Military Technical College
Kobry El-Kobbah,
Cairo, Egypt.

18th International Conference
on Applied Mechanics and
Mechanical Engineering.

PRODUCTIVITY ENHANCEMENT THROUGH LEAN IMPLEMENTATION – A CASE STUDY

S. A. Salah[1] and N. Sobhi[2]

ABSTRACT

Many organizations are nowadays interested in adopting lean manufacturing strategy that would enable them to compete in this globalization market. Lean production philosophy striving for elimination of all kind of waste, which is becomes the main target in industrial companies, as well as in food industrial organizations. Decreasing the process time and identifying all types of defects in the production line are critical in improving the productivity, especially in mass production companies. The objectives of this paper are implementing the lean production tools in a mass production company for food industry to reduce the major kinds of waste and increase the productivity of the company. This paper is focusing on collecting qualitative data about the major kinds of waste in the production line, and analyzing those data to find the root causes of the major wastes in all processes in the production line and trying to eliminate them in order to improve the productivity. The achieved results indicate that implementation of some lean tools in the company with the available resources without additional cost such as; routine maintenance, correction, adjustment and repair has a great impact on increasing machines availability, the total productivity and the net profit in the company.

KEY WORDS

Lean production; seven waste; improve the productivity.

---

1 Dr., Dpt. of Industrial System Engineering, October University for Modern Science and Arts, Cairo, Egypt. Email: ssalaheldein@msa.eun.eg.

2 Professor Dr., Dean of Faculty of Engineering, October University for Modern Science and Arts, Cairo, Egypt. Email: nahed.sobhi@gmail.com.

INTRODUCTION

Almost variety of Manufacturing' companies adopted lean production philosophy to satisfy economical product, whoever in mass production food industry companies. The main target for those organizations is to optimize the product lead times and processes time and minimize the all kind of wastes. The critical thing in those companies is to increase the productivity with minimum waste rate to improve the net profit. As a result batch sizes have reduced and continue to shrink [1]. Food industry companies are embracing and try to adopting the various new lean manufacturing concepts to reduce the production time, with shortest lead time and changeover time to satisfy flexible production systems and quick change over systems from one kind to another. The variety of market demands forces the manufacturing companies modify the production line to be able to act with high flexibility to satisfy the quick change in demand. This leads to higher flexibility in terms of volume and style change over [2]. It is very important for any organization to identify, reduce & eliminate waste in order to improve the productivity. Waste elimination is the most important thing for competitiveness and continual improvement' organizations. Waste elimination is an effective way to increase profitability [3]. Lean philosophy enables companies to be more flexible and profitable. Lean production is the most effective investment among companies [4].

This paper study the case of food industry company which has more than 5000 direct wholesale customers and 30,000 direct retail customers, with exports to more than 16 markets in the region. The production contains variety kinds of candy biscuits. The purpose of this paper is to decreases the percent of wastes and defects in the daily production line, which is considered with tens of thousands of pieces every day.

LEAN PRODUCTION

The main objectives of lean production system are continuous improvement of processes, and cost reduction through the elimination of waste. The concept of waste (Muda in Japanese) is defined as any activity that does not add value to the product in the customer's perspective. The seven types of waste considered by [5]; overproduction, inventory, waiting, defects, over-processing, motion and transportation. Lean Production provides a set of tools and techniques that can be applied to reduce those wastes namely; SMED, 5S, visual control, standard work. Implementation of lean production tools and techniques help organizations to minimize all kinds of waste [6]. All tools of lean are developed to support the implementation of lean principles and overall organization strategy [7]. Hence, the companies will achieve the desired success [8].

Kinds of Waste

The main objective of the lean philosophy is eliminating all kinds of waste within a company's process [3]. The eliminated wastes will further expose other wastes and quality issues within the system. The seven types of wastes in lean manufacturing are considered as the following [8]:

1. Overproduction: producing too much or too soon which results in poor flow of goods and increased inventory.

2. Defects: problems in the product quality, poor delivery of products, or paperwork errors.
3. Inventory: storing finished products or raw materials may incur unnecessary expenses.
4. Over processing: using complex tools, or procedures, when simpler ones could produce the same output with the same efficiency or more.
5. Transportation: excessive movement of people, goods, and information.
6. Waiting: inactivity causes poor flow and increases the lead time (the time between the initiation and the completion of a process)
7. Unnecessary motion: bending, reaching, or walking long distances to perform a task, caused by poor ergonomics.

Lean Tools

There are many tools in implementing the lean methodology; they are used to analyze the product and the environment to identify wastes. Some of these tools are:
Value stream mapping (VSM): Value Stream Mapping is defined by [9] as the simple process of directly observing the flows of information and materials. Summarizing them visually and then envisioning a future state with much better performance. VSM is used to collecting information about the process to help identifying and eliminating the wastes. and reduce inventories, therefore increasing the overall performance of the system. The main goals of VSM are visual representation for all current operations and processes to identify the types of waste and to implement steps to eliminate them. The information about the processes and the flow of information are recorded and analyzed to identify the opportunities of wastes. After analyzing the current state, the future state map could be developed to show how the operation could be done in a more effective manner [10]. Overall Equipment Effectiveness (OEE) is one of the most important requirements for measuring the continuous improvement in the process [11]. Establishing the appropriate metrics is essential for purposes of measuring the performance. OEE is an effective method for analyzing the efficiencies of a manufacturing system [12]. OEE value is depends on three factors; availability, performance rate, and quality rate as follows:

- Availability losses are caused by machine breakdowns, for example a failure causes the line to stop when it should be running.
- Performance losses occur when the line is running at less than the maximum possible speed due to machine wear, or jams for example.
- Quality losses occur when a product is rejected due to not meet the quality standards.
- OEE indicates how successful the process is, the lower OEE the less successful it is.

The Gemba Walk: According to [13] the word Gemba means “where things happen” which is the shop floor in the business context, this includes the workers in the shop floor as well. The shop floor is where both value adding and non-value adding processes can be detected, and either improved or eliminated. It is based on the go and-see principle which requires the manager to get out of his office and checking the processes with the staff to discover wastes and eliminate them. Consequently, it requires extensive knowledge of the lean concept [14].

Application of Lean in the Food Processing Industry

The implementation of lean in the food processing industry may pose a challenge due to the unique characteristics that distinguish it from other discrete manufacturing industries [15]. Three examples of these characteristics are proposed by [16]:

- Strict regulations due to political reasons, since it is critical that a supply of safe, affordable, and sufficient food be maintained.
- The large batch sizes make the availability of products, reliability of supply chains, and the price competiveness critical to success.
- Complexity of the production process, since companies have to launch new products to stay competitive in a market, where customers are tempted to try new products, which further complicates the production process.

In other words, the high perishability of the products, complex operations, variable availability of raw material, and erratic demand are all constraints imposed on the implementation of lean in the food industry. This mean that lean can be implemented within the food processing industry; with considering all of the constraints attached. For example, in a case study performed by [17] on a biscuit manufactured on the applicability of lean practices, it was found that lean tools such as SMED, 5S, and Total Productive Maintenance can be effectively implemented which resulted in increased machine availability, reduced waste, and improved overall quality.

Improving the Productivity

Lean Production methodologies have been known to eliminate waste in the manufacturing and service industry. The emphasis of lean is to eliminating non-value-added activities and to improve the efficiency of all processes. Many firms have been practicing lean production to improving productivity and as a process improvement approach. There is a relation between lean and the competitiveness of the company's parameters for performance improvement such that; quality, cost flexibility, delivery reliability, and decreasing the process time [16].

CASE STUDY

The data was collected from a candy food Industries Company which has four production lines**,** the most defective line is the Wafer production line, so this paper dealing with this line to improve the productivity.

Wafer Line Process Description

The layout of the Wafer line is shown below in Fig. 1. The production line is U shaped it runs automatically as long as the raw materials are provided. The process begins with the workers moving the raw material from the storage room containers into a cart. The worker then moves the cart manually towards the mixer, which creates the wafer batter by mixing the ingredients together. After the mixer is finished its work, the batter is then transferred to the buffer tank where it awaits to be pumped by the injectors in the oven. The batter is moved to the injection part of the baking oven using double jacket insulated pipes. The batter is then injected into the baking trays in the shape of different straight lines. The trays are then moved to the oven where the batter is baked into thin wafer sheets. The baked sheets are then moved into a cooling tower before going into the next process. The humidifier increases the humidity of the sheets so that the chocolate is spread properly on the sheets and to help the chocolate stick. The sheets that exit the humidifier are transported on a conveyor going directly into the spreading machine. The sheets moved by the first conveyor are moved through the spreading machine where the chocolate cream is spread on their surface. The stacked sheets are then compressed together using a compressing machine. The cooled books are then moved to the cutting machine where they are first cut horizontally, then vertically into required shaped bars. The coated bars are then moved through a cooling tunnel to solidify the chocolate and prepare the bars for packaging.

Identification of Waste in the Production Line

The Wafer line was studied closely and the wastes were identified in all production processes and categorized as shown in Table 1. The types of waste are summarized as follows:

Defects; Defects in the injection process occur when the trays close and the batter is spread and parts of it are squeezed outside the tray. These parts are broken and fall into the trays under the oven when the wafer sheets are unloaded from the trays. Defects were also found within the oven during and after the baking process is complete, where parts of the wafer sheets often break and fall into the trays under the oven. Defects were also found within the humidifier where bits of the wafer sheets break resulting on the part falling into the trays. In the cutting process, defects are found as well, after the wafer books are cut, they are separated by mean of vacuum suction which leads to breakage in the top layer. In the automatic packaging phase, some defects occur when the machines fuse the wrapper and the bar together and the bar will then need to be scrapped. In the manual phase, the workers sometimes place more or less bars than it is required in the boxes, which leads to the boxes being kicked out of the line during the weight checking process.

Over-processing was identified in the baking, humidifying, and cutting processes. The broken wafer sheets that fall into the trays during each of the baking and humidifying processes are not scrapped but rather reworked by mixing them with the chocolate filling cream ingredients. The humidifying was classified as over processing because it is possible to complete the entire wafer production process without the need of a humidifier. That can be accomplished by adjusting the baking conditions from the start.

Transportation was identified in the mixing process. The worker transports the raw ingredients from the preparation room to the mixer manually.

Motion was found in the last manual packaging process where the worker unfolds the cartons; it is possible to unfold the cartons prior to the start of the shift to save time.

Data Collection for the Waste

The value stream map is used for visual representation of the entire production process, from receiving the raw material to shipping the final product. The collected data used in construct the value stream mapping to facilitate understanding and identifying all wasted areas to start improvement the process as shown in Fig. 2.

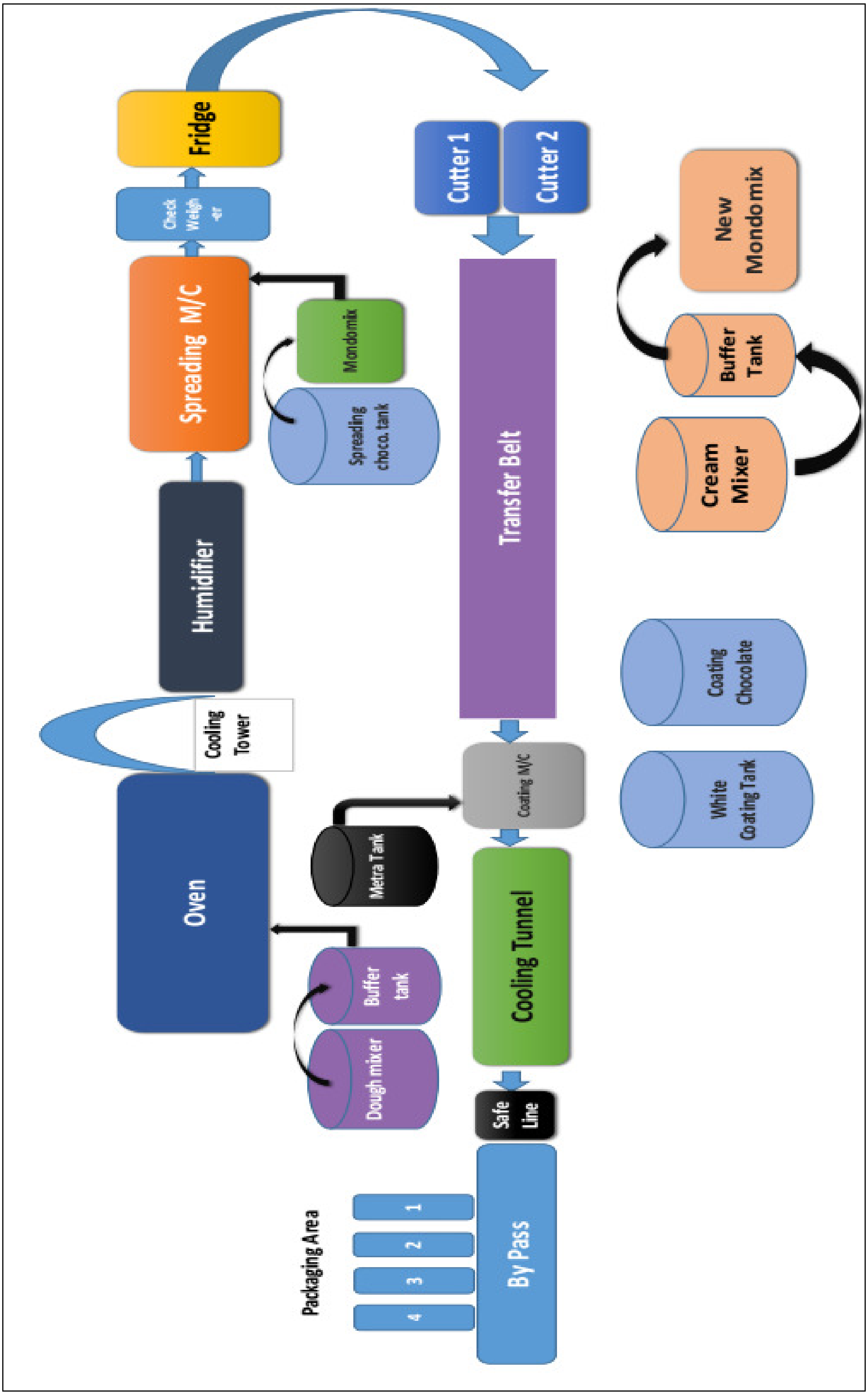


Fig. 1 production line description

Table 1. Present Wastes on the Wafer production line.

Process	Time (seconds)	Waste
Mixing	413	Motion
Injection & Baking	106	Over processing, Defects
Cooling tower	130	-
Humidifier	821	Over processing, Defects
Spreading	5.45	Defects
Refrigeration	621	-
Cutting	105	Defects/Rework, Over processing
Conveyor	301	Defects
Chocolate coating	25	-
Cooling tunnel	187	-
Packaging 1 (automatic)	5	Defects/Rework
Packaging 2 (manual)	5.67	Defects/Rework
Packaging 3 (manual)	16.5	Unnecessary motion

Table 2. Waste Data in the production line.

	Oven Scrap	Sorting	Cut Pieces	End Product	Sheets	Total
Average waste, (Kg/shift)	83.64	73.6	17.98	14.40	27.41	217.03
Average waste, (Kg/day)	250.92	220.8	53.94	43.2	82.23	651.09
Average waste, (Ton/Year)	60.22	52.99	12.95	10.37	19.74	156.25

After analyzed the collected data, the three major kinds of wastes were found on the line; defects, inventory, and over processing. The achieved results from data analysis showed that the defect is the major kind of wastes in the production line. So this analysis is dealing with the defects only. There are five main types of defects in the wafer line, average defects per day were calculated as shown in Table 2. The percentages of every type of defects are presented in Fig. 3. The highest amount of waste is due to the scrap and sorting with (38 and 34) % respectively.

Data Analysis for the Defects

Cause and effect (fishbone) diagram was studied to determine the root causes of the defective sheets. Construction brainstorming sessions and open discussions with both the workers and the management to investigate the root causes of the defects. The achieved results show that the variations between the amounts of batter injected by each injector are the root cause of the defects as shown in in Fig. 4. By reducing this variability the wastes could be reduced. Two improvement solution are proposed to eliminate the variation between the injectors is maintaining the equipment effectiveness and changing their design as illustrated in Fig. 5.

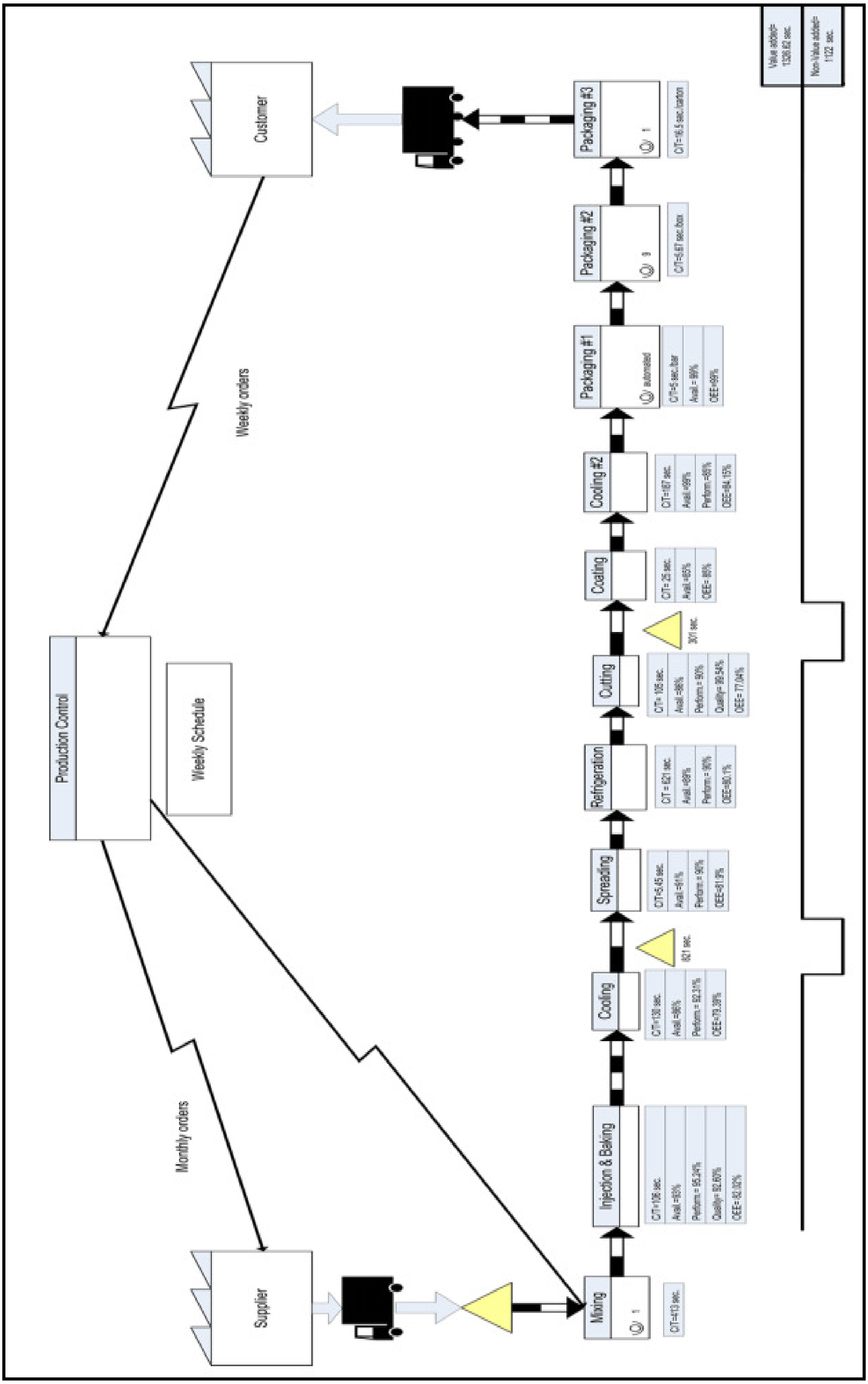


Fig. 2 value stream mapping for production line

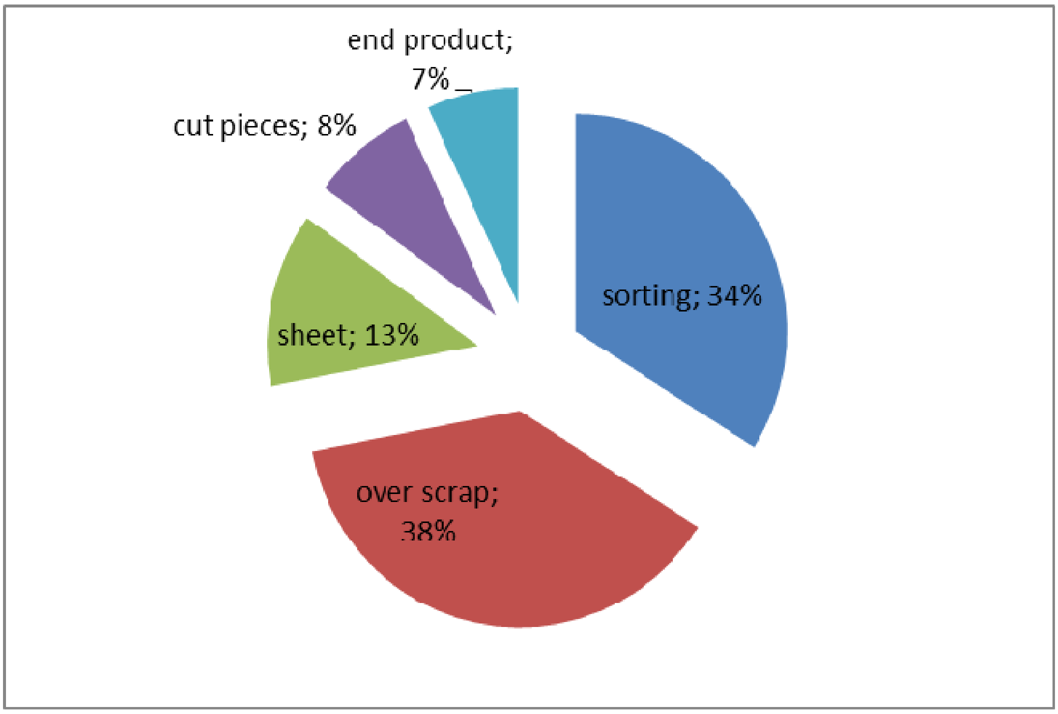


Fig. 3. percentage of waste in the wafer production line.

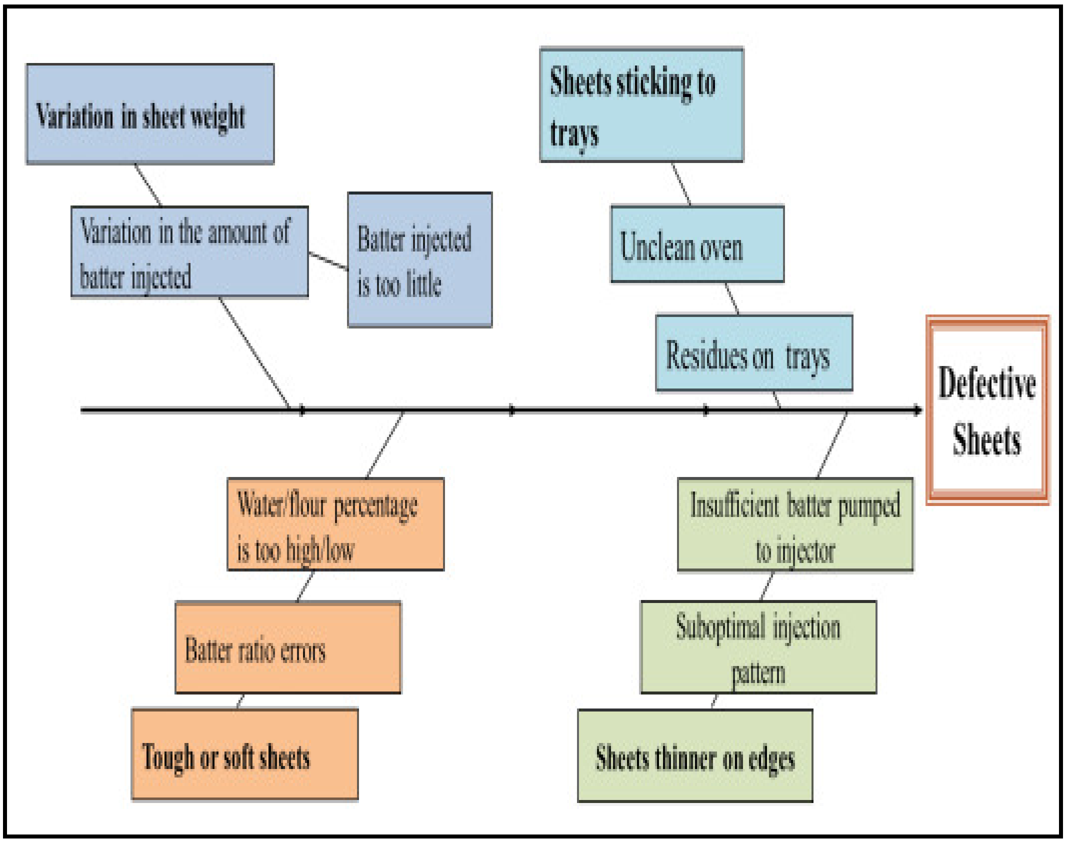


Fig. 4. Cause and Effect Diagram for production defects.

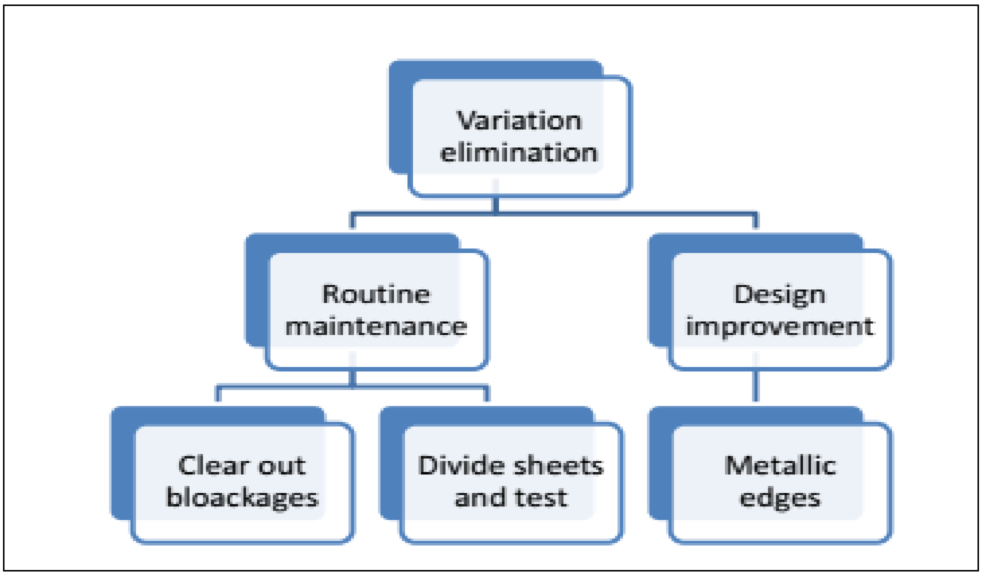


Fig. 5. Steps to solve the injections variation.

IMPLEMENTATION OF THE PROPOSED SOLUTION

The suggested solution includes two parts; routine maintenance and a design improvement to eliminate the variation; however the design improvement is relatively high cost. Thus, the routine maintenance part was prioritized and applied with the available resources and it does not incur any extra costs on the plant. Implementing routine maintenance is required for the injectors and the pump. The injectors should be checking if any of the nineteen holes are blocked or not well cleaned, which can affect the amount of batter injected. The pump that pumps the batter into the injector should also be maintained by checking if the pressure is sufficient to supply the nineteen injectors equally. These maintenance procedures are simple and will not require special tools. It only requires training for the workers on how to properly perform them. Furthermore, the maintenance procedure can be scheduled during changeovers as to prevent downtime.

Oven Cleaning

The baking oven was completely stopped and cleaned, which a process is done once or twice per year, and that is to make sure there are no blockages or residue that could affect the baking process. Different issues were encountered during the cleaning process, such as the detergent used to clean the trays requiring the first wafer batch produced after the cleaning to be disposed of. The reason for the disposal of the first batch is because the sheets may contain traces of the detergent. Another issue that occurred is that the burners inside the oven were blocked by the detergent that dripped on them from the trays, which prevented heat to be equally distributed over the oven and thus increased the rate of defective sheets. After the burners were unblocked, however, the rate of defective sheets decreased.

Oven Maintenance

During the cleaning process it was discovered that the injector is slightly bent, which cause the sheets to be unevenly thick in some areas and thin in other areas. The variation caused the sheets to break as soon as they exit the oven. The bending was caused when one of the workers dropped the part during the cleaning process. Nevertheless the injector was taken out and replaced with a new one, which in turn helped reduce the variation thus eliminating wastes. Figures 6 (a) and (b) illustrate the injector before and after repair.

(a) Before fixing

(b) After repapered

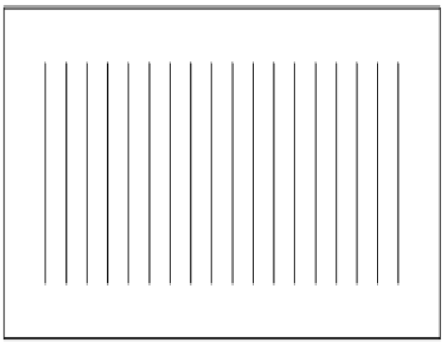
Fig. 6. Batter Injector configuration.

Adjusted Sheet Weight

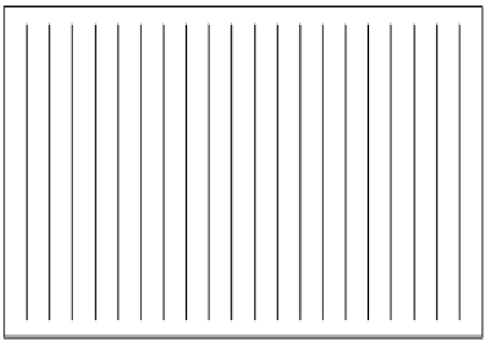
After adjusted the amount of batter injected, consequence the amount of batter injected to the wafer sheet has been increased. Previously, the wafer sheets" weights always fell within the lower limit of the specified weight. The weights now fall within the average range. This leads to producing stronger and thicker sheets that do not break as easily as before while still remaining within the specified weight limits of the product.

Injection Pattern

There is a problem with the injection pattern, which is the injection of the batter is in the middle of the baking tray only and leaving the outer edges empty as shown in Fig. 7a. This created a wafer sheet that was thick in the midsection and thin on the edges. The injection pattern was rectified and the batter is now injected from edge to edge completely, this led to producing a more uniformly thick wafer sheets as shown in Fig. 7b.



(a) Before improvement



(b) After improvement

Fig.7. Batter Injection Pattern.

RESULTS AND DISCUSSION

Routine maintenance was implemented in production line with the available resources and it does not incur any extra costs on the plant. In addition to, some changes to settings or configurations were applied in order to optimize the wafer production processes and minimize the wastes. After the implementation of the aforementioned improvements, the wastes per shift were decreased and the quality of the sheets improved and in turns affects the entire production line. The total production wastes decreases by 7.02 % per shift. The oven scrap waste was reduced by 2.6 %; the sorting waste was reduced by 2.93 %; the sheet waste was reduced by 0.47 %; the cut pieces waste was reduced by 0.54 %; and the end product waste was reduced by 0.48 %,as shown in Fig. 8.

This difference was taken into consideration when comparing the data from before and after the improvements as shown in Table 3. The reason for this reduction is because the sorting waste is caused directly by the defective sheets produced by the oven, and since the oven produces less defective sheets, this improved the total line output. The obtained results from the improvement made a great impact on the increasing the total production and the total profit per year as shown in Table 4. The impact of waste reduction on the annual profit is illustrates in Fig. 9.

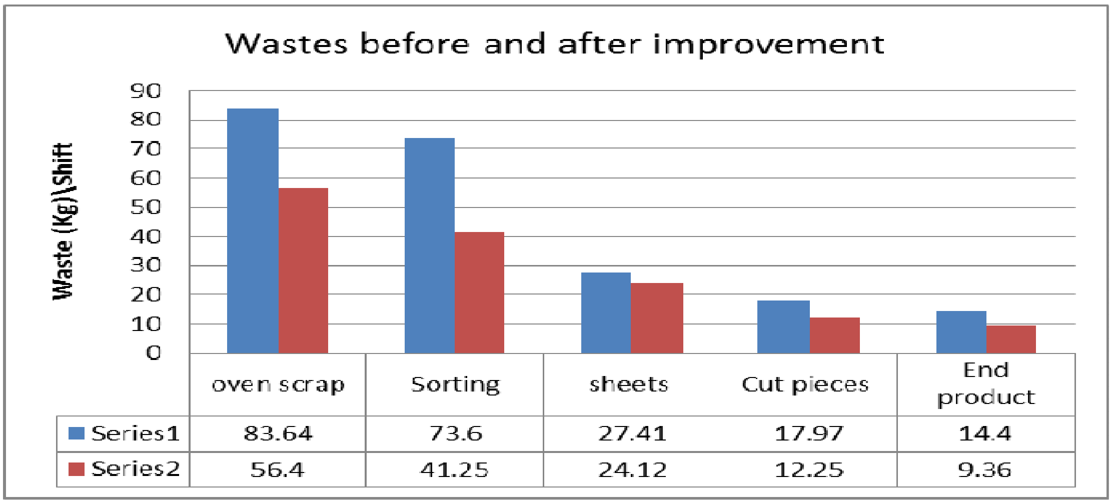


Fig. 8. Waste reduction before and after improvement.

Table 3. the obtained results before and after eliminating the wastes.

Type of waste	Before improvement Average kg/Shift	After improvement Average kg/Shift	Waste reduction kg/Shift	Waste reduction Percent/Shift
Oven scrap	83.64	56.40	27.24	2.6
Sorting	73.6	41.25	32.35	2.93
Sheets	27.41	24.12	3.29	0.47
Cut pieces	17.97	12.25	5.72	0.54
End product	14.40	9.36	5.04	0.48
Total	217.02	143.38	73.64	7.02

Table 4. The results of waste reduction.

Type of waste	Waste saving (Kg/Year)	Production increase (pieces/year)	Profit increase (EGP)/ Year
Oven scrap waste	19612.8	178298	267,447
Sorting waste	23292	211745	317,618
Sheets waste	2368.8	21535	32,302
Cut pieces	4118.4	37440	56,160
End product	3628.8	32989	49,484
Total waste	53020.8	482007	723,011

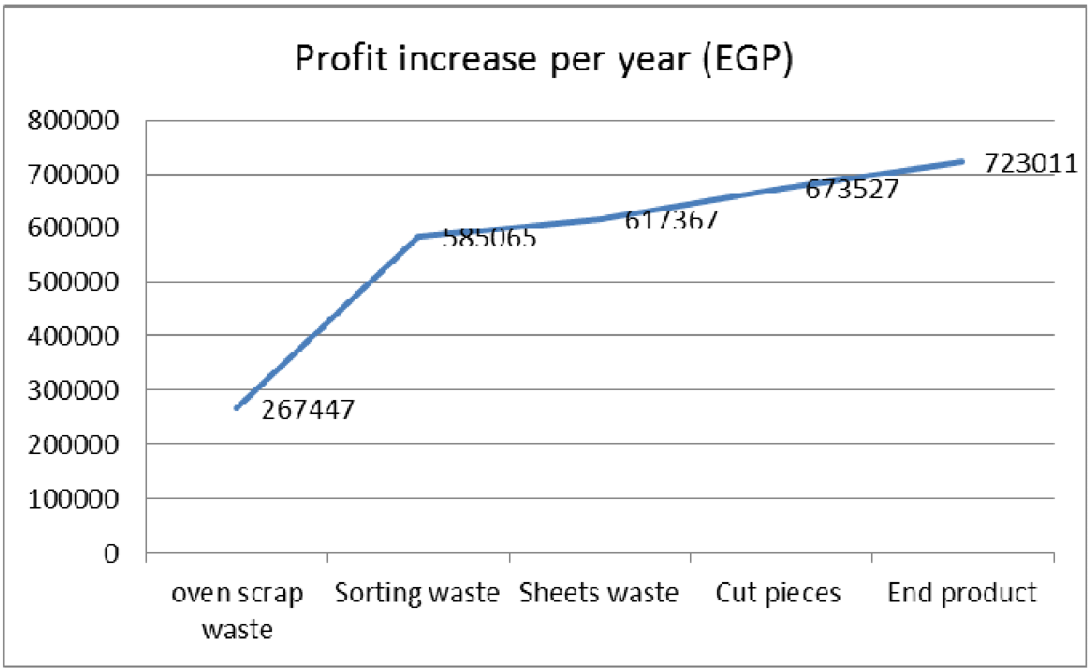


Fig. 9. Effect of waste reduction on annual profit.

CONCLUSION

This paper provides a broad perspective on study the impact of implementing the lean production tools in a candy food Industries Company. Value stream mapping was used to study the current state of the production line and focuses on the major defects rate and also identify the main kind of waste in the production line. The improvement includes implementation of routine maintenance to the Oven and Injector; improve the injection pattern; and adjusted sheet weight. The obtained results showed that the most kinds of wastes, such that oven sheets, end product, and sorting wastes are decreased after implementation of lean tools. Also the total production waste decreases by 7.02%. This achievement led to increasing the production, and also increases the profit with value equal to 723,011 EGP/Year.

REFERENCES

[1] Cavallaro F., "Assessment and Simulation Tools for Sustainable Energy Systems", Green Energy and Technology, 129, 333–356 (2013).
[2] K. Ravi Kumar, "Improving the performance of manufacturing sector-lean methodology and its impact", International Journal of Engineering Science Invention, Volume 2 Issue 3 (2013).
[3] Lehtinen U., and Torkko, M., "The Lean concept in the food industry: a case study of a contract manufacturer". Journal of Food Distribution Research, 36, 57–67 (2005).
[4] Demeter, K.; Matyusz, Z., "The impact of lean practices on inventory turnover". Int. J. Prod. Econ., 133, 154–163 (2011).
[5] Shingo S., "Non-Stock Production: The Shingo System for Continuous Improvement". Cambridge, MA: Productivity Press (1989).
[6] Shah R. and Ward P.T., "Lean manufacturing: Context, practice bundles and performance", J. Operation. Management, 21, 129–149 (2003).
[7] Melton T., "The benefits of lean manufacturing: What lean thinking has to offer the process industries", Chem. Eng. Res. Des., 83, 662–673. 33 (2005).
[8] Motwani J. "A business process change framework for examining lean manufacturing: A case study", Ind. Manag. Data Syst., 103, 339–346 (2003).
[9] Jones, D. W., "Seeing the Whole: Mapping the Extended Value Stream", Lean Enterprise Institute (2000).
[10] Melvin A., and Baglee, D., "Value Stream Mapping: A dairy industry prospective", IEMC-Europe 2008 - IEEE International Engineering Management Conference, Europe: Managing Engineering, Technology and Innovation for Growth (2008).
[11] Tsarouhas, P., "Implementation of total productive maintenance in food industry: a case study", Journal of Quality in Maintenance Engineering, 13(1), 5–18 (2007).
[12] Nakaiima, S., " Introduction to Total Productive Maintenance (TPM)", Cambridge, MA: Productivity Press (1988).
[13] Imai, M., "Gemba Kaizen", New York, NY: McGraw-Hill (1997).
[14] Tyagi, S., "Using value stream mapping to reduce the lead-time of a product development process", International Journal of Production Economics, 202–212 (2015).
[15] Lopes R. B., "Application of lean manufacturing tools in the food and beverage industries", Journal of Technology Management and Innovation, 10(3), 120–130 (2015).
[16] Dudbridge, M., "Hand book of lean manufacturing in the food industry", (2011).
[17] Upadhye, N. D., "Lean manufacturing in biscuit manufacturing plant: a case", International Journal of Advanced Operations Management, 108-139 (2010).