ERGONOMICS AND IN-PLANT LOGISTICS

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ABSTRACT

In-plant logistics is of great importance for companies to run production smoothly. The system discussed in this study is the supermarket system, which reduces the inventory level of materials located next to the production lines but increases the burden on supermarkets and affect milkrun cycle times negatively. How in-plant logistics can be improved, within the framework of just-in-time production and lean manufacturing philosophies, is investigated from different perspectives such as ergonomics, time spent, and distance traveled. Based on our findings we have provided solutions based on operational needs of a washing machine factory.

Key Words: In-plant logistics, milkrun, ergonomics, just-in-time production.

INTRODUCTION

Logistics activities, regardless of whether it is in manufacturing or service business, have become an important business function as they are seen to contribute to the competitiveness of the enterprise. In such a competitive environment, logistics activities are one of the most important factors for companies in delivering products and services in a timely and competitive manner. In other words, the logistics service quality emerges as an important element of being able to compete.

Logistics can be seen as in-plant logistics and out-of plant logistics. In-plant logistics or internal logistics covers the activities between the arrival of raw materials and the full output of the product. Out-of plant logistics or external logistics covers the remaining activities. In recent years, the importance of in-plant logistics has increased as it is of great importance for running production smoothly. In-plant logistics implies the co-ordination of activities within the plant. One would agree that the elements of the in-plant logistics need to be integrated with the external logistics. For manufacturers, managing the in-plant logistics is as important as managing the external logistics to improve the efficiency of production activities.

Running in-plant logistics in the best way is of great importance for businesses that adopted just-in-time and lean manufacturing philosophies to continue functioning without problems.

This study reports on the experiences of redesigning in-plant logistics operations of a washing machine manufacturing facility. A real-life example is presented in terms of how in-plant logistics activities can be improved through ergonomics.

LITERATURE REVIEW

Logistics management can be defined as that "part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements" (CSCMP, 2012). Kample et al., (2011) suggest logistics is both a fundamental business activity and the underlying phenomenon that drives most other business processes.

All the management and movement of materials within industrial units correspond to internal logistics (Saboia et al. 2006), and the ultimate objective of in-plant logistics is to eliminate waste and increase the speed and flow of material and information. As pointed out by Jiang (2005), in-plant logistics plays a key role in maximizing the value of an organization as a whole. Further, optimized in-plant logistics is an essential component of lean manufacturing, which is a management philosophy derived mostly from the Toyota Production System. Lean manufacturing considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination of waste (Womack et al., 1990; Holweg, 2007). Jordan and Michel (2001) emphisizes that lean manufacturing requires that all resources, such as material, capital, energy, human, data, and technology, be measured so waste is minimized and outcomes are maximized.

As part of in-plant logistics, to reduce cost of transportation, traveling path and fuel consumptions, various manufacturing facilities have been implementing a milkrun logistics system (Brar and Saini, 2011). In milkrun logistics, vehicles circulate between the warehouse and the production facilities of the plant according to a pre-defined schedule, often with multiple routes serving different departments (Kovacs, 2011).

One of the most important components of milkrun logistics is a supermarket, which is a decentralized in-house logistics area in the direct vicinity of the final assembly line, which serves as intermediary store for parts. Small tow trains are loaded with material in a supermarket and deliver parts Just-in-Time to the stations lying on their fixed route (Emde and Boysen, 2012)

An important factor that merits consideration when designing internal logistics is ergonomics, which ensures that employees' capabilities fit workplace conditions and job demands. Hence, designing a human-centered factory layout becomes an important policy of today's enterprises. Neumann et al., (2009) concur and claim that to improve the performance of logistics activities, to enhance operation efficiency and enterprise competency, ergonomics should be integrated into production system design. Ergonomics is a key issue when it comes to increasing satisfaction among the workforce, and minimizing risk factors usually found in jobs requiring heavy lifting, and carrying heavy objects. Tasks, the working environment, and the equipment should be ergonomically designed to avoid injury risks and negative impact on the employees. This is espacially true for those who will be doing tasks requiring heavy lifting or carrying heavy objects (Chow et al, 2011).

AN APPLICATION

This project was undertaken at a Bosch-Siemens washing machine factory located in Turkey. In this study, we report on a real-life example of improving in-plant logistics.

Company Profile

The Bosch-Siemens Home Appliances Group (BSH) is the leader in the European appliance industry and the world's third largest appliance manufacturer. With 12 brands, and a total of 41 factories around the world, the BSH group runs the largest production center in Turkey. Consisting of nearly 4000 dealers across the country with a strong distribution network, the company also provides after-sales support services to its customers. Spread over a land area of 450.000 m2 and industrial facilities, and having spent 66 million euros improving and modernizing its manufacturing facility in 2005, the company makes 3.5 million units of washing machines.

The Current Situation

The factory has two assembly lines: Line A and Line B. The BSH washing machine production process consists of two main categories: the manufacturing of semi-finished materials, and the assembly process. After packaging, finished products are transported to the logistics center.

To manufacture a washing machine 820 different materials of different volumes and weights are used. Materials in the plant are moved around using various means such as a conveyor, a forklift and a milkrun system. Milkruns distribute materials on certain frequencies to stations using a particular route. There are five milkrun systems in the plant: green, light blue, dark blue, orange, and the newly designed milkrun. The plant has four units of supermarkets and this study was conducted in the first one (SM1) (Figure 1). Materials are moved from the warehouse by forklifts on pallets and left in designated areas in the supermarket. They are then distributed to the assembly line by milkruns. This cycle continues at certain intervals.

SM1 is the place where the light blue milkrun is fed which carries small-to-medium-volume materials. The yellow sections labeled as SMB and SMA in figure 1 are shelves. The red-colored section is where the computers are located. Located next to the computers are six light-green-colored roller systems. The section labeled as A-RAMP is not part of SM1. A kanban system is used in the distribution of the material. There are 5 trolleys for the light blue milkrun. A milkrun is run for lines A and B separately. Each time 3 trolleys are moved around. A designated common trolley is used to carry materials to both lines. The two of the other 4 are used to distribute materials to line A and the other 2 to Line B.

A shift is 8 hours long. However, after allocating time for such activities as an information meeting, a tea break, and lunch time, an employee works 413 minutes a day, which is about 7 hours. Three employees work in SM1. Employee 1 (MRE-A) fills the common trolley and takes it to the line A. Employee 2 (MRE-B) fills the common trolley and takes it to the line B. Employee 3 maintains a fixed position in the supermarket and fills the remaining trolleys. Milkrun employees also at regular intervals perform regular maintenance and collect garbage.

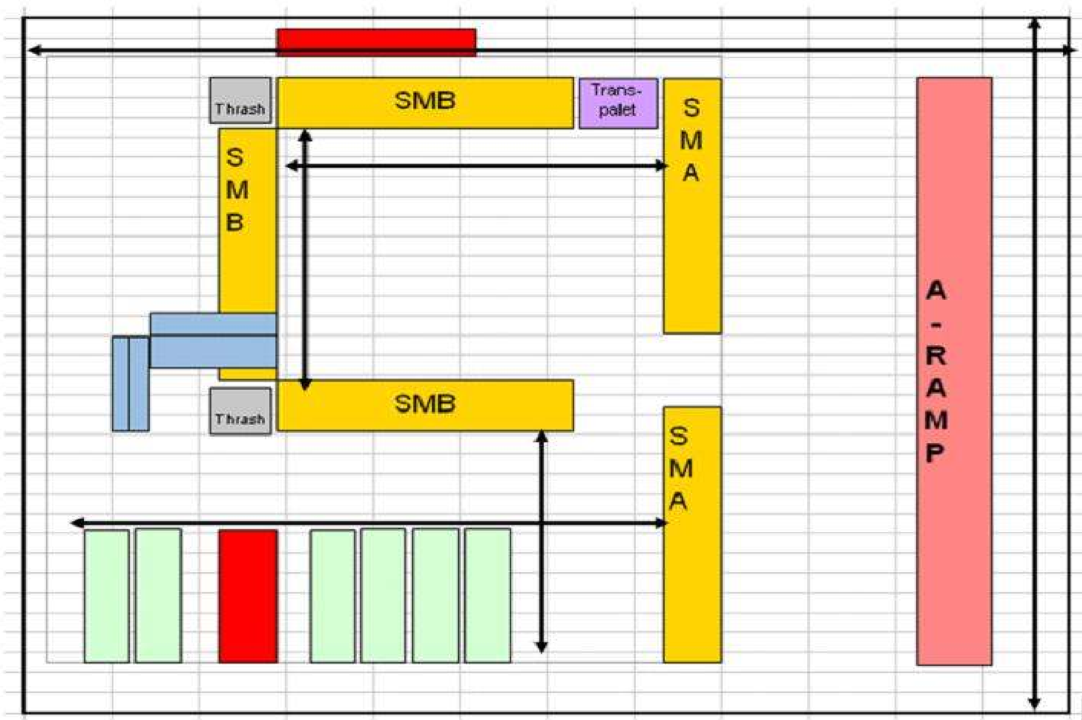

Figure 1: Layout of SM1.

Because employees working at SM1 complained about being too tired at the end of each shift, it was decided to examine the current system.

DATA ANALYSIS

First, the tasks and how long it takes to perform the tasks are examined. As indicated before, supermarket employees' job is to fill out four trolleys, and perform maintenance at regular intervals. Activities performed by employees are classifed as value-added work (VAW), half-value-added work (HVAW), garbage collection, maintenance, and leisure, as shown in figure 2. Value-added activities are those that directly affect production. Half-value-added activities are found by subtracting value-added activities and leisure time from the net time. Half-value-added activities are those such as collecting garbage, and opening a box.

Having analyzed the time spent by employees, weights handled in each shift were evaluated on the basis of employees.

Milkrun employees lift heavy weights and the way they lift them is not ergonomic at all. Often, they must lean down to lift weights, which lead to more fatigue. Fatigue is caused by the amount of heavy load and the non-ergonomic posture they assume while lifting weights. Thus, to reduce fatigue, the loads should be examined in terms of ergonomics and weights.

Fatigue Index

Fatigue index was created in order to calculate the impact of the materials on employees' fatigue working at SM1.

$$G \times T_f \times t \times F_r = F_i$$

G: Material's weight,
T_f: Transport frequency,
t: Transport time,
F_r: Fatigue rate (computed using the values in table 1), and
F_i : Fatigue Index

Fatigue Index = Material's Weight* Transport Frequency*Transport Time*Fatigue Rate

When computing fatigue index, the number of boxes carried by an employee is used in the formula. The reason for this is that other calculations are done on the basis of the same unit.

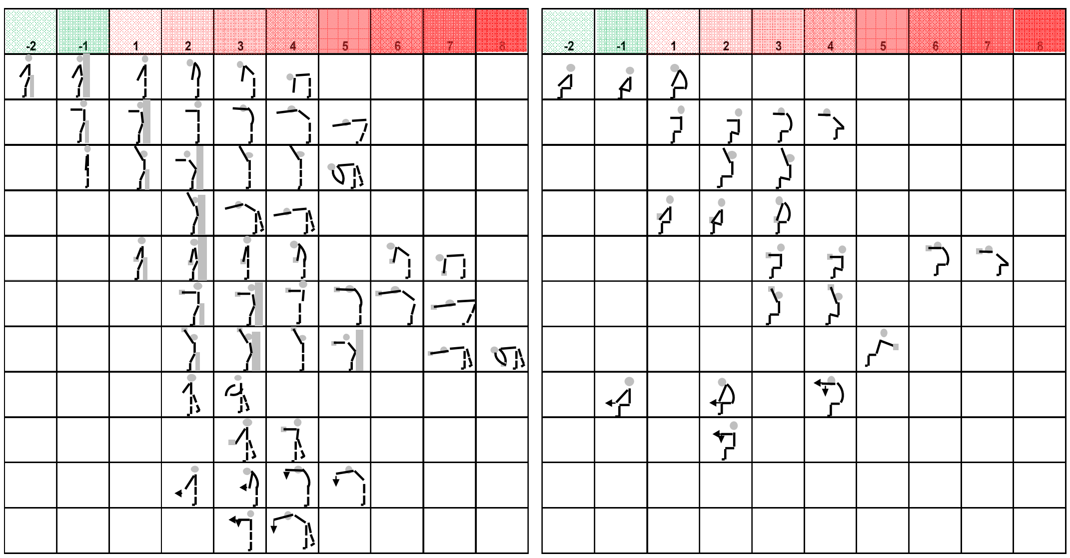

Table 1: Ergonomic ratings template (Berlin University, unpublished work, 2010)

Table 1 shows the ergonomic ratings. Excluding sitting and standing by, employees' movements have been assigned numbers between -2 and 8, where -2 is the most comfortable position, and 8 is the most uncomfortable position.

Fatigue index is made up of three different phases for a material: lifting, handling and loading. Fatigue indeces for SM1 were computed, as seen in table 2. In each shift, the materials weighing less than 100 kg are not taken into account. Calculations were made separately for lines A and B. The total weight of materials was calculated for a shift. The time it takes to stand up with a material is called lifting time, and the time to load the material onto a trolley is called loading time. Lifting and fatigue rates are taken from table 1. The reason for fractions in table 2 is that materials are not always removed from or put to the same height. For example, fatigue rate for a drain pump is computed as follows. Materials are often stocked together on top of each other. An employee lifts the first one with little bending, thus the value for that is 6. The employee will have to bend more to lift a material located under the first one. Its value would be 7. Thus, fatigue index for the drain pump is 6 +7 = 13, 13 / 2 = 6.5. Using the fatigue index formula the lift-and-drop fatigue index values were calculated. On the basis of the total value, the loading index value is calculated for each material. Then, a percent of the total and the cumulative total are computed based on the values. If Pareto analysis is performed, it would be observed that specific materials make up 80% of the index. These materials are:

For line A: Bellows hose, drain pump, water inlet valve, transportation reinforcement bolt, and resistant

For Line B: Drain pump, bellows hose filter, water inlet valve, transportation reinforcement bolt, resistant, and damper.

	Material name	Total weight lifted	Total units carried	Time to lift (sec/unit)	Time to load (sec/unit)	Lifting fatigue rate	Loading fatigue rate	Lifting fatigue index	Loading fatigue index	Total fatigue index	%	Cumulative %
Line-A	Bellows filter hose	353.4	46.5	1.6	1.6	6.5	4.5	262.93	182.03	445	26.57%	26.57%
	Drain pump(F02)	486.9	27.4	1.6	1.6	6.5	7.0	207.76	223.74	431	25.77%	52.34%
	Water inlet pump	162.8	38.8	1.7	1.7	6.5	5.0	105.95	81.50	187	11.19%	63.54%
	T. R. Bolt	263.3	28.6	1.4	1.4	6.5	4.0	103.96	63.98	168	10.03%	73.57%
	Resistant	266.6	31.0	1.6	1.6	4.0	4.0	82.90	82.90	166	9.90%	83.47%
	Damper	273.3	19.0	1.6	1.1	6.5	6.0	80.40	52.67	133	7.95%	91.42%
	Adjustable foot	152.5	18.6	0.9	0.9	6.5	4	24.68	15.19	40	2.38%	93.80%
	Capacitor	111.6	18.6	1.5	1.1	4.5	4.0	21.56	14.05	36	2.13%	95.92%
	Fixed bellows hos	106.3	13.3	1.1	1.1	6.5	7.0	15.53	16.73	32	1.93%	97.85%
	Bearing-front	165.6	10.8	1.5	1.0	4.5	4.0	17.92	10.99	29	1.73%	99.58%
	Bearing-Rear	80.2	5.4	1.5	1.0	4.5	4.0	4.38	2.69	7	0.42%	100.00%
Line-B	Darin pump(F10)	378.7	23.7	1.4	1.4	6.5	6.5	122.06	122.06	244	25.62%	25.62%
	Bellows filter hose	269.8	35.5	1.0	1.0	6.5	5.7	90.99	79.32	170	17.88%	43.50%
	Water inlet pump	124.3	29.6	1.6	1.6	6.5	5.0	58.81	45.24	104	10.92%	54.42%
	T. R. Bolt	201.0	21.8	1.4	1.4	6.5	4.0	61.47	37.83	99	10.42%	64.84%
	Resistant	203.5	23.7	1.4	1.4	4.0	4.0	40.02	40.02	80	8.40%	73.24%
	Damper	208.7	14.5	1.4	1.2	6.5	6.0	42.33	33.49	76	7.96%	81.20%
	Cuff	130.6	28.4	1.3	1.1	6.5	4.0	47.12	25.12	72	7.58%	88.78%
	Bearing-front	197.9	12.2	1.4	1.0	4.5	4.0	23.91	14.86	39	4.07%	92.85%
	Adjustable foot	116.4	14.2	0.9	0.9	6.5	4.0	14.38	8.85	23	2.44%	95.29%
	Fixed bellows hos	81.1	10.1	1.1	1.1	6.5	7.0	9.05	9.75	19	1.97%	97.26%
	Capacitor	85.2	14.2	1.4	1.0	4.5	4.0	11.31	7.45	19	1.97%	99.23%
	Bearing-Rear	81.5	5.5	1.5	1.0	4.5	4.0	4.56	2.78	7	0.77%	100.00%

Table 2: Supermarket 1 fatigue index values

Five materials at the top the fatigue index are common to lines A and B. There is also damper for line B. Improvements in these five materials should provide a huge decrease in fatigue index, allowing supermarket employees to suffer less fatigue.

Recommendation 1

The first observation we made was that the drain pumps and bellows hoses were placed very close to the ground. The drain pumps and bellows hoses can be placed on a waist level shelf. Thus, employees will not need to bend to lift the materials, allowing them to save time. In addition, the height of the rack should be adjustable.

- The sum of the fatigue index values before the improvements: 2627.
- The sum of the fatigue index values after the improvements: 2174.
- Fatigue index value of the gain: 17.25%.

The values obtained after installing the adjustable selves are listed below. Time values were computed by the manager.

- The sum of the fatigue index values before the improvements: 2186.
- The sum of the fatigue index values after the improvements: 1733.
- Fatigue index value of the gain: 21%.

As seen in the comparison of these improvements, it will not be a long-term solution as it only reduces supermarket employees' fatigue. Therefore, it can be used as a short term solution.

Recommendation 2

For a long term solution, the manual handling process time should be reduced to the lowest level possible. For this, a rolling rack system and a rolling trolley should be installed.

Three different design options may be employed here:

1-Supermarket shelves are redesigned. The end of the racks must be blocked so that the materials do not fall to the ground. Also, trolleys can be designed like the ones in figure 6 so that the movement of materials can be facilitiated on the trolley. With this design a trolley's racks can be rotated in different directions so that the materials can easily be loaded and unloaded. The problem with this is option is that the materials are brougt to the supermarket on pallets and boxes of materials should be put over the rolling racks by hand. As a result, there will not be any reduction in supermarket employees' fatigue index but milkrun employees' fatigue index value approaches zero.

2- Materials are moved without having to lift by supermarket employees from the warehouse directly into the rolling racks. This option is the perfect option for the long term but the transport system, trolleys, SM1 must be redesigned.

3-Trolleys are designed with rotating rollers, and an extension apparatus is added to the trolley so that they can be docked onto the shelves. The trolley approaches the loading rack, extension-side connection is provided between the rack and the trolley and the materials are loaded. Milkrun carries the materials to the assembly line and the materials are discharged off the trolley. There is no need to re-design the supermarket. This option provides greater

advantages and benefits for both milkrun workers and supermarket employees and the cost of this option is lower that that of option 1.
A comparison of options:

- Fatigue index: 2>3 ~1
- Cost: 2>1>3
- Long term usability: 2>1>3
- Planning and implementation time: 2>1>3

In addition to the above mentioned improvements, the following also need to be done.

The fatigue index must be calculated during feeding of materials to the assembly line.

- Problems that may emerge during trolley design and feeding of materials to the assembly line must be identified.
- Professional opinions about the designs of the options should be taken.
- The costs of options should be examined in detail.
- Benchmarking should be done and the solutions produced by other companies should be observed.
- The plant should select one of the appropriate options in accordance with future goals and plans.

CONCLUSIONS AND DISCUSSIONS

In this study, improving in-plant logistics through various activities within the framework of just-in-time production and lean manufacturing philosophies was investigated through ergonomics.

Through a real-life example, at a BSH washing machine factory supermarket workers who suffer from fatigue as a result of intensive work were examined in terms of ergonomics and fatigue-causing activities were determined. Some suggestions were made to create ergonomic working conditions and to make the necessary improvements to the services performed.

It should be noted that production efficiency is not achieved by using machines alone. Ergonomics also should be integrated into the design of in-plant logistics. Providing employees with an ergonomically-designed working environment will lead to increased performance and production efficiency.

In this study, we have provided solutions based on operational needs of a washing machine factory. The major contribution of this study is that it demonstrates how redesigning in-plant logistics can improve human and organizational performance as a whole.

References:

References available upon request from Tuncay Bayrak, tbayrak@wne.edu