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Full Length Research Paper

Lean software tool for lead time reduction

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Lean manufacturing, or simply lean, is a production process used to eliminate the waste from all phases of an organization's operations and in improving the long term maximization of company resources. Finding a problem is the first step and essential part of a research process that can be investigated in the production process of a factory. For example, the major problems found in the warehouse area of a food factory were related to products' space allocation, loading and uploading. This study deals with the application of a computerized lean manufacturing technique to reduce waste by decreasing lead time in the warehouse area of the food factories. The created software, named survivor tool, is tested on the warehouse area of a food factory and the percentage of the lead time reduction was 33.3%. The achieved value for the lead time was calculated based on the 80% reduction on products waiting time for space allocation, the 12% reduction on products' handling and the 85% reduction on products' uploading process.

Key word: Lean manufacturing, food factory, warehouse area.

INTRODUCTION

Lean manufacturing, simply known as lean, is a system which consists of tools and methodologies that employ a lesser amount of inputs to produce the same output in a traditional manufacturing system (Panizzolo, 1998). Lean manufacturing focuses on making the highest quality product at the lowest cost and delivering them on time (Liker and Wu, 2000). It works as a systematic method to remove waste by all members of the organization from all areas of the value stream (Worley, 2004). In summary, it is called lean as it uses the less amount of everything required to make manufactured goods or do a service (Hayes and Pisano, 1994). Lean identifies seven types of waste which are correction, motion, overproduction, conveyance, inventory, processing and waiting (Askin and Goldberg, 2002). So, lean reduces the human attempt, the engineering effort, the defects in the finished product, the factory space for the same output and the in-process inventories in the factory. The practical research of lean manufacturing uses an efficiency improvement technique which consist of discovering a practically-relevant trouble, examining the potential for research co-operation, obtaining a deep understanding of the subject, innovation of an answer or idea in building a problem-solving construction, realizing and testing the answer, considering the applicability of the solution, and discovering and analyzing the theoretical contribution (Lukka, 2003).

Finding a problem is the first step and essential part of a research process that can be investigated in the production process of a factory. Surveying is a method used to evaluate the implementation grade of the selected lean theories (Wan and Chen, 2008). The surveys provide data collection tools during leanness testing of the firm (Soriano-Meler, 2002). The lean evaluation techniques should be able to assist in selecting areas that have improved, whereas supervision for development can be classified into compliance and performance based assessment (Nightingale and Mize, 2002).

This research is focused on finding problems related to the warehouse area of food factories and in creating a software tool to reduce the waste associated with the activities of the warehouse area.

Problem statement

Based on the investigation, study, inspection and

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observation of this research, the major problem in the warehouse area of food factories consist of:

(i) Delivering goods from the production area to the warehouse area.
(ii) Waiting for space allocation by the operator.
(iii) Loading the products on the platform.
(iv) Selecting the product for uploading based on the expiry date.

A simple guide plan organized by the operator reduces the waste because of the required time to manage the loading-uploading process in the warehouse area. This research presents how the operation system of a storing area can be improved using computerized lean manufacturing concepts and techniques.

Research objectives

The main objective of this research is to generate a computerized lean manufacturing system to reduce waste due to lead time and processing time in loading-uploading practice in the warehouse area. This study includes both theoretical analysis and experimental work in site. The detailed objectives and scope of the topics explored in this dissertation are as follows:

(i) Lead time reduction in the warehouse area due to the decreasing product's waiting time for space allocation, delivering and product uploading process.
(ii) Preparing the guide plan of the platform which presents the best location for products' loading, the products' expiry date alerts to order for uploading, the best location of products on the platform for uploading, and the loading-uploading order reporting in a selected sequence time by the user.

LITERATURE REVIEW

The lean manufacturing system cannot be organized in a similar path or employ a similar tool for different cases (Lewis, 2000). Different sections of companies have different lean implementation methods and tools. Finding the best tool, to remove problems, from the vast tool packages of a company is difficult (Wan and Chen, 2008). In a study by Pavanskar et al. (2003), it is reported that companies have applied wrong lean techniques and tools when changing to a lean association. This misapplication can be as a result of using a single tool to eliminate all the wastes in a factory and using all the tools to eliminate each single problem (Marvel and Standridge, 2009). Using an incorrect tool causes waste in organizations' time and money, and decreases the employee's confidence as well than lean tools (Marvel and Standridge, 2009). So, it is important to use the correct lean tool at the correct time for the right kind of company.

This study deals with the application of computerized lean manufacturing theories in reducing waste by using improvement methods, such as decreasing lead time and processing time in the warehouse area of the food company. Frank and Garcia (2003) introduced the following issues used to decrease both lead and processing time as improvement methods in the warehouse area:

(i) Decrease in the material management time, that is, uploading from deck, put away, and the palletizing process.
(ii) Dependability concerns with the strapping and finding of metal machines.
(iii) Decrease in the time spent on loading a truck.
(iv) Reduction in the time spent on checking inventory position and aging.

In addition, the significance of space allocation has long been documented in many situations to reduce waste in the warehouse areas (Vollman et al., 1968). There are several lean assessment tools of the roadmap approach developed by researchers and they are summarized in Table 1.

By creating a software program which presents a simple plan with a specified position on the platform for space allocation, and products' loading and uploading, products' expiry date can be useful in decreasing lead time and processing time in the food company.

METHODOLOGY

The data collected for the case study in the current research are provided based on the in site inspection and investigation, questionnaire courses, and face-to-face interview. The categories mentioned in the questionnaire courses were provided after the in site inspection was used to complete the investigation practice. The face-to-face course improves the data collection provided through inspection and questionnaire courses. The data collection helps us to find the major problem in the warehouse area of the Persian Dairy Company as a case study in the current study. The significance of space allocation in contributing to efficiency has long been reported in many situations, such as factories, offices and warehouses (Vollman et al., 1968).

The investigated platform consisted of 300 spaces in three layouts, 100 spaces in each layout, as shown in Figure 1. The dimension of each space is 1000 × 1000 mm. The surveying tool was created based on the following variable items:

(i) Space allocation is based on the nearest position to the production area in reducing the transferring time.
(ii) Products' loading on the platform is based on the space coloring order which indicates the free shelf in each space division.
(iii) Uploading is based on products' expiry date.
(iv) Alert for uploading is based on the expiry date as a result of loading products on the platform.

A software tool is used as a computerized lean manufacturing method in eliminating waste by reducing lead time in the warehouse area. The created software algorithms are defined in Java

Table 1. Various lean software tools in different applications.

No.	Software tool name	Tool application
1	LESAT tool	A software tool used to review the degree of a company's maturity in its use of lean theories and practices
2	Rapid plant assessment (RPA)	A software tool applied to find the improvement opportunities in manufacturing services and processes
3	Soriano-Meier and Forrester's Method	A system used to evaluate both the grade of commitment to lean manufacturing and the degree of the adoption of lean theories in developed companies
4	Lean checklist self-assessment (LCSA)	A tool used to recognize the large sort of outcomes resulting from lean implementation
5	LAYOPT	An investigation and optimization software tool used to find the best solution of facility layout problems in single and multiple floors
6	Time Wise Simulation	A tool applied for flow material which is supplied to the warehouse by a supplier and then is supplied by material handlers to different workstations
7	Quick changeover (QCO)	QCO tool is a technique used to decrease the required time for operation setup that causes elimination of waiting time, NVA activities and overproduction.
8	Total productive maintenance (TPM)	TPM tool causes minimization of disruptions, elimination of waiting time, and emphasizes on employee involvement and preventive maintenance
9	Visual controls	Visual control tool ensures the smooth and safe running of the production process and so eliminates overproduction and waiting time

programming. The applied software tool surveys the allocation of the empty space of the warehouse area based on the expiry date on the platform, while the generated software tool surveys the best space for the products' loading on the platform and the products' uploading for outside delivery. Using the current software tool as a space allocation package helps engineers and layout planners to properly order the loading-uploading products to reduce lead time.

ANALYSIS AND DESIGN

As earlier mentioned, the main objective of the current study is to reduce waste by reducing the lead time and processing time in loading-uploading practice in the warehouse area of food factories. The overall structure of the system applied for the software generation is shown in Figure 2.

Software analysis

The total qualities or attributes of the resulting system are described by non-functional requirement (NFRs). Other expressions for NFRs are "constraints", "quality attributes", "quality goals", "quality of service requirements" and "non-behavioral requirements" (Stellman, 2005). Actually, NFRs describe how an engineering system is assumed to be, but functional requirement describes what an engineering system is assumed to do. NFRs are usually the case of "system shall be <requirement>", while functional requirements are usually in the form of "system shall <do requirement>". The NFRs, in terms of quality, are classified as follows:

(i) Performance qualities: Observable at running time, such as security and usability.
(ii) Evolution qualities: Embodied in the static structure of the software system, such as testability, maintainability, extensibility and scalability (Wiegers, 2003).

The functional and non-functional requirements applied in the current study are as follows:

(i) Functional requirement: The case study used determines a goal-oriented set of interactions between external actors and the system under consideration. The user with a special objective in mind creates a used case which drives the system to a satisfactory goal. The sequence of interactions between actors and the system is explained by the defined used case to deliver the service that satisfies the goal. The mentioned used case

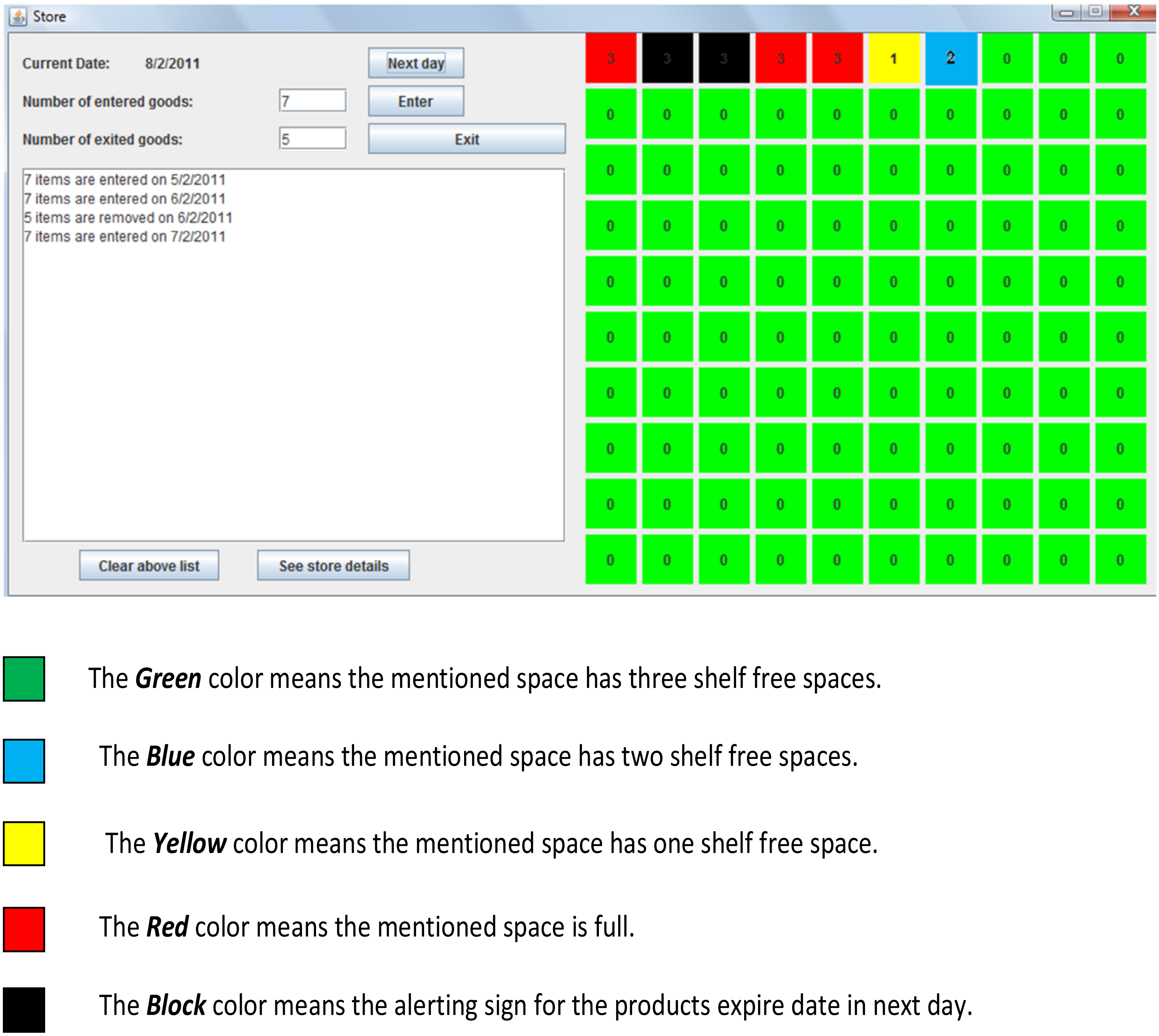

Figure 1. The space defined for each layout on the platform. The first, second and third layouts in the program are defined by green, blue and red color, respectively. Also, the alerting sign for the expiry date has been shown by the black color.

diagram involves the following four functional requirements:

(1) Identification of the capacity of the store.
(2) Finding the best free space for storage.
(3) Considering the products input-output date.
(4) Uploading the products according to the expiry date.

(ii) Non-functional requirement: This comprises performance requirements, reusability and flexibility requirements, usability requirement, maintainability requirements and extensibility requirements.

Software design

The software component named Survivor was designed with the following classes:

(1) Date: The class date saves the date of products in day, month and year. The presented class has three attributes which are defined as follows:

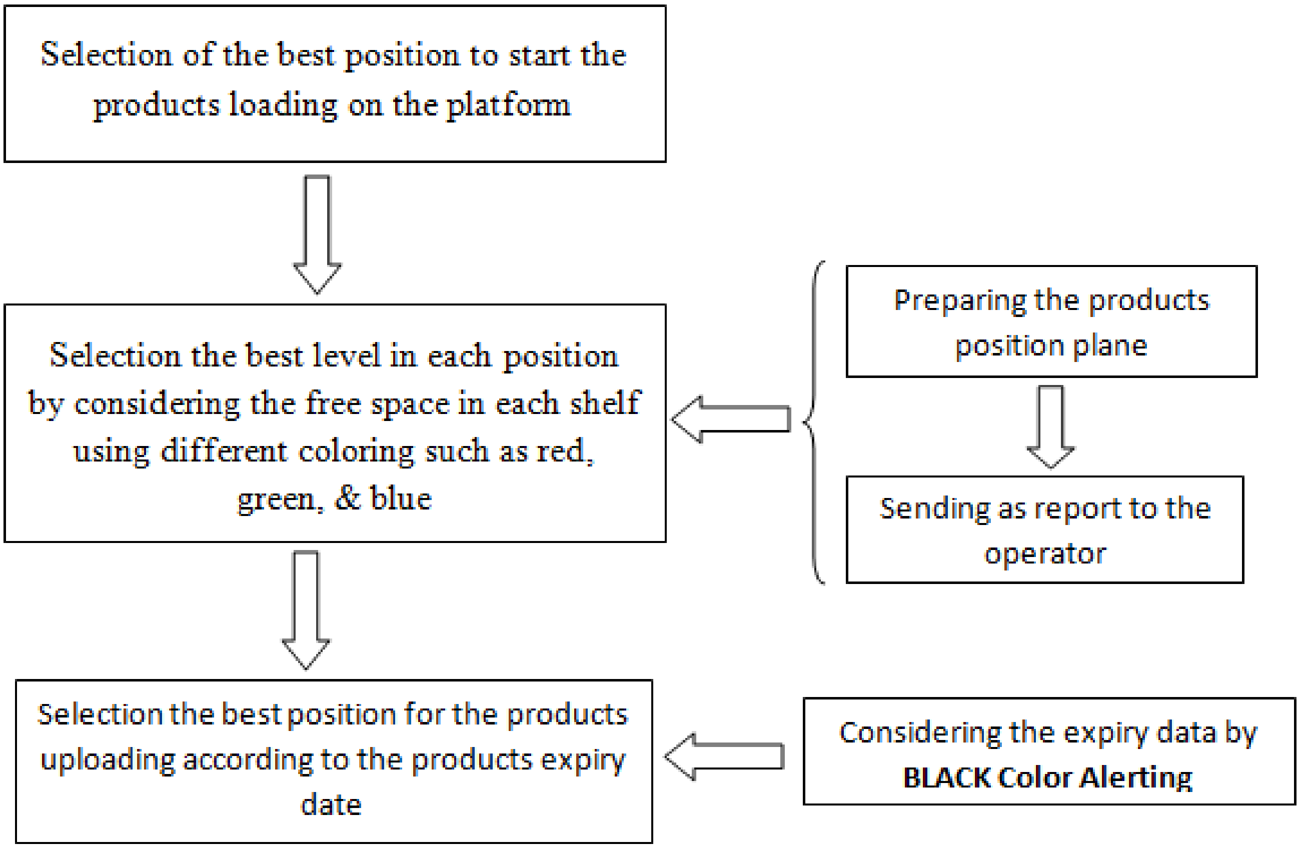

Figure 2. The overall structure of the applied system for software generation. The best position for the manufactured goods' uploading must be close to the production area in order to reduce time for products' transfer.

(i) iny y: It represents the year.
(ii) int m: It represents the month.
(iii) int d: It represents the day.

(2) Goods: The starting date of the products' storage, the duration of the storage in the warehouse area and the expiry date are saved by this class. The presented class has five attributes which are defined as follows:

(i) Start date: This item represents the starting date for products' storage.
(ii) Duration: This item represents the duration of the products' storage in the warehouse area.

(iii) Expiry date: The products' expiry date is represented by this item.
(iv) Name: This item, as a string variable, represents the products' name.
(v) Def: The definition of the products is represented by this item.

(3) Main: The main page is visible after program running and also all variable items are arranged by the 'main class'. The three attributes in the 'main class' is presented as follows:

(i) Start page: This item is a string variable that represents the main page for entering products' information.
(ii) Title: This item represents each part title related to products' information.
(iii) Visible: This item represents the visibility of the system.

(4) Store space: The capacity and limitation of the store's space is determined in the "store space" class. The two attributes in the "store space" class is presented as follows:

(i) Capacity: This item is an integer variable that represents the present capacity of the goods stored in the warehouse area.
(ii) Goods number: This item, as an integer variable, represents a set of information regarding the number of products in the storage area, the number of loaded products, and the number of uploaded products. Also, all the information regarding the number of products in the storage area can be printed out.

Table 2. A comparison between before and after lean manufacturing and lead time reduction.

No.	Activity	Expected time (h)		Lead time reduction (%)
		Before lean	After lean	
1	Handling products	2.5	1.5	40
2	Waiting for space allocation	1.5	-	100
3	Loading products on the storage area (platform)	1	0.5	50
4	Looking and selecting products for uploading according to the expiry date	1.5	-	100
5	Uploading products	1.5	1	33.3
6	Loading on truck	2	2	0

(5) Store: The information regarding the stored goods in the storage area is reported in the “store” class. The four characteristics in the “store” class are defined as follows:

(i) Current date: This item represents information regarding input, output and expiry date.
(ii) Goods: This item, as a string variable, represents the information about the stored products.
(iii) Number goods: This item, as an integer variable, represents the number of the stored products in the storage area.
(iv) Store spaces: This item represents a report regarding the free spaces in the storage area.

DISCUSSION

The manufacturing processes in the tested companies before simulation are presented in the following activities:

(i) Raw material: Client prepares the fresh milk and delivers to factory.
(ii) Production area: The products’ manufacturing consists of the following stages as described earlier: (a) boiling milk, (b) mixing and packing, (c) putting into warm air room, (d) putting into cold air room, and (5) preparation of the handling of products to the warehouse area.
(iii) Products’ handling: It entails handling products to the warehouse area and waiting for space allocation.
(iv) Loading products on the platform (storage area): Searching for the best position for products’ loading.
(v) Uploading products for customers: Looking for the products according to their expiry date.

The time requirement for different activities is measured during the inspection and investigation process as a result of the products’ loading-uploading process in the warehouse area. A comparison between before and after lean manufacturing by using the created software is shown in Table 2 and Figures 3, 4 and 5. The mentioned time is considered for transferring one set of products to customers.

The time requirement after lean manufacturing in different activities mentioned in Table 2 and Figures 3, 4 and 5 is reduced. The causes of the time reduction after lean manufacturing are explained as follows:

1. Handling products: The starting position for products’ loading in the warehouse area is selected in the created software and there is no need to handle products between the stored products.
2. Waiting for space allocation: Due to the prepared plan of the warehouse area’s free space by the software, there is no need for time requirement.
3. Products’ loading: The created software specifies the free space and so the products’ loading will be reduced.
4. Selecting the products’ position for uploading: There is no need for selection because the printed plan specifies the position.
5. Uploading products: This activity will proceed by using the printed plan by the system.

According to Table 2 and Figure 3, the created software reduces the time requirement for the “waiting for space allocation” (Item No. 2) and “looking and selection of products for uploading according to their expiry date” (Item No. 4), but Items No. 6, 5 and 3, “loading for transfer”, “uploading” and “storing”, were not affected by the created system. However, the percentage of the lead time reduction for different activities is presented in Figure 4. The lead time reduction occurs for Items No. 2 and 4 by 80 and 85% reduction, respectively. Also, the effect of all activities in the total lead time reduction is shown in Figure 5. The effect of different activities in lead time reduction according to the presented figures is presented by the following equation.

Selection products > Waiting > Handling > Uploading > Storing > Loading for customer

A comparison between before and after lean manufacturing process presented a mean lead time reduction that equals 33.3%.

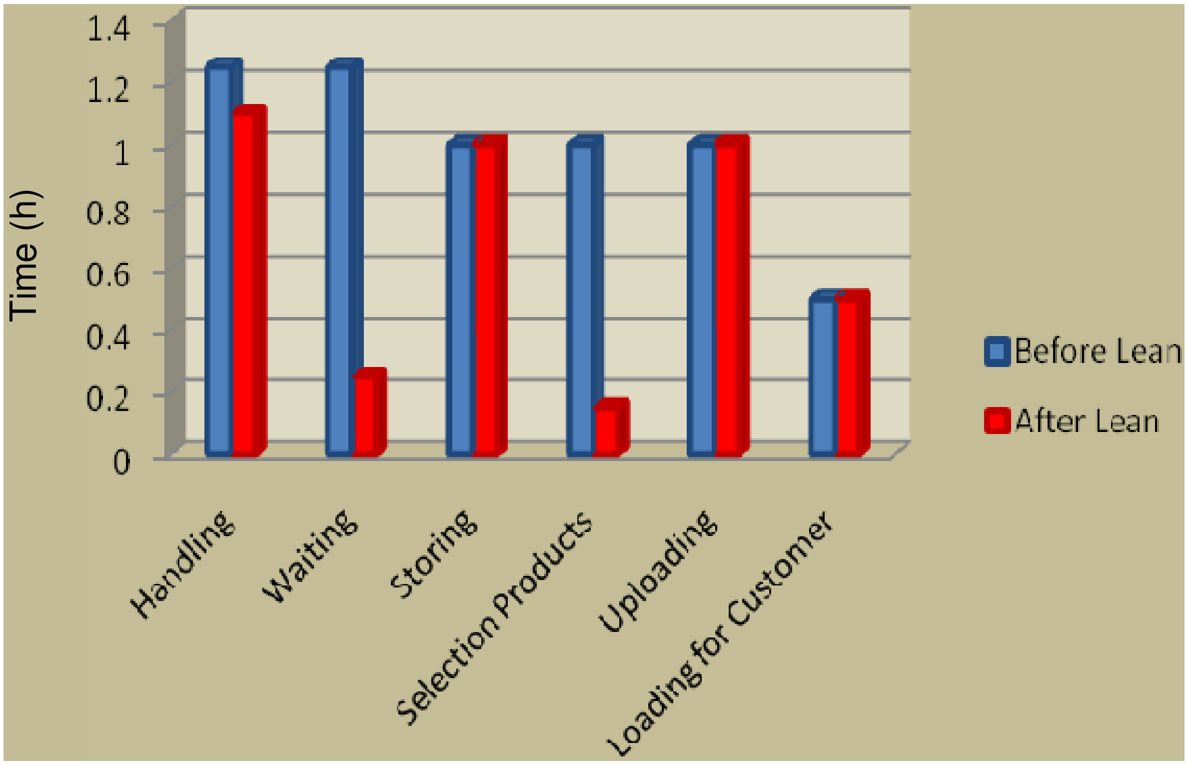

Figure 3. Time measurement of the production activity before and after lean manufacturing.

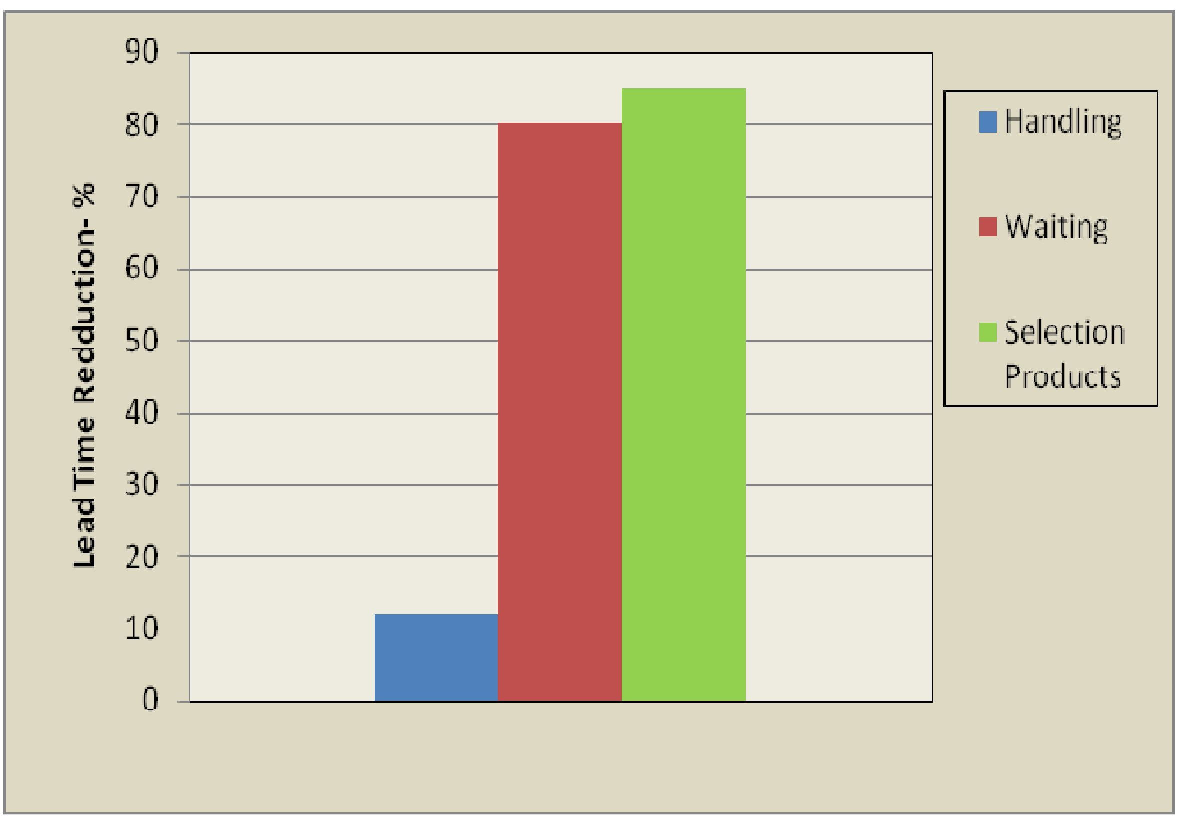

Figure 4. Lead time reduction for different manufacturing activities.

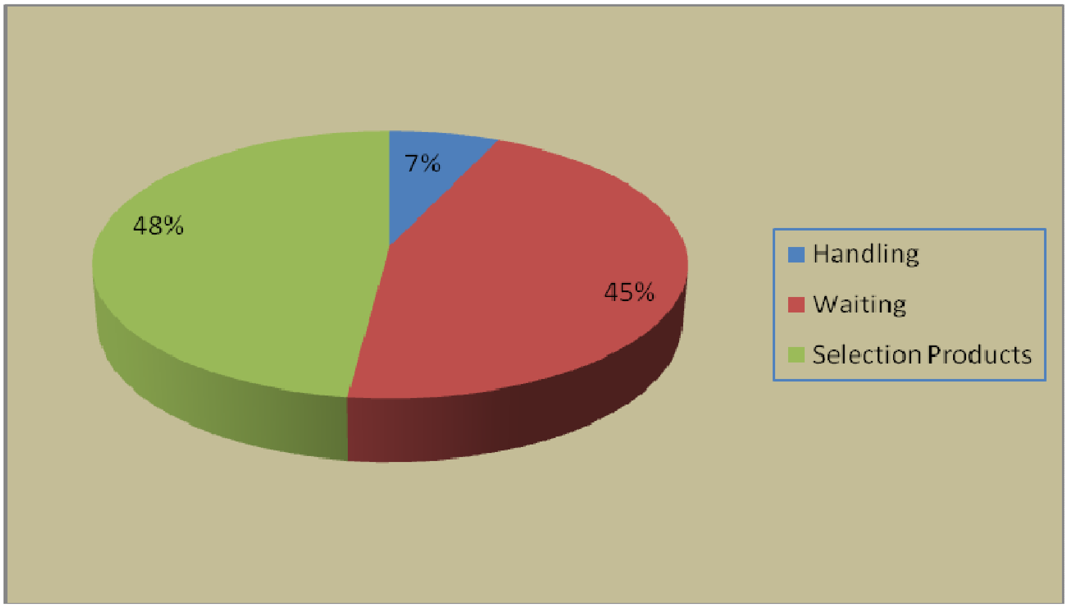

Figure 5. The effect of the different manufacturing activities in lead time reduction.

Conclusion

The main objective of this research is to generate a computerized lean manufacturing system that can reduce waste due to lead time and processing time in loading-uploading practice in the warehouse area. The installing results of the created system (Survivor Tool) in the food factory consist of the following:

1. The created software is tested on the Persian Dairy Company and the percentage of the lead time reduction is 33.3%. The achieved value for the lead time is calculated based on the 80% reduction on products' waiting time for space allocation, the 12% reduction on products' handling and the 85% reduction on products' uploading process.
2. The created software tool, named survivor tool, is capable of preparing a guide plan for the platform which presents the best location for products' loading, the products' expiry date alerts to order for uploading, the best location of products on the platform for uploading, and the loading-uploading order reporting in a selected sequence time by the user.

FUTURE WORK

Considering various food factories as a case study to install and test the created tool is introduced as a future work to extend the application of the generated software. Also, allowing for the other causes of waste, such as material flow and customers' ordering of the generated tool, can be a prospective issue in this study.

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