A Theoretical Model of Lean warehousing

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A Theoretical Model of Lean Warehousing

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Chapter 01

Introduction

Lean and warehousing are well known terms and largely discussed in academic literature and research. Lean has its roots in mass production sector and in the automotive industry, mainly in Toyota. With the passage of time, the lean concept has spread its wings from manufacturing sector to the service industry environment as well and warehousing is one example of that. Warehouses play an important role in a supply chain; like material and products receiving, storage and delivering to the customer or to the next phase of the supply chain. It may also include the value adding processes like inspecting, kitting, packing, labelling and pricing etc. Frazelle (2002) has defined seven different types of warehouses eg. Raw material and components warehouse, work in process warehouse, finished goods warehouse, distribution warehouse, fulfilment warehouse, local (regional) warehouse, and value added warehouse.

The subject of lean warehousing deals with the application of lean concepts and practices in warehousing operations that help to improve the overall efficiency of the warehouse by reducing the total lead time of the operations that is the sum of total processing time and storage time. Gu et al. (2006) has further elaborated that market competition requires continuous improvement in the design and operations of production-distribution network, which in turn requires higher performance from warehouses. The adoption of new management philosophies such as Just-In-Time

(JIT) or lean production also brings new challenges for warehouse systems, including tighter inventory control, shorter response time, and a greater product variety. The benefits associated with lean warehousing are higher performance, improved quality of operations, continuous improvement, improved profitability and a leading edge in the market competition. However, there is a point of view that is contrary to the concepts of lean warehousing. Bozer (2012) has described it in detail as there is a contradiction between lean thinking and warehousing practice because lean thinking does not support the storing of materials in between the processes and it strives at being just in time with a pull flow with no batching production and with preferably no inventory kept between the different processes. However Bozer (2012) has further described that this type of situation (i.e no inventory between the processes) can be an ideal scenario because there exist variations in demand, uncertainty in lead time and longer lead times that cannot be fully predicted and it makes a warehouse necessary to provide items to the production, assembling or customer in time as needed.

Bozer (2012) has further presented an analysis of the literature review on the topic of lean warehousing according to which lean as well as lean manufacturing have been discussed in literature quite broadly, similar is the case of warehouse operations and its allied topics eg. warehouse design, control and warehouse automation etc. But, on the other hand, the topic of lean warehousing has not been much explored or documented in academic literature and research, and so far, there are no scholarly or refereed publications on the topic of lean warehousing. The available literature on this topic consists of a book “Lean Warehousing” written by Ken Ackerman who was an ex CEO of a warehouse management company. The book mainly looks at the warehousing operations and management in general and the lean applications in warehousing operations are discussed as a minor part of it. The other important writing related to the topic is a PhD thesis with the objective of developing and applying a lean assessment tool for assessing lean warehousing. For the purpose of validation of the tool, twenty eight assessments were performed at twenty five facilities. However the results and outcomes of these validation assessments have not been the part of thesis report because of the privacy of information. The other literature on the topic consists of two Master degree theses; of which the first study is about applying 5S lean applications in a raw material and components warehouse of a shipbuilding company in Norway. The concerns like cultural transformation, resistance to change and personnel involvement in the application of 5S are also discussed in the report, however the other lean considerations such as value stream mapping, flow management, pull and takt times have not been discussed in the report. The study was concluded while the implementation of 5S lean applications was still in progress, therefore a complete description of the process or a follow up has not been provided by the author. In the other Master degree thesis, the authors has presented a comparison among three case study warehouses and discussed the opportunities of lean implementation in these facilities. The study is of qualitative nature and the topics focused in the study are about minimizing the distance of pickers' route using traveling salesman problem, levelling the workload in the picking process by applying heijunka lean principal and ABC analysis and slotting. The authors have concluded that the tools suggested for further lean applications in warehousing are improving the flow of materials and increase the visibility and both of these tools have to be used together as an effort to control the waste and non-value adding activities. Other than these literature resources on lean warehousing, there are some articles or reports written by industrial and academic experts, these articles include the discussion of selected lean applications in warehousing operations. However, more details about these articles have been discussed in the literature review part of this thesis.

The benefits of lean warehousing have been discussed to highlight the importance of the topic. However, the review and analysis of existing literature shows that despite the importance of lean applications in warehousing operations, there is an acute deficiency of knowledge and research on this topic and it has not yet been established as a topic of study and research in comparison to other topics like lean manufacturing or warehouse operations and management. This situation, on one hand, depicts the deficiency in literature on the topic of lean warehousing while on the other hand paves way for exploring the topic through further research and developing and improving the knowledge and literature on this topic. The outcomes of this research on lean warehousing would better elaborate, organize and make it more understandable and would establish the basis for further study and research on the topic.

The objectives of this thesis include a thorough review of the existing literature on lean warehousing as well as the other related topics like lean manufacturing, lean supply chain, Toyota production system, warehouse management, lean warehousing, Just in Time (JIT), human resources and quality management. The first part of the study is aimed to develop and present a literature based theoretical model of lean warehousing. This model is composed of five constructs of lean warehousing. These constructs are further composed of lean applications that attribute to the objectives of each construct in the model. The five constructs as presented in the model are waste control, flow management, quality assurance, human resources management and continuous improvement. The selection of said constructs for the model of lean warehousing is based on the learning outcomes of the literature review of the topics mentioned earlier. Similarly the lean applications in the composition of each construct have been discussed in detail its importance and role for its relevant construct.

Considering the outcomes of the conceptual analysis and the model of lean warehousing, the second part of the thesis is aimed at developing an approach for the theoretical application of the model to a case study warehouse. In this part, the first most construct of the model of lean warehousing i.e waste control has been focused as an initial point to start with the theoretical application of the model of lean warehousing in a case study warehouse. The outcomes of this part of the study are presented as a 3-step framework. The framework starts with the analysis of wastes ("muda") for warehouse operations. The taxonomy of seven wastes classification developed by

Ohno (1943) has been considered for this purpose and the lean tool of 5 Ws (what, when, where, why and who) has been used for the analysis of each of the seven types of waste in warehousing operations. The outcomes of the first step set a baseline for selection and effective implementation of lean tools for waste control in the warehouse operations. In second step of this proposed framework, the work place organization (5S) lean tool is theoretically applied for waste control in warehouse operations. The proposed outcomes of this step of the framework are improved visibility, smoother material flows, workplace organization and standardization. In the third step is introduced and discussed the lean application of Value Stream Mapping (VSM) for warehouse operations. This current state value stream map is used to represent the materials and information flows and highlight the value added and non-value added activities in the warehouse operations. It also highlights the elements that control the time of warehouse activities and, thus the lead time of the whole process. After necessary improvements in the flow of information and materials in warehouse operations, the improved state of warehouse operations is highlighted and presented as the future state value stream map that represents the reduced lead time of the whole process.

The model of lean warehousing and the framework for its theoretical application in a case study warehouse have been developed to explain the organizational, operational and human related factors that apply in lean warehousing. It is aimed to improve the understanding of the topic of lean warehousing and would take the topic steps forward to establish as a subject of study. The outcomes of this study would help to reduce the described gap of knowledge in academic literature and improve the understanding that how lean concepts can be applied to warehouse operations. The outcomes of the study can be helpful for both i.e the warehouse practitioners by providing a better guideline for understanding and applying the lean concept and practices in a case study warehouses and at the same time it would help the academic researchers to further explore and contribute to the subject of lean warehousing.

Chapter 02

Literature Review

Lean

Taichi Ohno's book Toyota Production System (TPS) was originally written in Japanese in 1976 and translated to English version in 1986. The main elements of TPS are Just in Time (JIT) and automation or the automation with human intervention. The other related concepts of lean manufacturing are derived from these two. As described by Ohno (1986), the development of the manufacturing system was merged out of the necessity to develop the production flows with minimized or zero inventory. With this objective in the background and to reduce the cost of production, the lean practices like JIT, pull system, kanban, production levelling, supermarkets, fool proofing, automation, andon, team work and flexible work force are developed. It can be concluded that the TPS was merged out of necessity in post WW-II Japan. The lean principals applied in manufacturing operations i.e value added work and non-value added work and waste were developed from the resource constraints and are discussed and defined in detail by ohno (1986). The concept of seven types of waste are defined by Ohno (1986) namely over production, waiting, transportation, over processing, inventory, movement and defects. There are also some other important applications introduced by TPS i.e the ideas of profit making industrial engineering, maximizing worker utilization rather than machine utilization, small lot sizing, quick set up and preventive maintenance are presented. The decentralization of tasks and assigning duties with creating standard work sheets to operators is discussed with the concept of visual control, cycle time, takt time, work sequence and standard inventory. Ohno (1986) provides the fundamental framework from which the concepts associated with TPS are derived and subsequently the framework associated with lean manufacturing.

As quoted by Sabonski (2009), Shingo (1989) has developed the principals and guidelines for Toyota Production System (TPS) which describes the process of eliminating waste through continuous process improvement. The basics of this process as discussed by Shing (1989) are achieved through studying and mapping the processes, it has provided the basis of value stream mapping (VSM). The major waste to be eliminated in TPS is the waste caused by over production that would be controlled by Just in Time approach for the goods to eliminate inventory and work in progress (WIP). As described by Shingo (1989), the waste of over production can be reduced by set up time reduction techniques and it would allow for the other common lean practices related to TPS to be achieved like pull system, super markets system, one piece and small batch flow, reduce buffer sizes, levelled flow, demand stabilization, eliminating batching and queuing, and increasing order frequency. Shingo (1989) has also associated some other practices with basic principle of waste elimination i.e fool proofing, inspection processes, visual controls, five whys, andon systems, statistical process control, supplier integration and standardized work. It has provided additional support to the fundamental concepts related to TPS or lean manufacturing as described by ohno (1986).

The book “The Machine that changed the world” discusses the methodologies of mass production in USA’s automotive manufacturing industry. As described by the Womack et al (1990) and quoted by Sabonski (2009), the lean organization has two characteristics as it transfers the maximum number of tasks and responsibilities to those workers actually adding value to the car on the line and it has in place in system for detecting defects that quickly traces every problem, once discovered to its ultimate cause.

As described by Womack et al (1990), Taichi Ohno found that the American mass production system was suffering from waste of time, effort and material that was adding to the overall costs of the system and this type of working system would not be feasible in Japan under given system constraints. As a result, the waste elimination and maximizing workers utilization became the core features of lean manufacturing. The other important practices of lean manufacturing as identified by Womack et al. (1990) are quick change over, just in time system, kanban, production levelling, small batch production and supplier integration. The quality practices associated with lean production are quality circles, Kaizen, error proofing and problem solving through root cause analysis (five whys). The practices related to workers and organizational culture as defined by Womack et al. (1990) are the organization of employees into teams, replacing supervisors with team leaders, worker empowerment for decision making and improvement and the use of andon systems to fix quality problems upon detection.

According to Womack and Jones (1996), the five main concepts of lean thinking are value, value stream, flow, pull and perfection or continuous improvement. A human activity which absorbs resources but creates no value is called as waste or “muda” in Japanese. For waste there are two types i.e avoidable waste and unavoidable waste. The basis of lean are to increase the ratio of value creating activities to waste by eliminating the seven types of waste as defined by ohno (1986). Womack and Jones (1996) describe that the value stream is the combination of activities to complete a production cycle covering the important management aspects like problem solving, information management, and physical transformation. The value extends to other businesses in up and down stream related organizations and works as a system across organizations that helps to reduce waste and increase profit in the supply chain. As the supply chain is evaluated in terms of value, the next step would be to create a product flow. The lean concepts related to lot sizing and material flow are derived from the lean product flow principal, just in time, one piece and small lot flow, quick change over, standardized work, takt time, employee empowerment, standard operating procedures, visual control, Andon, demand levelling, total productive maintenance and mistake proofing. According to Womack and Jones (1996) product flow is to be managed according to customer demand, just in time, as upstream production process is initiated as customer would buy the products at downstream that will pull the product from producer through suppliers. The fifth lean concept as given by Womack and Jones (1996) is called as perfection which means the complete elimination of muda (waste) so that all activities along the value stream create value.

As described by Liker (2004) and quoted by Sabonski (2009), the lean principals of management, business control process, and management structure used by lean production organizations. He explained the lean principals related to manufacturing as well as vehicle development, engineering and corporate strategy. Liker (2004) highlighted the difference between traditional automotive firms and Toyota, the difference between their performances and the principals of problem solving, people and partners, processes and corporate philosophy. He describes the core of the TPS as eliminating (8 types of) waste as defined by Ohno and also one extra than Ohno i.e underutilized people (employees). There are fourteen points (lean principals) as identified by Liker (2004):

1. Base your management decisions on a long-term philosophy, even at the expense of short term goals.
2. Create continuous process flow to bring problems to the surface.
3. Use pull system to avoid overproduction.
4. Level out the work load.
5. Build a culture of stopping to fix problems, to get quality right the first time.
6. Standardized tasks are foundation for continuous improvement and employee empowerment.
7. Use visual control so no problems are hidden.

8. Use only reliable, thoroughly tested technology that serves your people and processes.
9. Grow leaders who thoroughly understand the work, live the philosophy and teach it to others.
10. Develop exceptional people and teams who follow your company's philosophy.
11. Respect your extended network of partners and suppliers by challenging them and helping them improve.
12. Go and see for yourself to thoroughly understand the situation.
13. Make decisions slowly consensus, thoroughly considering all options; implement decisions rapidly.
14. Become a learning organization through relentless reflection and continuous improvement.

Sabonski (2009) has analysed the theoretical framework developed by ohno (1986), Shingo (1989), Womack et al (1990), Womack and Jones (1996) and Liker (2004) and described a summary of the lean attributes outlined by each author in Table 1.

Author / Constructs	Ohno (1986)	Shingo (1989)	Womack et al. (1990)	Womack & Jones (1996)	Liker (2004)	Summary
Standardized Process	X	X	-	X	X	X
People	X	-	-	X	X	X
Quality Assurance	X	X	X	X	X	X
Visual Management	X	X	-	X	X	X
Workplace Organization	-	-	-	X	X	X
Lot Sizing	X	X	X	X	X	X
Material Flow	X	X	X	X	X	X
Continuous Improvement	X	X	X	X	X	X

Table 1: Summary of Lean Constructs and Authors by Sabonski (2009)

As described by Womack (2006) and quoted by Sabonski (2009), in comparison between General Motors and Ford to Toyota, the five weaknesses identified by Womack (2006) are design, supplier integration, management culture, brand identity, and customer relations, not the factories, pensions, and unions. According to Womack

(2006), GM and Ford factories actually now compete with Toyota in terms of productivity and quality. This illustrates the success that can be achieved in traditional manufacturing operations in quality and productivity through the long-term commitment of creating a lean enterprise. According to Womack (2006), the U.S. automotive focus will have to shift from internal manufacturing operations to other internal functions and external functions to achieve a truly lean enterprise and continue to close the performance gap with Toyota.

Quinn (2005) has conducted an interview with the lean manufacturing expert James P. Womack where he described the implementation process as a slow five or ten year process, which many western managers have difficulty dealing with and managing. Also he describes the key components of lean as the process of creating value from the customer perspective, mapping the process, improving material flow, eliminating waste, pull systems, and customer demand, similar to the key constructs identified.

Balle (2005) described and quoted by Sabonski (2009), the improvement paradigm is more than a combination of tools, it is a system and its successful application requires a specific managerial attitude. Balle (2005) further describes the importance of time spent by lean implementation managers on the shop-floor, continuous improvement, and having willingness to experiment with operations and learn. About the characteristics of organizational culture, Balle (2005) describes that these are leadership direction, the level of commitment to the initiative, and the overall understanding of the operations by management, supervisors, and employees.

Rooney and Rooney (2005) have developed the set of terminologies related to lean manufacturing by including terms from Andon to waste. They have outlined a five steps lean approach to systematically implement lean manufacturing as creating process stability, continuous flow to reduce work in process (WIP), synchronous production, a pull system for replenishment, and level production demands. Other important lean practices Rooney & Rooney (2005) identify and define are Andon, automation, reducing batch and queue, cellular manufacturing, quick changeover, cycle time, error proofing, FIFO, 5S, flow, levelled production, inventory, JIT, Kaizen, kanban, one-piece flow, Plan-Do-Check-Act (PDCA), process control board, shadow board, standard work, standard operating procedures (SOPs), supermarkets, total productive maintenance, value added, value-stream mapping, visual controls, waste, and WIP.

As identified by Hunter (2004) and quoted by Sabonski (2009), a ten-step approach for creating lean production for reengineering a manufacturing system. The corresponding practices Hunter (2004) has mentioned are reducing setup times, integrating quality control, integrating preventative maintenance, levelling and balancing the system, integrating a pull system, utilizing inventory control, integrating suppliers, applying automation and fool-proofing, and implementing computer integrated manufacturing system.

Hancock and Zayko (1998) have described top management, union management, staff personnel, workers, and process engineers, which is just about everyone, as being the important personnel for implementing lean production. Hancock and Zayko (1998) have further identified manufacturing equipment reliability, machine setup times, quality detection and resolution methodologies, WIP inventory, levelled production requirements, finished goods inventory, cross-trained employees, and shift communication as the important factors that can enhance or limit lean implementation success.

Chapman (2005) has defined the 5S system of workplace organization as sort, set in order, shine, standardize, and sustain which has become a foundational principle associated with lean manufacturing in practice. Chapman (2005) has further mentioned that the principal of “a place for everything and everything is in its place” is the core of 5S system. The first step is to sort out what material, equipment, machines, and supplies are needed in the workplace to perform the work and which are not. The second step is to set in order, organize, and visually represent the essential material, equipment, machines, and supplies to minimize travel, motion, and searching movements. The third step is to shine, clean, and inspect all the work areas, equipment, and machines. The fourth step is to standardize the workplace organization initiative and maintain the improvements daily by allocating time, creating checklists, and developing schedules for maintenance. Finally, the fifth step is to sustain the initiative by making it a part of everyday business by auditing, providing feedback, and managers, supervisors, and employees verifying compliance to the initiative. The 5S system of workplace organization eliminates many of the forms of waste, creates and enhances visual management, and can reduce potential for errors. 5S is of even greater importance in organizations implementing lean where cross-training is taking place or turnover is high to reduce the amount of time associated with learning a new task.

Worley and Doolen (2006) have discussed the importance of communication and management support in a lean manufacturing implementation case study using a qualitative methodology. Worley and Doolen (2006) have also found that that management support plays a role in driving lean implementation and that communication was positively affected by lean implementation. The tools and practices as identified by Worley and Doolen (2006) as lean manufacturing are 5S, Kaizen, kanban, pull systems, quick changeover, and value-stream mapping. Worley and Doolen (2006) develop a balanced scorecard measurement approach to assess the effects of lean manufacturing implementation on the following categories: customer needs, customer satisfaction, employee attitude, employee skills, processes streamlined / wastes removed, and lean concepts adopted.

Mehta and Shah (2005) have described the principals of lean as workflow integration, formalization and standardization, and team interdependence. It can be measured by using work in progress, number of standard operating procedures (SOPs) and regulations, and the percentage of workers involved in teams, respectively. Mehta and

Shah (2005) have further identified the characteristics of work design as skill variety, task identity, task significance, autonomy, and feedback from the job; it can be measured through applying survey instruments. The elements of culture and organization as defined by Mehta and Shah (2005) are the degree of technical uncertainty and the degree of coercion, and the employee outcomes identified are job satisfaction and job related strain.

An important work by Treville and Antonakis (2006) has examined organizational culture and the intrinsically motivating nature of lean production job design and the theoretical relationship between job enrichment and intrinsic motivation as it relates to lean manufacturing. As defined by Treville and Antonakis (2006), lean manufacturing practices regarding reducing inventory and increasing capacity utilization as WIP control and kanbans, pull systems, and setup reduction. Treville and Antonakis (2006) have further defined variability reduction as a lean production practice with regard to standardization, documentation, SOPs, statistical process control, fool-proofing, andon systems, visual management, inspection processes, supplier integration, and workplace organization. Treville and Antonakis (2006) has also outlined organizational culture with respect for workers regarding cellular structure, cross-trained employees, and worker empowerment.

As defined by Kojima and Kaplinsky (2004), there are three poles of change related to the development of a lean manufacturing i.e flexibility, quality, and continuous improvement. The attributes of flexibility further include seven elements of WIP and finished goods inventory, setup time reduction efforts, cross-trained employees, kanbans, just-in-time, cellular layout, and teamwork and team leaders. The attributes of quality include the achievement of quality accreditation and external quality performance arising from customer returns. The continuous improvement includes improvement in flexibility through setup reduction, external quality performance, and suggestion usage rates over a five year period.

Kojima and Kaplinsky (2004) have presented a framework to operationalize and measure some of the principles and practices associated with lean manufacturing. Martinez-Sanchez and Perez-Perez (2001) have also developed a framework composed of six lean indicators and related practices. The first of the indicators is about elimination of zero-value activities, is characterized by the percentage of common parts in company products, value of work in progress in relation to sales, inventory rotation, number of times and distance parts are transported, and percentage of preventative maintenance over total maintenance. The second lean indicator as defined by Martinez-Sanchez and Perez-Perez (2001) is continuous improvement constituted by the number of suggestions per employee per year, percentage of implemented suggestions, savings and benefits from suggestions, percentage of defective parts adjusted by production line workers, percentage of time machines are standing due to malfunction, value of scrap and rework in relation to sales, and the number of people dedicated primarily to quality control. The third indicator as defined by Martinez-Sanchez and Perez-Perez (2001) is multifunctional teams comprised of percentage of employees working in teams, number and percentage of tasks performed by the teams, average frequency of task rotation, and the percentage of team leaders that have been elected by their own team co-workers. The fourth Martinez-Sanchez and Perez-Perez (2001) indicator is JIT production and delivery consisting of lead time of customers' orders, percentage of parts delivered just-in-time by suppliers, level of integration between supplier's delivery and the company's production information system, percentage of parts delivered just-in-time between sections in the production line, and production and delivery lot sizes. The fifth lean indicator as defined by Martinez-Sanchez and Perez-Perez (2001) is the integration of suppliers including percentage of parts co-designed with suppliers, number of suggestions made to suppliers, the frequency with which suppliers' technicians visit the company, the frequency with which company's suppliers are visited by technicians, percentage of documents interchanged with suppliers through EDI or intranets, the average length contract with the most important suppliers, and the average number of suppliers in the most important parts. The sixth and final Martinez-Sanchez and Perez-Perez (2001) indicator is flexible information systems that includes the frequency with which information is given to employees, number of informative top management meetings with employees, percentage of written procedures in the company, percentage of production equipment that is computer integrated, and the number of decisions employees may accomplish without supervisory control.

As described by Rasch (1998), eight fundamental management practices related to lean manufacturing are built-in quality, preventative maintenance, just-in-time delivery system, equipment standardization, pull system, levelled production, balanced line capacity, and standardized work. Rasch (1998) has further defined the basic elements of lean manufacturing as team-based work organization, empowered employees, cross-trained employees, Kaizen activities, small batches, error-proofing, root-cause problem-solving, and supplier integration. Rasch (1998) operationalizes various human organization, production technology and methods, and quality system performance measures to predict overall company-wide performance. The practices related to organizational culture and structure as defined by Rasch (1998) are unionization, shop floor management layers, formal teams, relaxed work rules, production worker involvement and suggestions, production worker authority, production worker training, production worker cross-training, and pay incentives. These practices directly relate to the cultural aspects of lean manufacturing identified in the literature. The Rasch (1998) practices of production technology and methods are automated machine control, automated bar code tracking system, business system automation, just-in-time inventory methods, shop scheduling, preventative maintenance, and housekeeping. The quality system practices identified were the use of statistical process control, formalized quality programs and procedures, quality measurement efforts, and product inspection. The Rasch (1998) practices are related to various interim performance measures of shop floor efficiency, product quality, employee grievances, and unscheduled downtime and the significance of their effects estimated in predicting each using regression analysis.

All the literature findings and lean characteristics and traits as discussed above have been considered and incorporated during the development process of theoretical model of lean warehousing and for the development of the theoretical approach for implementing this model in a case study warehouse. The lean principals defined by different lean experts have been incorporated while defining the lean constructs and its attribute for the proposed model.

Warehousing

Warehouses are an essential component of any supply chain. Their major roles include: buffering the material flow along the supply chain to accommodate variability caused by factors such as product seasonality and/or batching in production and transportation; consolidation of products from various suppliers for combined delivery to customers; and value added-processing such as kitting, pricing, labelling and product customization (Gu et al, 2006).

Sabonski (2009) has described that the major functional areas within warehousing operations are inbound operations, outbound operations, inventory control, material returns, value-added service operations, and office functions. Inbound operations are material receiving, sorting, checking, stocking, and put away processes for inventory purposes. Further described by Sabonski (2009), outbound operations are picking, packing, loading, and shipping processes for material moving from inventory to the customer. Inventory control operations are inventory accuracy related for quantity verification, maintenance of stock locations, slotting, and overall facility inventory integrity. Material returns are the processes involved with accepting, rejecting, and restocking material returned from customers. Value-added service operations are the various tasks performed within warehousing operations such as kitting, packaging, light assembly, and various other tasks performed to ensure customers receive products according to specifications. Office functions relate to managing employees, invoicing, records, human resources, and various office requirements necessary for facility operation.

Bozer (2012) has discussed in details the different types of warehouses as described in literature by different writers. According to Bozer (2012), there are numerous studies and publications that provide us with various ways to classify and categorize warehouses. For example, according to Frazelle (2002), there are seven types of warehouses are identified, which are described below.

1. Raw-material and component warehouses are used to hold raw materials at or near the point of induction into a manufacturing process.

2. Work-in-process warehouses are used to hold partially completed parts or assemblies while they are going through the manufacturing operations.

3. Finished good warehouses that are used to buffer against variations in customer demand.

4. Distribution warehouses are used to accumulate and consolidate products from various sources for combined shipment to various customers.

5. Fulfilment warehouses are used to receive, pick, and ship small orders for individual customers that often represent consumers.

6. Local or regional warehouses are distributed in the field in order to shorten transportation distances to permit rapid response to customer demand.

7. Value-added service warehouses are used to perform services such as labelling, light assembly, and kitting.

As defined by Rushton et al (2010), warehouses can be classified by their stage in the supply chain i.e raw materials, work-in-process, or finished goods. Warehouses can also be categorized according to the geographic area they serve i.e national, local, regional, or international, the type of products they store for example, small parts, large assemblies, frozen food, perishable items, hazardous goods etc. The other types can be based on the ownership i.e user-owned, third-party, public warehouse etc. Based on usage, warehouses can be of types for example warehouse dedicated to one company versus a warehouse shared by multiple companies. Warehouses can also be classified according to dimensions and area classification according to the storage dimensions and area for example their storage height such as low-bay or high-bay warehouses. The other classification may be on the basis of the type of equipment they use ranging from mostly manual operations to highly automated equipment.

Van et al (1999) have provided another classification of warehouses, according to which the classification scheme can be as distribution warehouses where products are collected (sometimes also assembled) from different suppliers and subsequently redirected or sorted to individual customers. The second type is production warehouses that are used for storage of raw materials, work in progress (WIP) and finished goods in a production facility. The third type of warehouses as defined by Van et al (1999) is contract warehouses that are providing warehouse facility and services to one or more customers.

As described by Bozer (2012) the principles of lean warehousing do not change by the type of warehouse. Therefore, the results of this study should be applicable to all types of warehouse as much as possible. Accordingly, the outcome of this study is quite generic and is applicable to warehouses of all types.

Lean Warehousing

In literature, the topic of lean warehousing has been aimed at discussing the opportunities of applying lean tools and applications in the warehouse operations that would help to save the time and cost of these operations. The literature resources available on the topic mainly include the case study research theses conducted by two master degree students in Europe and one PhD student in USA. Also there is a book "Lean Warehousing" written by Ken Ackerman and some articles and reports written by industrial or academic experts.

The importance of lean concepts and applications for warehouse operations have been discussed by different writers, for example, Gaunt (2006) has described that in comparison to manufacturing processes, warehouse operations are simpler and not very much considered for lean applications. However there exists the opportunity for time and cost savings in warehouse operations.

Another writer Garcia (2003) has explained the applications of lean tools in warehousing operations in one of his articles on the topic of lean warehousing. Garcia (2003) has explained that the most commonly adopted lean tool in warehousing is value stream mapping (VSM), it can be used to analyse operations and evaluate the associated lead time and the total processing time. It highlights waste and non-value added activities and indicates areas of improvement. Gu et al (2006) has also discussed and highlighted the importance of lean applications in warehousing by noting that market competition requires continuous improvement in the design and operations of production-distribution network, which in turn requires higher performance from warehouses. The adoption of new management philosophies such as Just-In-Time (JIT) or lean production also brings new challenges for warehouse systems, including tighter inventory control, shorter response time, and a greater product variety. A similar approach has been explained by Myerson (2012) that most of the lean tool concepts can be applied to warehouses, such as 5S, value stream mapping (VSM), team building, kaizen, problem solving and error proofing, kanbans / pull systems, line balancing and general waste reduction. Mayerson (2012) further suggests that in order to obtain performance improvements, warehouse activities may be considered as an assembly line. Non value added tasks can be reduced by analysing physical operations, paths of picking, and waste motions and by trying to avoid a poor availability and maintenance of tools and equipment.

Bozer (2012) has presented a thorough analysis of the available literature on the topic of lean warehousing, according to Bozer (2012), there is a book "Lean Warehousing" written by Ken Ackerman. The writer has been a seasoned warehouse practitioner and ex CEO of a warehouse management company. The book mainly looks at the warehousing operations and management in general however the lean tool applications like VSM, takt time etc for warehousing operations have not been discussed in sufficient details. The other literature on the topic consists of two Master's degree theses; of which the first study is about applying 5S in a raw material and components warehouse of a shipbuilding company of Norway. The concerns like cultural transformation, resistance to change and personnel involvement in 5S are also discussed in the report, however the other lean considerations such as value stream, flow management, pull and takt times are not discussed. The study was concluded while the implementation of 5S was still in progress, therefore a complete description of the process or a follow up has not been provided by the author. In the other Master's degree thesis, the authors present a comparison among three case study warehouses and discuss the opportunities of lean implementation in these facilities. The study is of qualitative nature and the topics focused in the study are about minimizing the distance of pickers' route using traveling salesman problem, levelling the workload in the picking process by applying heijunka Lean principal and ABC analysis and slotting. The authors conclude as the tools for further applying lean in warehousing are improving the flow of materials and increase the visibility and these to be used together with the efforts to control the waste and non-value adding activities. Other than these resources on lean warehousing, there are some articles or reports written by industrial and academic experts. As further explained by Bozer (2012), one of the important writing available on the topic of lean warehousing is a PhD thesis by Eric Sabonski in 2009. This doctorate dissertation is aimed at development and validation of an assessment tool for lean warehousing. The assessment tool has based on eight lean constructs and fifty eight lean practices that were identified by the writer from the literature on lean manufacturing and other related topics. The identified eight lean constructs include visual management, standardized processes, continuous and levelled flow, pull system, work place organization, empowered employees, quality assurance and continuous improvement. The proposed tool was validated by applying in twenty eight assessments at twenty five facilities, however, for privacy reasons; the results of the assessments have not been included in the report.

Paul Mayerson (2012) has written a book "Lean Supply Chain Management" where has been included a chapter titled "Lean Warehouse: Low-Hanging Fruit". The writer has explained that because lean is in its early stages in supply chain management; therefore it is sometimes difficult to define the starting point for lean applications but many companies find the warehouse as the more convenient and suitable point to start the lean applications in a supply chain. Mayerson (2012) believes that most of the lean concepts can work well in warehouse, especially 5S, VSM, team building, kaizen, problem solving and error proofing, kanban/ pull system, line balancing, and cellular applications and general waste reduction. Mayerson (2012) further explains that constant motion of people and equipment in warehouse does not mean productivity and may not be necessarily moving as they might be stuck up in between processes causing the waste of time and space.

One of the important articles on the topic of lean warehousing (Applying lean concepts in warehousing operations) is authored by Frank C. Garcia who is a director of a business solutions and engineering services company in Bristol, USA. In this article the writer has discussed the application of value stream map (VSM) in a meet processing factory and in its warehouse. As a result of applying the technique of VSM, it highlighted the value added as well as non-value added activities in the form of a current state value stream map. After applying the necessary amendments and improvements in the flow of materials a future state value stream map is drawn to highlight the process time and lead time reductions. In the end it has been concluded that the lean improvements have reduced the order processing time by 50% and order lead time is reduced by 25%.

Other than by Garcia (2003), there are some articles available from internet (website) sources that highlight the importance of lean applications in warehousing. For example, in another article "Are your warehouse operations Lean?" Ken Gaunt (2006) has described that a typical warehouse order was being worked on 38 per cent of its cycle time; 56 per cent of orders time was idle while the remaining 6 per cent involved employees dealing with problems such as waiting for equipment, computer issues, interruptions and blocked aisles etc.

Contrary to the above discussion that supports the implementation of lean concepts in warehousing, there is a point of view that opposes the lean applications in warehousing operations. It explains that there is a contradiction between lean thinking and warehousing practices because lean strives at being just in time with a pull flow with no batching production and with preferably no inventory kept between the different processes. This given contrary point of view has been discussed and answered by Bozer (2012) that elimination of warehouses can only be in an ideal scenario because in real life there exist variations in demand, uncertainty in lead time and long lead times that cannot be fully predicted. This makes a warehouse necessary for in time delivery of the materials or the products to the production, assembling or customer.

In this study, it is also reviewed and analysed the available literature resources on the topic of lean warehousing as well as its allied topics including lean manufacturing, Toyota Production System (TPS), just in time (JIT) and warehouse management etc. A detailed overview of the literature based on books, journal papers, research articles and other sources of academic literature has been made. The topic of lean warehousing, however, still seems quite uncovered and least discussed in the academic literature. Prof. Bozer (University of Michigan) in 2012 has presented a project report titled “Developing and Adapting Lean Tools / Techniques to Build New Curriculum/ Training Programs in Warehousing and Logistics”. The report includes a detailed analysis of the literature on the topic of lean warehousing. Bozer (2012) has concluded that the warehousing and its related operations have been the subject of much academic research eg. warehouse design, control and operations, order picking, and automated storage/retrieval systems etc. However the topic of lean warehousing has been largely unexplored and undocumented in the academic community. Bozer (2012) further explains that certain links can be established between lean warehousing and some of the techniques mentioned in the said articles but none of the papers published in warehousing focus directly on the topic of lean warehousing. The techniques and metrics used in the papers published to date are more often aligned to conventional warehousing, such as minimizing picker times/distances for order picking as opposed to considering order due dates, takt times, and planned cycle times for the pickers. To the best of available information, till date, there are no scholarly, refereed published papers that focus on the subject of lean warehousing.

The review and analysis of the literature highlight the importance of the topic of lean warehousing and its relevance to the efficient performance of a supply chain. On the other hand the given situation depicts that the topic of lean warehousing yet has not been established like the subjects of lean manufacturing or warehouse management. The existing resources for understanding and explaining the topic of lean warehousing lack a broad basis of academic literature for research on the topic as well as for a thorough implementation of the concept in a warehouse. The topic of lean warehousing, however, has a good potential to be established as a subject of study and research although it has not been explored as much and so has remained uncovered.

The present study on lean warehousing is aimed at further exploring, explaining and organizing the topic of lean warehousing. The study is based on a thorough review of the existing literature on lean philosophy and concepts applied as lean manufacturing, warehouse operations and management, lean warehousing and Just in Time (JIT) etc. The learning outcomes of the literature review and analysis have been applied and presented for developing a theoretical modular approach for understanding the subject of lean warehousing and a practical approach to apply this model in a case study warehouse by developing a theoretical framework of lean warehousing. The proposed model of lean warehousing has been discussed and presented in chapter 03 of this thesis. The theoretical model of lean warehousing is composed of five main lean constructs and twenty lean applications. The main five constructs presented in the composition of the model are waste control, flow management, quality assurance, human resources management and continuous improvement. Each lean construct and its attributing lean applications have been discussed in detail to explain and justify its inclusion in the composition of the model of lean warehousing. Next to it, in chapter 04, there has been presented and discussed a theoretical framework for lean warehousing. It is has been discussed as a theoretical approach for the application of the proposed model of lean warehousing in a case study warehouse. Chapter 05 of the thesis is aimed at presenting the analytical conclusions of the study and expected benefits for the topic of lean warehousing.

Chapter 03

Model of Lean Warehousing

Lean warehousing is a combination of terms i.e lean and warehousing where as lean is a philosophy, a concept, an approach or a way of thinking that helps to shorten the total lead time, improve efficiency, reduce the cost of operations and enhance the productivity of the system. The lean concepts and tools are generic in nature, therefore it can be applied in multiple situations and working environments eg. manufacturing, services, supply chain management or warehousing etc. The implementation of lean tools in a given organization or working environment can be done under certain theoretical and practical guidelines that help to understand and implement the fundamental operational and organizational changes in the system. These guidelines would also help to understand the compatibility or incompatibility of existing practices in the system to lean implementation guidelines. Accordingly the implementation of lean in warehousing operations would also require some set of theoretical guidelines that would represent the operational and organizational requirements of lean warehousing. The theoretical model on lean warehousing is based on the detailed literature review of the topics mainly lean manufacturing and the other important topics like just-in-time (JIT), the Toyota Production System, Quality Assurance and Control, Human resources Management and Warehouse operations and management etc.

The conceptual analysis and thorough review of the topics mentioned above has been the baseline for shortlisting the important lean constructs that would be included in the model of lean warehousing. The characteristics desired to be included in the model of lean warehousing can be listed as comprehensiveness and applicability i.e the model has to be comprehensive in structure and should be easy to apply in different types of warehouses and should be helpful for the design, operations and performance evaluation of the warehouses.

The comprehensiveness of the model of lean warehousing means that the theoretical model of lean warehousing should include and discuss all the organizational, operational and human related characteristics that relate to the lean warehousing. In fact, lean warehousing is not simply a warehouse management practice but is a comprehensive organizational system and the proposed model of lean warehousing comprehensively covers all the related aspects.

The applicability of the model of lean warehousing means that the model of lean warehousing should be applicable to all types of warehouses and should not be type specific (types of warehouses have been discussed in the previous chapter).

The short listing of lean constructs for the theoretical model of lean warehousing has been based on the suitability of each lean construct for lean warehousing. It is important to mention here that it has been clearly described in literature that majority of lean application can be equally useful for warehousing operations, however it has never been mentioned in literature that all types of lean applications can be equally useful for warehouse operations. So for the warehousing operations only those lean applications would be short listed that can suitable for applying there in a warehouse set up. The second important point to be mentioned here is that lean applications have been grouped according to the aspects it covers in its application.

The most important aspect considered for defining the lean constructs for the proposed model is that the proposed lean constructs should sufficiently cover all the possible aspects of a lean warehousing i.e operational, organizational and human resources. Accordingly, there have been defined five lean constructs for the proposed theoretical model of lean warehousing. These lean constructs include waste control, flow management, quality assurance, human resources management and continuous improvement. For each lean construct have been short listed and defined its relevant lean applications that serve as the each attributes to lean constructs. The lean applications have been short listed by considering the aspect that they should be simple to understand and commonly discussed and applied in lean organizations. Learned from the literature, since the warehousing operations are simpler as compared to manufacturing operations, therefore the lean applications with simpler structure and easy to understand approach have been given importance as compared to rather complicated and more advanced lean applications.

The five main constructs of lean warehousing identified in this study are presented in figure 01. Each lean construct and its relevant lean applications have been discussed in detail for their relevance and justification of their inclusion in the proposed model of lean warehousing.

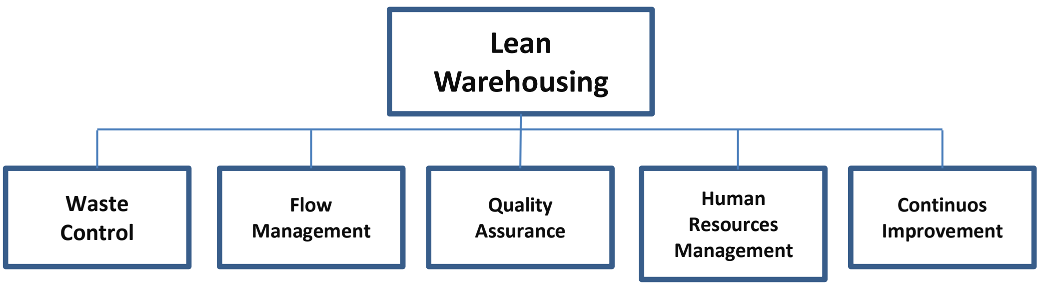

Figure 01: The five lean constructs of the proposed model of lean warehousing

1. **Waste Control**

Womack and Jones (1996) states that any human activity which absorbs resources but creates no value is called waste (“muda” in Japanese). The similar concept of muda has also been discussed by Womack & T. Jones, (2003), according to which the understanding of lean starts with the analysis of the so called "muda". Lean and "muda" are two contrary elements because "muda" means waste, specifically any human activity which absorbs resources but creates no value. Lean thinking supports waste control (muda reduction) by providing a way to specify value and line up value creating actions in the best sequence. Lean thinking helps to achieve better results with less human effort, less equipment, less time and less space, in order to satisfy customers' needs.

There are two types of waste i.e avoidable and unavoidable waste. The goal of lean thinking is to increase the value-creating activities to waste by eliminating the seven forms of waste presented by Ohno (1986). These forms of waste are defined as transport, inventory, motion, waiting, defects, over processing and over production. Waste has a fundamental importance for lean warehousing as the journey of lean starts with waste control and in the proposed model of lean warehousing it has been proposed as the first lean construct. In order to achieve the goal of waste control in warehousing operations, it needs to suggest the relevant lean application that can be important for this purpose. Based on the literature review and analysis, it has been suggested to consider four most commonly applied and simple lean applications i.e Value Stream Mapping (VSM), Workplace Organization (5S), Process Standardization and Preventive Maintenance for adding in the proposed model of lean warehousing. Each of the said lean applications have been discussed in detail for its relevance, importance and justification for suggesting for adding in the model of lean warehousing. Figure 02 represents the composition of lean construct of "Waste Control" along with proposed lean applications.

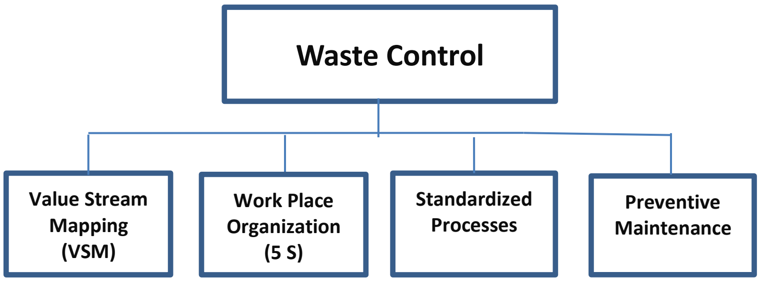

Figure 02: Waste Control in lean warehousing

i. Value Stream Mapping (VSM)

Value Stream Mapping (VSM) is a very useful technique used for identifying value added, non- value added and purely waste activities in all processes. Shook et al (1999) has described that the Value Stream Map (VSM) is the set of all specific actions (value added and non-value added) that are needed to take a product through the information and production flows of a manufacturing operation. In an article on “Applying Lean Concept in Warehouse Operation”, Garcia (2003) has described that in order to understand where to start the implementation of lean concepts in the warehouse, one of the most useful tools is the Value Stream Mapping. The current state value stream map shows how the warehouse currently operates and serves as the foundation for the future state changes. It serves as the starting point for developing the future state by highlighting the opportunities to reduce the lead time and processing time in the warehouse. Garcia (2003) has further described that using the current state map, the goal in developing the future state map is to eliminate as much as possible waste and make the flow continuous.

In previous work (a proposed framework for lean warehousing), Mustafa et al (2013) has also recommended the application of VSM in warehouse operations for highlighting the value adding and non-value adding / waste activities by drawing a current state value stream map. By applying lean techniques flow of material and information can be improved that would decrease the lead time of operations. The improved flow of material and information with reduced lead time can be shown by drawing a future state value stream map.

Value stream mapping (VSM) is a very relevant lean application to be recommended for waste control in warehousing operation and has been proposed to be added as one of the attribute to waste control in the theoretical model of lean warehousing.

ii. Workplace Organization (5S)

As described by Sabonski (2009), workplace organization has been identified as a basic lean principal by both Womack and Jones (1996) and Liker (2004). It has been already mentioned in table 1. Chapman (2005) has explained that 5S is a system of workplace organization that is composed of sort, set in order, shine, standardize and sustain. It is a basic principle related to lean manufacturing in practice. Chapman (2005) further explains that the philosophy of 5S systems can be explained as “there is a place for everything and everything is in its place”. The first step in implementing the 5S philosophy is to sort the useful or needed materials, equipment, machines and supplies for the work out of those are not. The next step after sorting is to set in order, organize, and visually represent the necessary material, equipment, machines and supplies. It would reduce the required travel and searching motions. The third step is to clean, shine and inspect all the work areas, equipment and machines. The fourth step towards better workplace organization is to standardize the actions required for workplace organization and maintain the improvements. The fifth and the final step towards workplace organization is to sustain the actions taken for this purpose. It includes creating check lists and developing schedules for auditing and reporting and providing feedback regarding compliance to the initiatives. The 5S system of workplace organization eliminates many forms of waste, improves visual management and can reduce the potential of errors. Gergova (2010) has explained that implementing 5S in the warehouse can improve the visibility, material flow, work organization and standardization of processes.

In previous work (a proposed framework for lean warehousing), Mustafa et al (2013) has also recommended the application of 5S (work place organization) lean technique for controlling the waste activities by making improvements in the system. The outcomes of this step present that how different waste activities as defined in previous step can be controlled by workplace organization. The outcomes of this step show as the good work place management (a place for everything and everything at its place), cleaning the work place, standardizing the process, preventive maintenance of tools and equipment, information and database management and ergonomics and safety applications can be helpful for waste control in warehouse operations and provide and good basis for the application of other lean tools.

iii. Process Standardization

Process standardization or Standard Operating Procedures (SOPs) is the third lean attribute proposed for including as the part of waste control lean construct. As described by Sobanski (2009), Standard Operating Procedures (SOPs) are the specific, written work instructions and steps that are required to complete a specific job, function, or task. Standardized work and planning are the amount of work dispatched to workers combining the steps, amount of work in process (WIP), and time required to complete the task.

The importance of proposing this attribute belongs to its significance as a very useful lean technique. The process standardization has been unanimously described as the fundamental principal of lean manufacturing by Ohno (1986), Shingo (1989), Womack and Jones (1996) and Liker (2004). It has been already mentioned in table 1. The importance and benefits associated with process standardization has been discussed in detail by Sobanski (2009) that states that standardized work dispatch information allows for accurate planning and tracking of work, the commodity grouping relates to combining similar types of products, tasks, or work into single dispatches to increase the density of the picking travel path. The common processes and best practices are identifying a standard process for determining the best methods for performing work and creating consistent output and the process for sharing that information internally and externally. Trailer loading and unloading processes relate to the methodology in which trailers are received and shipped to drive standard inbound and outbound processes. Creating standard loading, unloading, and storage principles for trailer's reduces variation, eliminates motion, and drives efficiencies between internal and external customers.

The process standardization can be a useful lean application for waste control in warehousing operations as it provides well defined work instructions that can help to reduce waste in warehousing operations. Accordingly it has been added in the model of lean warehousing as a lean attribute to waste control.

iv. Preventive Maintenance

It is a proactive approach for maintenance of equipment, machines and tools to avoid defects and breakdown from occurring. Regarding the importance of preventive maintenance function in lean warehousing, Bozer (2012) has described that preventive maintenance ensures that equipment and facilities used in warehouse operations are well maintained and available for use all the time. The outcomes learned of lean manufacturing regarding preventive maintenance is also applicable to warehousing operations. The proper maintenance and availability of dock equipment, pallet jacks, the fork lifts, the order picker trucks, the pick carts, the packing stations and their related parts is a basic function of lean warehousing.

The preventive maintenance can help to avoid types of waste in warehousing operations caused by out of order tools and equipment eg. The workers may have to wait due to non-availability or out of order equipment and tools that would cause delays and increase the time of operations and would ultimately add to the lead time of the whole process. A good preventive maintenance of tools, equipment and facilities used in warehouse operations can help to control the given types of waste and add to the overall efficiency of the warehouse operations.

2. Flow Management

Material flow has been considered as a basic principal of lean manufacturing by all five lean scientists i.e Ohno (1986), Shingo (1989), Womack et al. (1990), Womack and Jones (1996) and Liker (2004). This has already been mentioned in the table of lean constructs (Table 1). Flow is the third of the five lean principals presented by Womack and Jones (1996). It describes the motion of the products through the company. It supports an aspiration to go from batch flow with queues to single product flows. This is important when trying to keep the products moving and don't make queues.

As suggested by the book "The New Lean Pocket Guide XL (2006)", the advantages of continuous flow can be the ability to shorten the lead time by having no or minimum work-in-process inventory. It can make it easy to identify defects or problems before they get to the customers. It can also be helpful for the availability of multi-functional workers where they are most needed and also it creates the ability to utilize standard work to maintain flow with less experienced operators.

Flow Management has been proposed as the second lean construct for the model of lean warehousing. In warehousing operations the flow management starts with the arrival of materials or goods in receiving (unloading) area of the warehouse and continues through different processes and sub processes till the delivery to the customer. Flow of materials and goods through these steps is an important consideration in lean warehousing because it determines the velocity of goods and materials between different work stations and storage areas of a warehouse. The lean construct of flow management is composed of lean applications i.e levelled flow, pull system, optimized picking plan and cross docking. The figure 03 represents the composition of lean construct of "Flow Management" and relevant lean applications. Each lean application has been discussed in detail for its relevance, importance and justification for suggesting for adding in the model of lean warehousing.

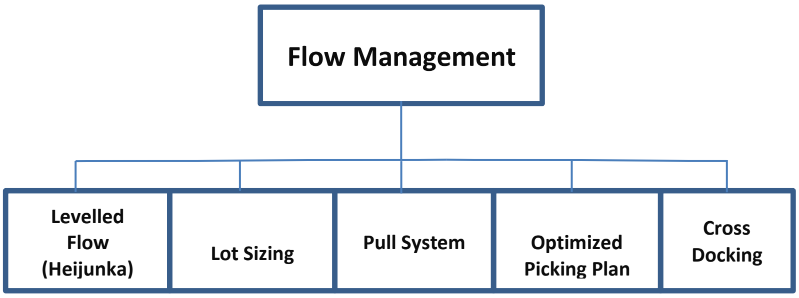

Figure 03: Flow Management

i. Levelled Flow (Heijunka)

According to Sabonski (2009), levelled flow is the concept of creating a balance between the movement of the materials and workers within work segments and between the work stations to manage the work in process (WIP). As described by the book "The New Lean Pocket Guide XL (2006)", the levelled flow has several advantages like it levels production in a value stream by volume and variety and reduces the inventory levels. It enables to establish a pull system in the flow of materials. In a production line, the process of load levelling includes several steps like calculation of takt time, determining the pitch for each product, create a production sequence, creating a heijunka box and putting the heijunka box into operation. Although that the majority of the discussion on levelled flow belongs to the manufacturing and production related set up but the concept of levelled flow is equally important for warehousing operations as well and helps to improve the flow of materials. The levelling of the flow of materials in warehouse operations i.e dividing the equal load of work among different segments of warehouse operation can help to improve the flow of materials in warehouse and avoids the bottle necks in flow of materials. Considering the advantage associated with this lean practice of "levelled flow", it has been considered as an attribute to flow management.

ii. Lot Sizing

Lot sizing was specifically identified as a fundamental principal of lean manufacturing by all five authors, Ohno (1986), Shingo (1989), Womack et al (1990), Womack and Jones (1996), and Liker (2004) and it is already given in Table 1. According to Sabonski (2009), lot sizing is related to batch sizes that are physical quantities of work utilized by functions to move material through each process step. The other lean techniques related to lot sizing can be work in process (WIP), kanban system, Quick Change over, lead time tracking, inventory turns and order frequency.

Bozer (2002) has explained that in lean manufacturing, the production batch size is reduced by reducing or eliminating machine set up time. The material handling batch size, on the other hand, is reduced by reducing the material handling distance through one piece flow manufacturing cells and internal milk runs that supply those cells. In warehouses as there is no production activity unless light assembly or kitting is performed and small production lot sizes means performing the above processes in small batches. In some cases, it may be difficult to achieve eg. materials often arrive at receiving in large batches such as truck loads, which is undesirable in terms of lean. In the process of unloading the truck, incoming large batches are often broken down into smaller lots for subsequent processes such as put-away, which often mean that incoming parts must be staged at receiving. Likewise work is generated when order picking is performed. Picking the orders in large batches (such as wave picking and batch picking multiple orders at a time) is contrary to one piece flow. In fact, for order picking, one piece flow means the orders must be processed (picked, verified and packed) one order at time, which will be considered as one piece order processing.

The concept of batch sizing is applicable in warehousing although the sense of batch sizing for warehousing operations is different from that of manufacturing processes. The discussion shows the importance of batch sizing in flow management for manufacturing processes as well as warehouse operations. Accordingly it has been included as an attribute to flow management in lean warehousing.

iii. Pull System

According to Womack and Jones (1996) and cited by Tostar (2008), pull means that no one upstream should produce a good or a service until the customer downstream asks for it. We can think of pull in two ways, macro and micro levels. In macro level the company push the products to a certain point and responding to a final customer pull signal. This is a very effective way to reduce overproduction. The similar point has been explained by Sabonski (2009), according to this pull systems are the triggering of production or material flow based on the demand at the downstream while the push system approach is pushing the product or material without considering the demand at downstream end. According to Thompkins et al (1996), emphasis on customer service has entailed a shift from the traditional system of distribution (push). This change in thinking has redefined the way companies perceive customer demands. Ken Ackerman (2007), a seasoned warehouse practitioner, in his book “Lean warehousing” has described that the traditional production and distribution companies produce in bigger quantities and push to the market through retailers. Improvements in logistics facilities have helped to replace the push system with pull. The pull system relies on a very high degree of reliability in storage and delivery at the level of distribution centres.

There are certain advantages and disadvantages of both Push and Pull system, therefore companies may prefer to adopt hybrid models. However, the introduction of pull system in a production system or a supply chain helps to regulate the flow of materials and information and reduces the total volume of inventory in process. It also affects the flow of materials and information among different segments or work stations in a warehouse and would help to avoid stocking of heavy inventory in the warehouse for longer time durations. It can be concluded that the Pull system applications in a production system or in a supply chain would ultimately improve the flow of materials in warehouse operations. According to the given importance of Pull system, it has been included as a lean attribute to flow management.

iv. Optimized Picking Plan

Picking mean moving the product from storage area to packing according to the customer order. Picking the right items within assigned time for the process is a very important activity among warehousing operations. As described by Mulcahy (1993), there are three basic methods where the picker (worker) either walks or ride to the product or the product moves from storage to the workstation. All these methods need a routing pattern for the picking to direct the picker to the products or vice versa and to minimize the non-productive time of walking, traveling between pick positions or hand movement between two pick positions within a container. There are several strategies (plans) that can be applied in a picking process in warehousing eg. order by order picking, batch picking, wave picking and zone picking.

The importance of the order picking process in warehouse operations has been discussed in literature as according to Berg et al (1999) order picking accounts for the largest percentage of warehouse costs. Order picking ranges upto 65% of the total cost and 50% of the workforce in a warehouse. According to Frazelle (2002) 50% of the total operation cost in warehouse belongs to order picking. The given information on costs of order picking in warehousing operations shows the importance of order picking process that can affect the total cost of warehouse operations in the end. However, a faster and an optimized picking plan can help to improve the flow of materials in warehouse operations as well as reduce the overall cost of operations. There are several applications that can help to optimize the picking plans. Toster et al (2008) has discussed two applications i.e Travel Salesman Problem (TSP) and Enterprise Resource Planning (ERP) system for optimizing picking operation and resources utilization in warehouse operations. There are also some other useful applications suggested by Sabonski (2009) that can help to optimize picking plans and improve the overall flow of materials in warehousing operations eg. Layout and zones, velocity and slotting, travel distance logic and programming and cellular structure. Picking plan optimization directly affects the cost and flow of materials in warehouse operations therefore optimized picking plan has been added to the model of lean warehousing as an attribute to flow management.

v. Cross Docking

According to Sabonski (2009), cross docking is the movement of product directly from receiving area to packing and delivery area where customer demand requires to eliminating the steps of placing the products into storage and consolidating freight to minimize transportation expenditures. As described by Frazelle (2001), materials can be received in several different manners. Direct shipping is when items go directly to the customer without going to the warehouse in between. In traditional receiving allocated areas are given to the receiving items and they are temporarily stored there before being put into the secondary or primary storing. Direct secondary put away is when items are put in a secondary storage direct after receiving, before going to picking area. Direct primary put away is when items are put into the picking area direct after receiving it. Cross docking is when items go into the warehouse and then reloaded and shipped. In direct shipping the items do n't enter into the warehouse at all, therefore items do n't pass through any warehouse processes and can n't be considered for comparing to other practices in terms of warehouse lead time (time between receiving and shipping; that is the sum of total cycle time and waiting time in storage). Among the other four practices of materials receiving in the warehouse, the traditional receiving practice has the maximum number of operations through which the items have to pass before shipping or delivery to the customer. Direct secondary put away and direct primary put away are the receiving practices with comparatively lesser number of processes and operations through which they have to pass before delivery to the customer. Among the given four receiving practices, cross docking is the most agile and less time consuming because it does not include the time spent by the items in storage area of the warehouse but are directly transferred to packing and delivery area. The ultimate advantages of this practice are saving of time and cost and improving the flow of materials in warehouse operations.

3. Quality Assurance

The third lean construct for lean warehousing suggested in this model is quality assurance. As described in table 1, it has been discussed as one of the basic construct of lean manufacturing by all five authors, Ohno (1986), Shingo (1989), Womack et al (1990), Womack and Jones (1996), and Liker (2004). According to Bozer (2012), in warehousing operations, a quality error (defect) can arise in many different ways, some common possible sources of which are: storing of SKU in wrong location during put away, picking of wrong items or wrong quantity of items and wrong order packaging. There can also be some information related errors in customer's billing address or shipping address etc.

In "A proposed framework for lean warehousing" presented by Mustafa et al (2013), it has been described in detail the quality related problems in warehousing operations and their potential causes. According to the given analysis there can be different types of defects (quality errors) in warehouse operations (receiving, storing and tracking, picking, packing and delivering). These errors can be like placement of goods in wrong order and place after receiving, items received but not appearing in database, items not yet received but entered in database, errors in tracking of inventory, picking the wrong items or wrong number of items from the storage, packing or shipping the wrong items or in wrong order or in wrong number or to the wrong address or with incorrect information given on the packaging. The possible reasons of said quality problems as described in the proposed framework are human errors (individual), poor coordination among workers, wrong information conveyed to workers, delayed entry method used for entering the received items in database, poor database management, lost data or information, errors caused by poorly prepared picking and packing lists and wrong information and errors given in delivery lists.

It can be explained with reference to given discussion that quality assurance with reference to warehousing means avoiding the mistakes and errors during different steps of warehousing operations. There may be several types of errors related to counting, sorting, placing, picking, packing or delivering of goods etc. These errors may be related to information, human understanding, or use of tools and equipment. To control and avoid these errors and quality related issues in warehousing operations, it needs to devise a strategy and define lean applications that help to control quality related issues and (where applied) assure the error free delivery of the products and items according to the customers' requirements.

In the proposed model of lean warehousing, quality assurance has been added as the major lean construct for its importance in warehousing operations. The lean construct of quality assurance has been added with the lean attributes that can help to avoid these mistakes and errors and can help to improve quality of the warehousing operations. The proposed lean attributes to quality assurance as suggested in the model of lean warehousing are quality at the source, visual management, root cause analysis and inspection and automation. Each of these proposed lean attributes has been presented in the given figure and discussed in detail for understanding its impact on quality assurance in lean warehousing operations.

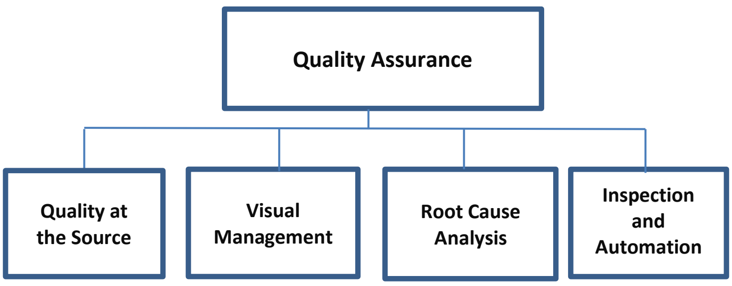

Figure 04: Quality Assurance

i. Quality at the Source

Quality at the source belongs to lean manufacturing and means that there should not be production of bad work at any workstation. Self-checks and successive checks can be good way of ensuring the quality at the source. According to Bozer (2012), the primary principal for quality in lean manufacturing is “quality at the source” that is opposite to inspecting the quality into the finished product. Errors and quality related issues should be checked at the source and defective materials and products should not pass through to downstream operations.

A similar approach for warehousing operations has been suggested by adding the lean attribute of “quality at the source” in the proposed lean warehousing model. The way it can be implemented in warehousing operations is by quality inspection by self-checks and by successive checks at every step of warehousing operations rather checking the quality at the last steps (packaging or delivery).

ii. Visual Management

Visual Management helps to improve organizational performance because when you see something you can understand it better. Visual management is a business management technique that makes important information visible to all workers. It can be in the form of a notice board, slogan, indication light, cards or visual display units etc. The objective is to use visual aids to make communication simpler and attractive. An extension of visual management is colour management. For example, both Toyota and Fanuc’s production lines make use of coloured bins and light signals to control production flow. Visual and colour aids are low cost tools but have very useful psychological effects (internet sources).

As described by Sabonski (2009) visual management has been specifically described as a fundamental principal of lean manufacturing by four of the five authors Ohno (1986), Shingo (1989), Womack and Jone (1996) and Liker (2004). It also has been mentioned in table 01.

As described by the book “The New Lean Pocket Guide XL (2006)”, there are different visual control tools and applications that serve specified objectives. The most commonly applied visual control tools and applications are story boards, sign boards, maps, kanban signals, checklists, indicators, andons/ alarms and mistake proofing. Storyboards are used to share information about projects or improvements for the purpose of education and motivation of employees. Signboards are used to share vital information at the point of use. Maps are used to share actual processes, standard operating procedures and directions etc. Kanbans are used to control the withdrawal of inventory (or tools) in and out of supermarkets, lines and cells. It can also be used to regulate orders from the factory to suppliers. Checklists are used to provide an operational tool that facilitates adherence to standards, procedures and criteria etc. Indicators are used to show correct location, item types, amount, direction or proper motion by building that information into the workplace. Andons / alarms are used to provide a strong or unavoidable sign when there is abnormality or action needs to be taken. Mistake-proofing is used to prevent abnormalities or problems from occurring or from moving to the next process or step.

The warehouse operations involve multiple searches for tools equipment and supplies, placement of items, picking of items and transfer to packing stations and delivery area. The support of different visual management applications in warehousing operations can help to control different errors and quality related issues mainly those which occur because of poor visibility or poor information.

The lean attribute of visual management help to reduce errors and wastage of time and resources and ultimately become a good source of quality assurance in warehousing operations.

iii. Root Cause Analysis

Root cause analysis is an application used in lean manufacturing to determine the root causes of problems and stratify defects to determine countermeasures. Pareto (fish bone diagram), 5 Ws (what, when, where, why and who) and 5 whys are some of the commonly known techniques that are used in lean manufacturing for root cause analysis. In fact the lean techniques for root cause analysis are quite generic in nature and can also be applied in different working environments other than manufacturing processes eg. warehousing operations or other service sector related organizations etc.

Mustafa et al (2013) has presented a root-cause analysis of 7 wastes of warehousing operations by applying 5 Ws lean technique. One of the 7 types of wastes is “defects” that represents the quality errors and mistakes occurring at different steps of warehousing operations. The application of 5 Ws for analysis of defects shows that there can be different types of defects in warehousing operations and there can be specific root cause for each of them that may relate to human error, poor flow of information, poor coordination among workers, poor database management, mistakes in packing and delivery lists etc.

For the flexibility and generic nature of lean techniques used for root cause analysis, it has been added in the model of lean warehousing as a lean attribute to the quality assurance.

iv. Inspection and Automation

As described by Sabonski (2009), inspection and automation are the quality assurance measures taken to identify defects during the process and after the process. Specifically about the inspection and automation in warehouse operations, Bozer (2012) has explained that several techniques most of them involving bar code scans or

RFID tags are used in warehouse operations to help minimize put away and picking errors. Workers can scan both the barcodes on a unit load and on the rack to ensure that the unit load was placed in the correct storage location.

Mulcahy (1993) in his book “warehouse distribution and operations handbook” has explained various automatic systems used for the purpose of identification in a warehouse operation. Some of the identification methods are used on transport systems and others are used to identify the products (SKUs). These identification tools include wire pong, photo reflective, bar code, magnetic strip, optical character recognition, radio frequency, machine vision, voice recognition and surface acoustic wave.

The use of automatic identification and inspection systems help to reduce errors and quality issues mainly caused by wrong information and human errors during warehouse operations. The reduction or control of errors in warehouse operations improves the overall quality of warehouse operations accordingly the lean attribute of inspection and automation has been added to the composition of lean construct of quality assurance in the proposed model of lean warehousing.

4. Human Resources Management

The fourth lean construct in the proposed model of lean warehousing is related to Human Resources Management. In the literature on lean manufacturing, it has been mentioned and discussed as “People” which also relates to the role of employees in lean implementation and lean transformation of an organization. According to Sabonski (2009), this construct (human factor) has been identified as a fundamental principal of lean manufacturing by four of the five authors Ohno (1986), Womack et al (1990), Womack and Jones (1996), and Liker (2004), also described in Table 1. Howardell (2004) has further described that to have lean organization; one has to have what he terms lean people. Lean people make a lean organization, and as such the people have to become lean before the organization get lean. Liker and Meier (2007) seem to agree, stating that it is not possible to operate a lean system without highly capable people.

Ken Ackerman (2007) in his book on lean warehousing has discussed the topic of lean leadership that relates to the coaching and management of human resources for better quality and productivity in warehouse operations. Also Bozer (2012) has described the human factor as a component of house of lean. According to this, the human resources / employees need to be flexible, capable and highly motivated as a key factor for successful implementation of lean philosophy in an organization. As described by Cook et al (2005), the house of lean for supply chain/ logistics includes in itself the factor of human resources as “culture” which represents the human related working culture in a supply chain organization. The characteristics of “culture” related to employees are: flexible employees, capable employees and reliable employees. For organization, the desired characteristics are; teamwork, empowerment and respect for workers. The lean attributes included in the composition of Human Resources Management are leadership and commitment, Training and communication, team work and empowerment, recognition and motivation. The Composition of this lean construct is described in the following figure.

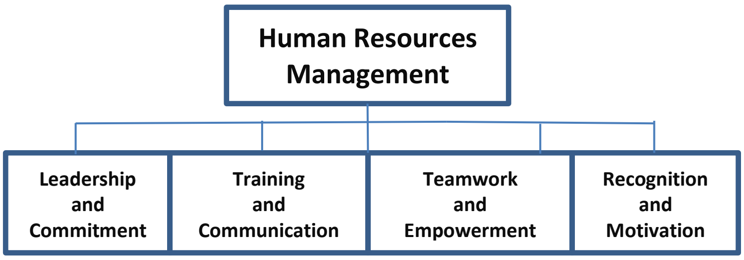

Figure 05: Human Resources Management

i. Leadership and Commitment

According to Sabonski (2009), Leadership direction and roles relate to the sense of urgency, change initiative origin, ownership and input of employees as it relates to implementing lean warehousing in the facility. Similarly as described by Ackerman (2007), the change agent is an absolute requirement for implementation of lean thinking in a warehouse operation, leadership is a necessary part of the program. An effective leader is one who has the ability to inspire others to make productive changes. The leader has a vision and inspiration that is accompanied by an in touch management style that makes the team enthusiastic about following the leader's vision. Ackerman (2007) further explains that the role of the warehouse leader is to constantly remind people that quality is of prime importance. The most important measurement of warehouse quality is the perception of the customers, and especially frequent experiences in receiving deliveries from that warehouse.

According to Wickens (1999), the role of leadership in lean environment is to create the strategy, the organizational values, the sense of purpose among the workers and the targets set by the organization, the living them so that all employees are inspired can be displayed at all levels: and in which all people are valued, can perform to their full potential, establish their own goals, successfully implement their goals and innovate. Lean leadership makes sure that the lean achievements are sustained and the organization is improving continuously.

According to Drew et al (2004) the team comprising of senior management must form the organization's culture by setting expectations about employees' behaviour. In organizations normally people take their directions from those with authority and influence, and would likely to modify their behaviour if they would see change being followed by those on the top. Part of the lean challenge is that senior management must be much closer to front line operations than ever before. Managers who want their employees to engage in the lean change effort must first be willing to engage with the employees. For a successful lean journey, the leadership should set the targets, devise plans to achieve it, and engage the wider organization in turning these plans into reality. The process of developing a shared understanding of the target state is as important as the solution itself and it can play an important role in aligning a leadership team. The leadership has both responsibilities of creating the lean implementation plans as well as to ensure their implementing through right roles to deliver the lean plan, and that all of the leaders take personal responsibility for their particular piece of the overall lean implementation plan. Senior managers demonstrate their commitment to lean and can see for themselves whether lean improvements are taking hold. The analysis of the literature on lean leadership shows that the role of the leadership and its commitment to change is an important factor for a successful lean implementation plan in an organization. The importance and role of the leadership and commitment for lean warehousing supports the inclusion of leadership and commitment as an attribute to human resources management in the model of lean warehousing.

ii. Training and Communication

As described by Wickens (1998) organizations can only succeed if they have a highly trained, flexible and innovative workforce or we can say that words what he terms is “knowledge workers”. Also described by Sabonski (2009), communication strategy is the depth of sharing and understanding of metrics and information and the frequency and timeliness of employee concerns being voice and resolution determined.

As described by Puvanasvaran (2013), since lean implementation involves employees at all levels, there is a need for a good communication process to enable a smooth flow of the process. One of the main challenges of communication is to ensure that the changes are being readily accepted and implemented by everyone at all levels. According to Piatkowski (2006) what organizations would normally forget is that it needs a total understanding of all the processes for the successful implementation of lean. Organizations must involve the right people for lean implementation and should adopt the learning model developed by Toyota. Many organizations start training activities and make effort to implement different aspects of lean as a quick solution. Toyota has developed in over 50 years what is known as the Toyota Production System (lean). Organizations cannot have long-term results if they try to implement lean fast without investing in training.

Liker and Meier (2006) have described that in lean organizations, development of people (human resources) can n’t be separated from the development of production system so that if the organization want to succeed with lean in the long term. For Toyota, developing exceptional people is the number one priority. Piatkowski (2006), based on his experience in North America with Japanese training practices, has described that the important aspects of the training system of Toyota. It describes that training is done by managers and leaders, it can also be on the job training, it includes understanding the principals of lean, five necessary skills of a leader (knowledge of roles and responsibilities, knowledge of job elements, training skills, leadership skills, and kaizen skills) and development of managers and leaders. Piatkowski (2006) further describes that training for a lean implementation is a multi-dimensional activity. It is not as simple as just creating a list of lean tools and methodologies, and learning how to use them. There must be reasoning that explains why certain tools or methodologies must be implemented first and later we learn how to use them in a correct way, we can learn more. Some tools and methodologies can be presented in a classroom; some must include exercises, a practical portion of training and the others can be learnt only by applying them i.e learning by doing.

The given discussion shows that lean is more about changing the way people think and behave to the situations than about changing the things i.e how they look and are run. The development of lean thinking is possible only by affective training and communication to organization (warehouse) employees regarding lean methods and requirements for their affective implementation.

iii. Teamwork and Empowerment

According to Sabonski (2009), teamwork and empowerment relate to the organizational work structure utilizing team leads, the authority given to individuals to make changes and to initiate the continuous improvement process. Further described by Miller (2005), the Toyota Production System or a lean organization is focused on the horizontal flow of the work that is managed by highly empowered teams that can make on spot decisions. It has become the most successful form of organization. It is not only a work system, but a management system and a social system. The lean teams can achieve high performance as well as high economic efficiency that should have been the objective of all organizations. Some of the required characteristics of lean teams or a team-based organization are that the teams are designed according to the process that clearly describes the purpose of the teams, do it top to bottom, be business focused, clarify who will make what decision and how it will be made and clearly redefine the role of managers.

Mullar (2005) further describes that the implementation of lean teams or a team-based organization is an exercise. It requires redefining of the organization, developing new skills, new habits and a new culture. It also needs motivation and discipline. An athletic team does not show high performance only by practicing when it is in the mood to perform. It does not develop by practicing randomly or in a disconnected way. It does not develop without a clear definition of the roles and responsibilities and a plan for each position on the team. To develop the skills and habits of a team based organization there must be a clear plan and a disciplined effort.

The given discussion on teamwork and empowerment explain the role and importance of this lean attribute (teamwork and empowerment) for human resources management system that has been included as a lean construct in the composition of proposed model for lean warehousing.

iv. Recognition and Motivation

According to Sabonski (2009), employees' recognition and compensation relates to the process for identifying individual and group outstanding achievements and the reward structure associated with the recognition. As discussed in Lean Culture: Collected Practices and Cases (2004- Productivity Press), for transforming a traditional company culture into a lean culture, you need to educate your work force and train them in lean methods and tools and constantly reinforce what you have taught. Detailed evaluations are a part of a comprehensive lean strategy that includes everything from a team based approach to extensive training, from manufacturing cells and kaizen events to employee recognition and rewards.

Nelson et al (2005), in the book "1001 ways to reward employees" has described that the recognition and motivation of employees is very important for transformation of the organizational cultural. It has its importance for engaging in good employee recognition practices when you want to create an efficient and productive workplace. But unfortunately, many organizations either don't do this or don't do this well as needed. The most useful method for employees' recognition and motivation for their efforts is to thank them by name, describe what they did that is being recognized. It is vital to be specific because it identifies and reinforces the desired behaviour, explains how the behaviour or activity made you feel. Assuming you felt some pride or respect for their accomplishment, point out the value created by the behaviour or activity to the team or organization; thank the people again by name for their contribution. Whenever you make life at work more satisfying for your employees, you are increasing the rewards they get by doing their jobs well and you make them want to continue to do so.

Learnt from the literature, the recognition and motivation of employees is one of the important factors of lean transformation and implementation at organizational level. Accordingly it has been included in the composition of lean construct of Human Resources Management in the proposed model of lean warehousing.

5. Continuous Improvement

In a business management process standards are set and employees have to follow them. Maintaining and improving the set standards is one of the main objectives of the management. When standards get improved, it must bring a noticeable improvement in the output of a process or procedure. The objective of the continuous improvement is to maintain the improvement and to improve upon it again and again as an endless cycle. On the other hand if the set standards are not maintained, the improvements and desired outputs would slip back. Lasting improvement can be achieved as people work to raise standards because maintenance and improvements go hand in hand (Kaizen: the Japanese Philosophy of Constant Improvement, 2006).

As described by Sabonski (2009), the continuous improvement was specifically identified as a fundamental practice of lean manufacturing by all five authors, Ohno (1986), Shingo (1989), Womack et al (1990), Womack and Jones (1996) and Liker (2004) also given in Table 1. According to the given importance of continuous improvement, it has been included as the fifth lean construct in the composition of the model on lean warehousing. It relates to the gradual and continuous review and elimination of waste activities from the operational stream and the system in general. This lean construct is composed of the lean attributes of PDCA (plan, do, check, act), Kaizen events and employees' suggestions.

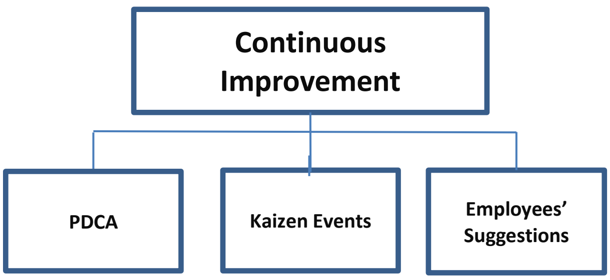

Figure 06: Continuous Improvement

i. PDCA (Plan, Do, Check, Act)

PDCA is the Deming (1994) cycle for continuous improvement and refers to the planning and sustaining activities as well as specific continuous improvement in this analysis. In the four step process, plan means analysing current situation, prioritise and select problem, opportunity, confirm root causes, choose solutions (long term, short term), set objectives, targets and measures, resources requirements and risk analysis. The second step is Do that means carry out plans. The third step is check i.e measure improvements or check improvement. The final step is Act that means to make it a standard practice and ensure that problem will never happen again.

As described by Goreflo and Moran (2010), to start the PDCA process, it needs to form the team that will participate and develop a communication plan for the activity. In fact PDCA involves a team approach to problem solving. It needs to nominate a team leader and team members, and check for the following questions: Do we have the right people i.e., those who are directly involved with the area needing improvement? Does the team need training? Who will facilitate the team and process? Another key step is to develop a team manifesto, which serves to provide focus and clarity regarding the team's work. Additional resources on tending to teams as they move through the PDCA process may prove useful to optimize the team's performance.

As described by Sokovic et al (2010) the PDCA cycle is more than just a tool; it is a concept of continuous improvement processes adopted in the culture of an organization. The most important aspect of PDCA lies in the act segment after the completion of a project when the cycle starts again for the further improvement. The approach described by PDCA seems to have quite importance for continuous improvement process. Therefore, it has been added as a lean attribute in the model of lean warehousing as a part of the composition of lean construct of continuous improvement.

ii. Kaizen Events

According to Sabonski (2009), the Kaizen Events means the physical continuous improvement activities and documentation of those activities and employees have the direct impact where changes are involved in developing solutions for improvement. As described by Thessaloniki (2006), it was learnt as the business lesson of the 80s that Japanese firms in their quest for global competitiveness demonstrated a greater commitment to the philosophy of continuous improvement as compared to the companies in western countries. Japanese used the term Kaizen for this philosophy that means improvement or continuous improvement involving everyone in the organization from top management to managers then to supervisors and to workers. In Japan, the Kaizen concept is so deeply engrained in the minds of both managers and workers that they sometime even do not realize that they are thinking of Kaizen as a customer driven strategy for improvement.

According to James Womack (1991), with Kaizen the job of improvement is continuous i.e never finished and the status quo is always challenged. Kaizen techniques became famous when Toyota used them to rise to world automotive leadership. Despite undertaking large projects, Toyota's staff was encouraged to identify problems, no matter how small but trace their root causes and apply all possible solutions. Thessaloniki (2006) has further described that the message of the Kaizen philosophy is that not one single day should go by in the firm without some type of improvement being made in some process in the company. Kaizen is everyone's job; it requires sophisticated problem-solving expertise as well as knowledge and professional skills and it involves people from different departments working together in teams to solve problems. Kaizen focus on the management of change and is a methodology in the correct way that helps to improve manufacturing operations, on a continual and incremental basis following the right steps i.e establish a plan to change whatever needs to be improved, carry out changes on a small scale, observe the results, and evaluate the results and the process and determine what has been learned. The starting point for improvement is to recognize the need. So Kaizen principles emphasis problem-awareness and points towards identifying problems. When identified, problems must be solved, so Kaizen is also a problem-solving process. But, most of all, Kaizen is a management philosophy that forces higher standards at all levels of the organization.

According to Imai (1986), there are three pillars of kaizen i.e housekeeping, waste elimination and standardization. He further states that the management and employees must work together to fulfil the requirements for each category. As described in the booklet “Kaizen: the Japanese Philosophy of Constant Improvement (2006)”, the value of improvement is sure. In business, improvements generally result in better safety, quality and productivity. The process of improvement starts with recognition of the need, the need is highlighted when a problem is recognized. According to the Kaizen philosophy, when a problem is identified, that problem must be solved. Once a problem is solved that typically results in the need to change standards that will replace a previously set standard. A new high standard is created and is the basis for the continual improvement that is resulted from kaizen.

The Kaizen as an approach for continuous improvement in a system is quite important. Therefore, it is believed that adopting Kaizen approach in lean warehousing can help to establish the process of continuous improvement as a strong lean warehouse practice. Accordingly, it has been added as an attribute to the model of lean warehousing.

iii. Employees’ Suggestions

According to Sabonski (2009), employees suggestions are the process used to capture employee ideas for improvement, implementation and recognition. According to Thessaloniki (2006), during 70s many business professionals from western countries visited Japan to observe the suggestion systems in progress as part of kaizen umbrella methodology and after return they started applying it in their companies by introducing the systems like that. However, the process of obtaining ideas from employees is not a new concept even in the western countries. Kodak company started a similar program in the United States. British Royal Navy adopted an employees' suggestion system in 1772. Since their inception, the suggestion systems have passed through an evolutionary process and new form of this system includes continuous improvement and employee driven idea systems (EDIS). On the other hand, some quality experts agree to the idea processes or suggestion programs are more alive but a well-designed idea program will significantly add to an organization's quality standards and help it to cut costs and improve its performance. By suggestions system, employees participate in continuous improvements activities in the workplace and play a vital role in upgrading standards. Employee suggestions or ideas management systems serve two kinds of objectives i.e serve as productivity enabler as well as a culture change enabler.

The importance of employees' suggestions system has its significance in developing a continuous improvement system in an organization. Accordingly, it has added as an attribute in the composition of model for the lean warehousing.

Model of Lean Warehousing

The figures 01 to 06 are meant to highlight the characteristics of the model on lean warehousing presented in this study. To have a complete picture of the model, the given lean constructs and applications have been combined and presented in the figure 07.

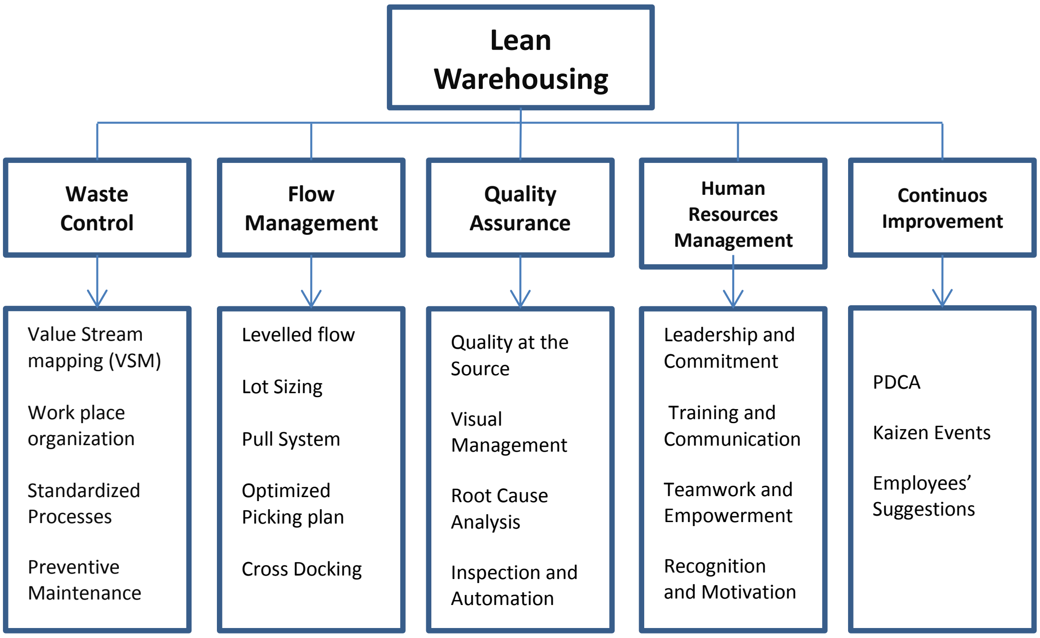

Figure 07: Model of Lean Warehousing

The proposed model of lean warehousing through its constructs and attributing lean applications, comprehensively, covers the topics of operational management, quality assurance, human resources management and continuous improvement. The model has been designed with a generic approach i.e without any specification of the type of warehouse. Since the study lacks a practical case study warehouse, in order to narrow down this short coming, it has been presented a theoretical application of the model in a case study warehouse by developing a frame work for lean warehousing. The structure of the framework has been based on the outcomes presented in the model. The framework has focused, discussed and included in it the first construct of the model i.e waste control and attributing lean applications i.e value stream mapping for warehouse operations. The framework has been presented in chapter 04.

Chapter 04

A Proposed Framework for Lean Warehousing

Considering the outcomes of the conceptual analysis and the model of lean warehousing, this chapter is aimed at understanding and developing an approach for the theoretical application of the model to a case study warehouse. The proposed approach has been structured as the framework of lean warehousing. For the comprehensiveness of the framework, not all the proposed constructs and lean applications as mentioned in the model of lean warehousing have been discussed and included in this framework but the framework has focused the first most construct (waste control) of the model of lean warehousing i.e waste control has been focused as an initial point to start with the theoretical application of the model of lean warehousing in a case study warehouse.

The outcome of this part of the study is a 3-step framework of lean warehousing. The first step of the proposed framework is about classifying and investigating waste ("muda") in warehouse operations by applying the 7 wastes categorisation and 5Ws (what, when, where, why, who) lean tools. 5Ws has been adopted here because it a generic and quite intuitive technique to find the causes of waste activities. The waste as classified by Taiichi Ohno (1943) is as transport, inventory, motion, waiting, over processing, defects and overproduction. However, overproduction would be excluded in this case as the warehouse operations do not include the conversion of raw materials into products. The taxonomy of 7 types of waste was originally developed by Toyota's Chief Engineer Ohno as the core of the Toyota lean production system. It has been used because the proposed 7 types of waste are the baseline of the lean concept and are applicable to both manufacturing and service industries.

The goal of the first part of the framework is to suggest an approach that relies on the combined benefits of the Ohno's waste classification and 5Ws technique to study types of waste and their causes. Such approach can be applied to all the warehouse processes, however, for example, just the outcomes of the receiving process are discussed in Table 02. The description of the waste in the receiving process is mainly based on the review of the literature on warehouse operations and management and lean warehousing as well. One example of this is the work by Toster and Karlson (2007-08). The said work has studied the warehouse operations in detail and has set a baseline for the waste classification and analysis performed in this research. The possible types of waste have been explained according to the description of activities provided by Toster and Karlson and their causes have been identified by using the questions suggested by the 5Ws technique.

Operation	7 Wastes ("muda")	5 Ws Analysis				
		What (Deascription of waste)	**When**	**Where**	**Why**	**Who**
Receiving (Unloading, unpacking, sorting)	Transport	Long turnaround time for vehicles/ trucks	After completion of receiving operations	Warehouse dockyard	Poor yard control , not optimized strategy for unloading vehicles	
	Inventory	Bottlenecks in the flow of goods / unnecessary stock	During the receiving / unloading process	In the area of the warehouse between receiving and storage	Poor layout planning Inadequate working methods Poor line balancing	
	Motion	Walking around by the warehouse staff to search and find the equipment and tools used in the receiving process. Walking around by workers to find empty spaces for placing the unloaded items	At the beginning and during the receiving process.	In the receiving / unloading area	Lack of straitening (setting in order) principles for tool placement Bottlenecks in the material flow Oversized inventory in the receiving area, information errors, human errors	
	Waiting	Vehicles have to wait a long time before starting the unloading process	On vehicle arrival at the warehouse	In or outside the dock area	Already occupied dock positions, poor scheduling, poor dockyard control. Arrivals of vehicles earlier or later than scheduled	Planning and scheduling department
	Defects	Placement of goods in the wrong order and area after receiving Items received but not appearing in the warehouse information system	During the receiving/ unloading process	In the receiving/ unloading area During the material handling process	Poor record keeping, information errors, delayed data entry	Multiple departments
	Over Processing	Unnecessary repeated checks for product quantity and quality	During the sorting and quality assurance processes	In the receiving area	Information errors Human errors	
	Over Production	Not Applied				

Table 02: The 5Ws Analysis of 7 Wastes of receiving operation

The outcomes of the first step of the framework helped to define the sources of waste in warehouse operations and to organize them in a structured way. Further it has paved way to devise appropriate actions to reduce such waste activities. According to the model of lean warehousing, the first proposed lean application for waste control i.e workplace organization (5S) lean technique has been applied to a theoretical case study warehouse. It has been included here in the frame work of lean warehousing as the second step of the framework. The proposed technique i.e 5S can be applied to all the considered warehouse processes. For example, the outcomes of applying 5S to the receiving process are detailed in Table 03. The waste description ("what") of the receiving process as given in Table 02 has been the basis for applying 5S to each of the identified types of waste separately.

Operation	7 Wastes ("muda")	Description Of Waste	5 S Applications				
			Sorting (Seiri)	**Straitening** (Seiton)	**Shining** (Seiso)	**Standardizing** (Seiketsu)	**Sustaining** (Shitsuke)
	Transport	Long turnaround time for vehicles/ trucks	Reduce the unnecessary stay of vehicles in dockyard areas Remove unnecessary equipment and material placed in receiving area	Assign an appropriate place to each vehicle in the dockyard area	Define and keep the paths for vehicle movement clean and tidy	Standardize the practice	Continue following the procedures and make periodic checks/ audits
	Inventory	Bottlenecks in the flow of goods / unnecessary stock	Remove the unnecessary stock on the way between the receiving and storage areas	Move the goods to the next phase in the warehouse process at the earliest Make line balancing for receiving and storage operations	Keep the working and transit areas clean and tidy	Standardize procedures for the inventory flow from the receiving to the storage area	Continue following maintenance and workplace cleaning standards
Receiving (Unloading, unpacking, sorting)	Motion	Walking around by the warehouse staff to search and find the equipment and tools used in the receiving process. Walking around by workers to find empty spaces for placing the unloaded items	Remove all the tools and equipment from the working area at the end of their use. Create an empty space in the receiving area for upcoming goods by moving the unpacked and sorted items to their next positions in the warehouse.	Put all the tools and equipment in designated places and mark it accordingly. Segregate and mark the places dedicated to different steps of the receiving process	Keep all the tools and equipment clean and maintained. Keep the receiving area clean and tidy during the receiving process as well as at the end of it	Develop corrective and preventive maintenance procedures for tools and equipment and standardize them according to the work requirements. Develop standards for keeping aclean work place and assuring the removal of the unnecessary inventory	
	Waiting	Vehicles have to wait a long time before starting the unloading process	Sort out the unnecessary inventory in the receiving area and remove the unnecessary activities before the start of the unloading process	Review the vehicle arrival schedules and synchronize them with the outgoing schedules		Develop special procedures for vehicles arriving out of schedule	
	Defects	Placement of goods in the wrong order and area after receiving Items received but not appearing in the warehouse information system		Place the goods in the predefined and designated area and order. Perform data entry process	Keep the storing areas clean	Standardize procedures for inventory handling	Continue following the procedures and make periodic checks/ audits
	Over Processing	Unnecessary repeated checks for product quantity and quality		Review the process of quality and quantity verification		Standardize the process of checking product quantity and quality	
	Over Production	Not Applied					

Table 03: Waste reduction in receiving operation through 5S Application

The second step of the framework suggests improvements to reduce the waste identified in the first step. However, a tool is needed in order to support the implementation of such improvements and the quantification of the associated effects.

To fulfil these objectives, the third part of the framework relies on another lean application that has been suggested in the model of lean warehousing i.e value stream mapping or VSM. It represents all the value added and non-value added activities in warehouse operations and the related flows of goods and information, together with the linkages between them. As described by Garcia (2003), the VSM gives a visual representation of a process and helps to evaluate the order lead time and the processing time.

The approach suggested in the third part of the framework is to draw a value stream map for representing all the warehouse processes. The sequence of operations in Figure 1 is adapted from Frazelle (2001). "Inventory stocking" and "storage inventory" represent the materials waiting between two warehouse operations, while c/t and c/o mean cycle time and change over time respectively. Additionally, the double-line arrows represent material flows and single line arrows represent information flows between warehouse operations and the information (database) system. Since this is an example of the way to implement the third step of the framework, the time values for the different operations have not been set and the lead time as well as the processing time cannot be represented in numerical terms.

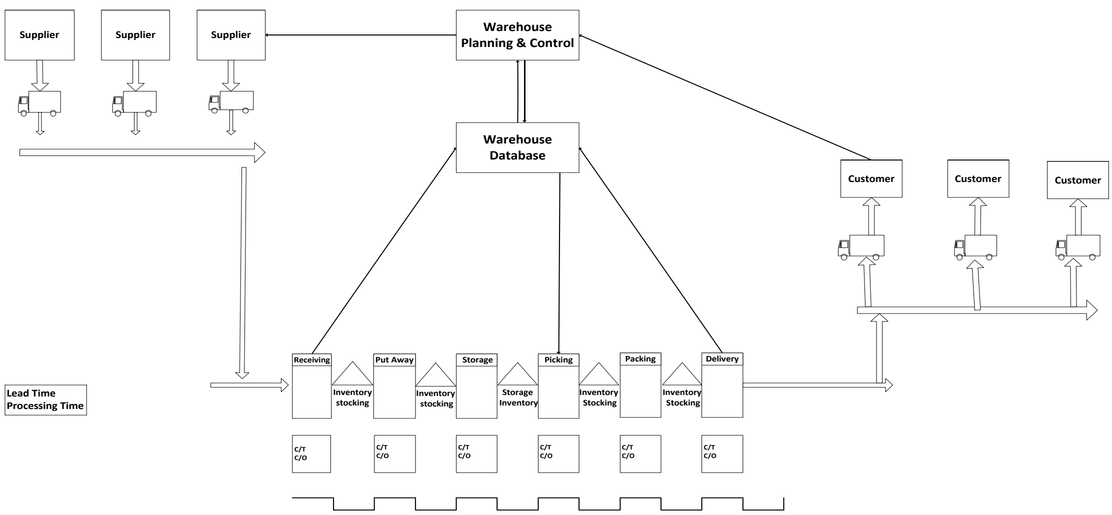

Figure 08: Current State Value Stream Map

The shown current state map is supposed to be a situation of a warehouse suffering from waste activities and information related problems, as mentioned in the first part of the framework (Table 02). In the current example, the receiving process is the operation considered for revamping. It is assumed that there is a need to reduce the material handling time by controlling waste and non-value added activities and by improving the information flow. Based on the conceptual outcomes of the first two steps of the framework, the processing time of the receiving process can be decreased by adopting the improvements out of the 5S application (Table 03). As a consequence to that, the total lead time of the warehouse will be improved. For example, the following re-engineering activities can be carried out:

- Revamping the information flows between different parts of the warehouse operations and the database.
- Improving the method of unloading vehicles.
- Improving yard control for incoming vehicles.
- Improving layout design by using the line balancing technique.
- Tools and equipment used in different warehouse operations are well cleaned and maintained and placed in dedicated places.
- Removing delays in the data entry in the warehouse information system.

It is important to mention that after the application of these improvements the future state VSM can be redesigned and the efficiency parameters, such as reduction in lead time or processing time, can also be assessed.

The most important benefit related to this framework is that it gives an idea how the given constructs and their lean applications can be applied in a case study warehouse and what affects and improvements they can bring. The discussion of constructs and lean applications is limited to waste control but it is just to draw an idea about the approach. The same approach can be used for other constructs and lean applications.

Chapter 05

Conclusions

The objective of this study is to thoroughly review the literature on lean warehousing and its allied subjects and present the concept of lean warehousing in modular form and develop an approach for theoretical application of the model in a case study warehouse. The outcomes of this study are based on enhanced literature review and analysis. The criteria for short listing of the constructs for the model of lean warehousing are based on two characteristics i.e comprehensiveness and applicability. It can be further elaborated that the proposed model would comprehensively describe all the relevant characteristics required to be in a lean warehousing system. It includes operational, quality assurance, human resources and continuous improvement related characteristics of lean warehousing system. Secondly because the model has not been designed for applying in a specific type of warehouse, therefore, it would be applicable to all warehouse organizations irrespective of the type of warehouse. The frame work of lean warehousing has been designed on the basis of the model of lean warehousing i.e the constructs and lean warehousing presented in the theoretical model of lean warehousing, therefore, the characteristics of the model of lean warehousing i.e comprehensiveness and general applicability are also the part of the outcomes of the framework of lean warehousing.

Keeping in mind both the theoretical and the practical aspects, it can be expected that the study may have implications for both practitioners and researchers. On one hand, to a general warehouse practitioner, it gives a baseline for investigating and re-engineering warehouse activities according to the lean principles. On the other hand, to a researcher it can help to find new opportunities for fostering continuous improvement in warehouse operations. In particular, it can be a good starting point in order to structure analysis on lean warehousing and can stimulate a more integrated use of lean approaches. Finally, the proposed approach can inspire studies about the connections between different lean tools and their applications for lean warehousing practices.

The most important limitation in this work is the absence of a real case study warehouse therefore the practical implementation of the proposed model of lean warehousing is still missing. In order to narrow down this short coming with the help of a theoretical application approach in a warehouse, there has been developed and presented a framework of lean warehousing. Since real time values are not available, general efficiency parameters cannot be applied. Additionally, this research has suggested several warehouse improvements. However, it has further elaborated these points by proposing an approach for theoretical application of the proposed model in a case study warehouse.

The combination of both i.e literature based theoretical model of lean warehousing and framework of lean warehousing covers all the operational and human related factors of lean warehousing therefore it can provide a better guideline for understanding and applying the concept and practices of lean in a case study warehouses and for academic researchers; it can provide opportunities to further explore the topic and contribute to the subject of lean warehousing. In nut shell, it can be concluded that the outcomes of this study can be beneficial to both practitioners, in order to evaluate and improve warehouse operations, and researchers, in order to find new opportunities for continuous improvement in warehousing. In general, it can be concluded that lean for warehousing is not just a tool but a way of dealing with every day operations. Lean warehousing assists in performing activities more efficiently, accurately, and with less damages and loss of inventory. The labour time can be more productive and resources, such as floor and storage space, are better utilized. Finally, the velocity is improved and efforts can give significant financial advantages for an organization.

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