to the full implementation and execution of Lean principles throughout the organization, eliminating waste and improving quality - regardless of the department.

The benefits of Lean for company are significant with managing the flow of products and information [23, 37]:

- Increased operational readiness;
- Increased product quality;
- Increased workers' efficiency;

- Increased utilization of machines and space;
- Reduced of machine failures;
- Compressed cycle times;
- Reduced logistics costs;
- Increased inventory levels;
- Increased supply chain visibility;
- Improved supplier and logistics performance.

The impact of Lean on a logistic is significant, as the goal of Lean is eliminate waste (inventory) which will decrease work in process inventories which in turn will decrease process and cycle times and ultimately increase supply chain velocity and flow.

Lean also has a vital cultural element to it that is crucial to a logistic. This is the concept "Total Cost ". The Lean practitioner does not focus on individual cost factors such as transportation or warehousing, but rather focuses on "total cost of ownership". With inventory carrying costs representing 15-40% of total logistics costs for many industries, making decisions based on total cost has dramatic implications for the logistician. Unfortunately though many organizations never fully embrace total cost concepts, poor decisions are continually made based on traditionally visible cost drivers like transportation, warehousing and ill-fated sourcing practices.

2. METHODS AND TECHNIQUES OF LEAN PRODUCTION

There are many methods and techniques that have to be implemented within the enterprise prior to the implementation of LEAN concept [5]. The two basic principles, continuous flow and pull system must be fully met, while others can be acquired through the LEAN philosophy in an enterprise, and everything must be focused on continuous improvement.

Methods and techniques of LEAN concept could be schematically presented as a house - a stable creation of human labor. If we had to explain LEAN as parts of that house, supporting pillars would be "Just in time" and Jidoka (or creating quality at the source). Foundation of the house would be easy visual system management, increased standardization, process stability and balanced production. Such a house would be maintained by teams of people through teamwork, aiming towards the continuous improvement of business (Figure 3).

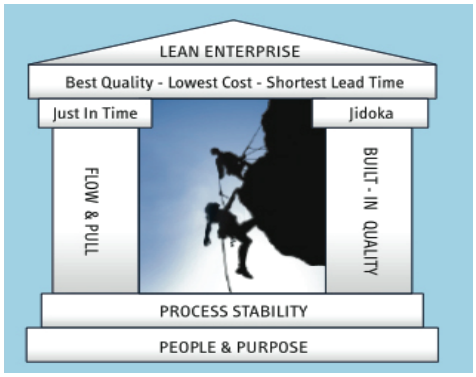

Fig. 3 Basic Elements of Lean Enterprise [14]

As it has already been pointed out, LEAN production [5] is based on continuous detecting and eliminating of wastes. The value is defined from the customer's point of view. That is why all methods and techniques in LEAN production aim to continuous waste removal.

Just in time – the concept of production and supplying guided by the following principle: a compound part that should be installed during the manufacturing process is

needed only when it is the time to be installed (neither sooner nor later than that). This mode of production and logistics support can be accomplished as a result of accurate planning of production and the planning of distributive chain management. "Just in time" was first applied in Ford's factories, but the true recognition of this concept came in the 70's of the last century.

Standardized work – means that the production processes and procedures that describe the production stages must be detailed and precise. Procedures must describe how each operation should be performed in a clear and visually simple way. This reduces variations in the manufacturing process. If the procedures are not clear, workers can misinterpret them and make errors during processing products. High level of the process standardization enables the company to expand its capacities without impairing production.

Standardized procedures of the LEAN are far more detailed than it is prescribed by ISO 9001:2001 standard (clause 7.5.2), especially the ones that explain outcomes, workers' movement, and the next step. Standardized work in LEAN manufacturing has several major elements [28]:

- *Standard operations sequence* – this element presents the exact operations sequence that a worker has to follow. He also has to obey the rules of standardized movements. This was precisely specified so that all workers can do their job in a similar way. This reduces variations in the process, and thus the spoilage. Ideal procedures should also go into detail of movements (MTM system);
- *Standard time* – Takt time is the desired time between units of production output, synchronized to customer demand. Takt time was introduced to accurately determine and supervise the rhythm of products manufacturing in different parts of manufacturing plants. In LEAN production, takt time of every production process is actively led and controlled which allows continuous flow;
- *Standard inventory* – required inventory minimum which can compensate for potential discontinuity of production and enables continuous, uninterrupted flow.

Standardized work explanation for the workers – procedures that explain the way in which they should perform tasks in their workplaces, must not include only text, but also figures, schemes and examples. Workers are not always willing to read the text, and it is much easier for them to accept drawings, examples and figures. Procedures must be clear and detailed, but easy to understand at the same time.

Standardized work and flexibility – although the procedures are very strict and precise, LEAN manufacturing promotes improvement in production process by the workers. It is necessary to update the procedure when some mode of improvement appears in the process.

To smoothly implement the improvement of the production procedure by the workers, certain responsibility for preparing and distribution of the necessary documentation and required equipment must be delegated. Also, all changes in the process should be presented to the workers in time by their supervisors. As long as the responsibilities are clearly and properly delegated, changes can be frequent. In fact, LEAN enterprises are recognizable for their flexibility, both in terms of manufacturing mix and the possibility to improve production processes rapidly, which leads to faster response to customers' demands.

Visual management – enables workers to be well-informed about production procedures, current status and other relevant matters, so that the process can be carried out as efficiently as possible. Large displays in the production halls are far better means of communication than written reports, and should be used as much as possible. When speaking in the context of eligibility in the process, visual management helps the team of workers to understand, in an easier way, the complex sequence of activities and their internal and external interaction with the surrounding working units.

Jidoka (quality at the source) – actually means that the quality should be an integral part of the manufacturing process. This, to a large extent, prevents any defects in the product. If a defect does occur, it will be noticed much earlier in the process. The main principles of Jidoka methodology are:

- *Direct inspection* – the main quality control is carried out by the workers, not by a controller who examines the entire series. Ideal state would be the one with eliminated quality controllers (because in LEAN, they are also considered to be the waste);
- *Inspection of the source* – quality controllers do not examine the defects in the product, but they try to determine how and why that defect occurred. Their job is to find and eliminate the cause of the problem, i.e. to perform corrective maintenance, or draw a worker's attention to disregard of the procedure and proper work;
- *Clear responsibility* - in LEAN enterprise traceability of the product is simple and precise, because it is clearly determined where the series comes from and who is responsible for the production of a specific part. When a defect occurs in a product, we know who is responsible and in which working unit the defect occurred;
- *Poka Yoke* – simple methods for direct inspection which prevent defective parts to be transferred to next production stage. All products must be controlled by such methods or devices because the most expensive product for the company is the one that was transferred to sales with a defect;
- *Deliberate shut down* – when a defect on a product occurs, production (more accurately, just a part of the production line) is stopped until the cause of the problem gets solved and permanently removed from the system. This enables the 0% spoilage philosophy, and prevents defective products to reach the next stage. In developed LEAN enterprises, the worker is allowed to stop the entire working process if he detects an error. This also increases the responsibility of workers, who become motivated to eliminate any losses from the process and achieve the absolute quality of the product. Deliberate shut down in the mass production process is strictly forbidden.

Mapping the manufacturing process – this is a set of methods that visually explain the flow of materials and information through the production system. The objective of mapping is to detect the activities that add value to the product and those that don't add the value directly. Maps of the flow of value should show the real state of the system, and not just to be the procedures that explain how the production process should look in ideal circumstances. Mapping is also used for the shortening of the production cycle and it is also the easiest way to find the spots where the manufacturing can be improved.

Five S – this is a set of rules used for organizing the workplace of each worker. Aim is to make every workplace organized in a way that will enable maximum efficiency and make the work easier for the worker. Given that LEAN emerged in Japan, Five S was also

named after five Japanese words: **Seiri** – obedience, **Selton** – tidiness, **Selso** – cleanness, **Seiktau** – perfection, **Shitsuke** – discipline. Since LEAN is practiced throughout the world, another definition was adopted. The point is the same, and the words are [7]:

1. *Sort* – sort and arrange tools. Sort by putting the tools that are often used at reach of hands, and those that are not used that often place farther;
2. *Straighten* – straighten the important things to make them easily accessible. The goal is to minimize the number of movements of hands that a worker has to make during performing the job. For example, tool boxes should be placed vertically with clearly marked places for tools, to reach them more easily and to notice immediately if there is some tool missing;
3. *Scrub* or *Shine* – clean machines and workplaces to minimize the problems connected to uncleanness. In some industrial processes, dust is the one of the causes of bad product surface or badly applied color. To detect the dust more easily, floors in LEAN factories are usually painted in bright colors and the light sources are improved within the factories;
4. *Stabilise* or *Standardise* – previous three rules need to be standardized and the procedures written. After a while, the best ways of sorting, straightening and cleaning should be chosen and presented to workers;
5. *Sustain* – sustain the Five S culture among workers. Sustain education and make the Five S become the part of corporate recognition.

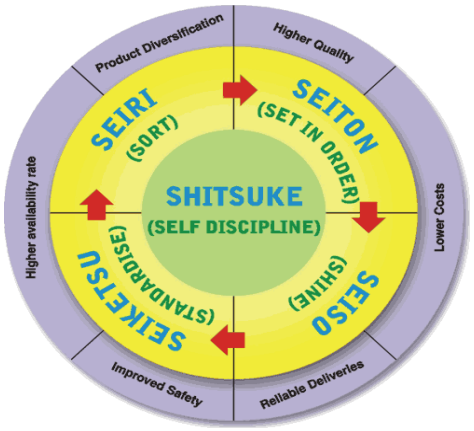

Fig. 4 Five S Principles [18]

One contribution of the Lean approach to business improvement has been a set of tools that anyone can leverage to improve workplaces and work processes. One of these tools, 6S (originally labeled 5S; see Figure 4), addresses just the situation i described. Some companies have also added a sixth-S, for safety, to assess the safety of work conditions and reduce the risk profile of the work area [3, pp. 29-31; 33, pp. 16-18]. Most people may think of it as relating to manufacturing workplaces, but it is just as applicable to office settings. As with all Lean tools, 6S is about eliminating waste and maximizing value-added work [20]. To this end, 6S uses its process to create and maintain an organized, clean, safe, and efficient setting that enables the highest level of value-added per-

formance. This means eliminating search, travel, transporting materials, inventory, and hazards. It achieves its ends by introducing organization and orderliness, eliminating unneeded materials, and establishing self-discipline. In a sense, it transfers some principles of "time management" from the "virtual space of your work schedule" to the physical space of your office or shop area.

Preventive maintenance – this is a series of practices and procedures that are undertaken in order to find and fix problems before they arise. LEAN production depends on preventive maintenance, because it prevents malfunction of the machines and the lack of spare parts. If the reliability of machines is not satisfactory, the manufacturer is forced to have unfinished products in storage, and they are considered to be the fundamental waste.

Total productive maintenance (TPM) gives the workers basic maintenance tasks. Basic maintenance tasks are inspection of the machines, cleaning, lubricating, tightening, and calibration. Each worker is obliged to maintain the workplace and the machine on which he works. TPM clearly gives responsibility to workers. The workers must act proactively, to monitor and correct possible causes of machine failures. This reduces failures of machines. TPM also obliges the worker to inform the maintenance about the state of machines and possible problems. TPM maintenance, as a function at an enterprise, is responsible for general repairs, improving equipment and staff training [32].

Reduction in the preliminary-finishing time – LEAN aims to reduce delays which occur due to tools changing and machines preparation. Great amount of time is lost during putting the tools on machines and calibration. In order to reduce the time required to change tools on the machine, it is necessary to improve working processes continuously. Preliminary-finishing times are often reduced by standardization. The uncertainty about the next step in reconfiguration of machines is reduced by creating the precise schemes of assembling tools and when the specific tool should be placed on the machine. Many enterprises neglect the preliminary-finishing time in belief that time is not long, but when the manufacturing mix in a factory is great, processing time of materials on the machine is only a few per cent of the total time that the processing subject spent on the machine. Everything else is preliminary-finishing time. Other ways to reduce the preliminary-finishing time include changing the manufacturing process or purchasing duplicate tools in order to avoid coming to a halt due to a single set of tools.

Reduction in series – the aim of LEAN is to have the movement of material through the factory in the smallest possible series. When the series are small, the unfinished production is also small, and the certainty that the working units, positioned lower in the process, will produce exactly what the customer needs is greater. This is why LEAN favors large number of small manufacturing lines and working units with U-shaped manufacturing lines. Basic benefits of small lines are reduced unfinished production, higher product mix and greater synergy among workers.

Manufacturing plant layout – it is necessary to place machines in the plant in a way that minimizes transportation within the manufacturing plant. Unfinished product should be placed close to the next workplace, immediately after the previous stage was finished. This reduces the space that inventory holds and the risk of damage.

Kanban – this is the method of supplying based on the pull-system which uses visual signals (for example, cards of different colors) to signal the production that is taking up its place in the manufacturing flow. It can be said that Kanban is a means of communication in the pull system. Kanban can be a card, visual display, i.e. anything that can give signal to start the production of a particular part [8].

Balance of working process in production aims to put the same amount of pressure on the manufacturing system and to minimize the accumulation of unfinished products. When the manufacturing volume increases, it is necessary to put the burden on the system equally. This enables better utilization of machines and it is easier to allocate necessary workers and equipment.

Takt time – each working unit has to manufacture a certain product at speed that is neither too small nor too great for the next unit in the process. In order to implement such production successfully, there is one working unit within the production process that sets the pace of manufacturing. Depending on the type of Kanban that is being used, the unit chosen to set the pace is usually the last one in the continuous flow, the one closest to customers.

Overall equipment efficiency – this is the measure of utilization of each piece of equipment in relation to the possible capacity. Overall efficiency can be viewed from two aspects. From the aspect of availability of equipment, i.e. how long the equipment was stalled in relation to activity time and from the aspect of utilization of equipment in relation to maximum projected capacity of equipment. Many enterprises get surprised by the inefficiency of their manufacturing systems when they calculate their equipment efficiency.

CONCLUSION

Waste reduction and the removal of unnecessary process can save companies millions of dollars a year. Getting the right product at the right price, at the right time to the end customer is not only key to the success of companies in competitive markets, but also the key to their survival. Therefore, satisfying the end customer and understanding the marketplace are key factors that managers of the company should consider when creating a logistics strategy. Only when the requirements and limitations of the market, the company has access to, the development of a logistics strategy, that will meet the needs of both the supply chain and consumers.

Lean supply chain management is not exclusively for those companies who manufacture products, but for all businesses who want to streamline their processes by eliminating waste and non-value added activities. Companies have a number of areas in their supply chain where waste can be identified as time, costs or inventory. To create a leaner supply chain companies must examine each area of the supply chain.

Both Lean and Six Sigma bring disciplines and tools to Logistics. Using these disciplines and tools will allow an organization to uncover and deal with waste (inventory) and gross inefficiencies. Although the tools are very powerful from both Lean and Six Sigma, companies should remember that for Lean and Six Sigma to work in logistics, a fundamental mind shift must occur. This mind shift requires that firms begin making decisions based on the concept of "Total Logistics Costs" and second, they must have the courage to eliminate inventories that are unnecessary.

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LEAN PROIZVODNJA I KVALITET SIX SIGMA U UPRAVLJANJU LEAN LANCEM SNABDEVANJA

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Analiziranje ralika između vrednosti i gubitaka kao i procesa koji dodaju i ne dodaju vrednost je od ključnog značaja za razumevanje Lean-a. Ponekad nije lako prepoznati razliku kada se posmatra ceo lanac snabdevanja. Najbolji način je da se sagledaju sve komponente u lancu snabdevanja i da se primeni Lean način razmišljanja kako bi se utvrdilo kako treba povezati procese i smanjivati gubitke. Upravljanje lancem sanbdevanja zahteva da kompanija ispita svaki proces u svom lancu snabdevanja i da identifikuje područja gde se javljaju gubici. Poseban akcenat u radu biće stavljen na objašnjenje metoda i tehnika i razumevanje filozofije eliminisanje bilo koje vrste gubitaka u preduzeću. Sličnosti između Six Sigma i Lean-a dovele su do spajanja ovih koncepata, tako da danas postoji i Lean Sigma koncept.

Ključne reči: *Lean proizvodnja, Lean logistika, Six Sigma, lanac snabdevanja, gubitak.*