We Got a **Henkel** on Things: Ergonomics, Simulation, and Facilities Planning to optimize factory processes

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***Abstract*— As industrial engineering students, the optimization of processes, elimination of wastes, and integration of efficient systems are important concepts that we have learned throughout our years at the American University of Beirut (AUB). In our Final Year Project (FYP), we intend to use all the different concepts, methods, and theories that we have learned throughout our years at AUB to support in the optimization of the factory processes of Henkel, a multi-national laundry and home care company. After thoroughly examining the different processes, focusing on the production process and the worker tasks, we will be suggesting solutions that tackle worker safety and optimization of production efficiency, in attempts to implement them. We decided to focus on these processes since we observed several issues that indicate a need for major improvement. With those in mind, and a chance of Henkel moving their factory to a different location, we came to an agreement that the three main components of our project, discussed in detail throughout the report, are ergonomics (by using the EMG device, RULA, NIOSH, and discomfort rating), simulation (by conducting a time study and using the Arena software), and facilities planning in order to optimize their spatial requirement. Our focus during the fall semester was on ergonomics and simulation, leaving facilities planning to be tackled during the spring semester. So far, since we discovered that one of the processes in the factory (the palleting process) causes harm to the lower back of the workers, we are working on finding a less harmful design for it. As for simulation, we have found the bottlenecks of the machines and are researching cost-effective ways to resolve them.**

Keywords—ergonomics, simulation, facilities planning, optimization

I. Introduction

The greatest source of inefficiencies found in many companies comes from an un-optimal capital utilization, in which 57.6% of companies are affected (Thomas, Callan,1992). Given the fact that we live in an economically struggling country, this is a problem that most companies face in Lebanon. This is why we believe that the help of industrial engineers is needed to minimize as much waste as possible and optimize company processes. By using the relevant concepts and tools we have learned (ergonomics, time study, simulation, and facilities planning), we will not only be able to increase their efficiency, but also provide cost-efficient solutions, and decrease worker fatigue.

We got to experience this first-hand when one of the members of our FYP team did her internship there. She noticed a lot of inefficient processes taking place which could have been made better through the help of some industrial engineering tools. That is why we decided to conduct our FYP at Henkel's factory. We visited Henkel several times, and during our visits, we noticed that the workers performed the same tasks for 12 hours straight, with just a 30-minute break for lunch. There were two tasks in particular that could cause extreme stress to the workers. We decided to help those workers out and find safer ways to perform the tasks. Since there is no recorded data on worker injury, the main motivation for choosing ergonomics is that during our member's internship, she witnessed several workers requesting pain killers due to pain in their lower back while manually loading an average of 18 kg boxes onto pallets.

Apart from worker safety, there are many things that could be improved. For example, the company uses a measure called OEE (Overall Equipment Efficiency) which detects the production lines' productivity, so we thought we could simulate the company's production line and see how we could increase productivity. OEE uses simple calculations of machine availability (A), performance (P), and product quality (Q) (Tang, 2019). Worldwide, the pain experienced by workers is mainly due to the frequent bending to place the boxes on the pallet. Work related musculoskeletal disorders (WMSD) incident rates reached 29.8 cases per 10,000 workers (Aje et al., 2018).

II. Goals and Objectives

Throughout our FYP, we will be focusing on the following goals and objectives:

1. Maximizing worker safety

   Aim 1: Replicate the palleting task in the factory, by taking the appropriate measurements of the workplace.

   Aim 2: Use ergonomic tools like RULA, NIOSH lifting equation, and Musculoskeletal Discomfort

Rating to evaluate the effect of the palleting task on the lower back.

Aim 3: Conduct tests in the AUB labs using different groups of students and propose a solution to ensure safety.

2. Optimizing the efficiency of their production process

   Aim 1: Conduct a time study to find standard time and use the process times to aid in the simulation process.

   Aim 2: Simulate the production line in order to optimize and improve.

   Aim 3: Perform an engineering economy analysis to propose a feasible, cost-efficient solution that could be implemented at the factory.

3. Optimizing the spatial requirements of the factory

   Aim 1: Study the data acquired from the factory to conduct multi-facility plans.

   Aim 2: Apply multi-facility techniques to find an optimal design and implement it at the factory.

III. Background

Nowadays, simulation is a leading technique that allows companies to visualize different possible scenarios to address problems and find solutions without having to incur drastic costs. Simulation allows companies to develop a program that captures the behaviour of a real-life system (John & Joseph, 2013). Hence, any changes observed in the system can be modified or adjusted. It can be used in many sectors ranging from the manufacturing industry to shipyards and ports (Neeraj et al., 2018). More specifically, a study showed that the output of a facility increased to 109 units/day over the usual 100 units/day (Ito, Mohamad, & Yuniawan, 2013). Similarly, in this project, we decided to use simulation on the different machines in the factory.

As for the workers' perspective, we are going to focus on preventing lower back pain through the use of ergonomics. The benefits of using ergonomics is not only limited to increasing employee performance and safety, but it also extends to fixing issues related to turnover and absenteeism as well as improving the quality of work-life for employees (Loisel et al., 2001). Several ergonomic steps should be taken (interviewing the workers, visiting the site and observing the tasks, etc.) in order to come up with results to improve a specific task (Loisel et al., 2001). The ergonomics tools used throughout our experiments are the NIOSH lifting equation, the Musculoskeletal Discomfort Rating, the Rapid Upper Limb Assessment and the EMG device. The NIOSH Lifting Equation is used as a guide to assess the risk of manual material handling (MMH) tasks. Its main purpose is to compute a recommended weight limit (RWL). The RWL is found at both the origin and destination of the lift to identify the most stressful location of the lifting task. Therefore, the lowest value of the RWL at either the origin or destination should be used to compute the lifting index (LI) (LI= weight actually lifted/RWL) for the task, since this value would represent the limiting set of conditions (Shahu, 2016). An LI that is less than or equal to 1 is considered good, between 1 and 3 shows potential problems and greater than 3 needs to be revised immediately. The Musculoskeletal Discomfort Rating is a common and valid method for the acquisition of pain intensity. It consists of rating the level of discomfort on a scale of 1 to 10, with 10 being high discomfort and 1 being minimal discomfort. The Rapid Upper Limb Assessment (RULA) tool uses a systematic process to evaluate required body posture, force, and repetition for the job task being evaluated. It consists of a single page worksheet used to evaluate required or selected body posture, muscle use frequency, and forceful exertions. Electromyography (EMG) is a device used to measure the response of the muscle or electrical activity after a stimulation of the studied muscle (Sleutjes et al., 2018).

On a larger scale, we will be looking into facilities planning to optimize the plant layout. Facility layout is considered a common topic tackled by industrial engineers. Studies have shown that 20 to 50% of costs in a manufacturing system are attributed to material handling, of which 10 to 30% can be reduced by effective facilities planning (Olanrele et al., 2019). An estimated $250 billion is spent every year on facilities planning in the US (Balakrishnan et al., 2007). Accordingly, optimization of the layout design contributes positively to a manufacturing process as it helps to minimize cost of manufacturing whilst maximizing space availability for the greatest possible output (Nitish et al., 2015). The method used throughout our project is systematic layout planning (SLP) which mainly helps in rating and visualizing the elements and areas in the facility. In addition, SLP is used to improve spatial distances between the different machines and workstations and the flow of material at a plant. The main advantages of this method is reducing material handling costs as well as increasing workers' productivity (Ashish, Sandip, Sachin, 2012).

IV. Methods

A. *Ergonomics:*

Throughout this project, we decided to focus on the palleting process. Palleting is the act of workers moving boxes from machines onto pallets, given that this task requires the utmost manual effort, hence causing the most pain on the lower back. Since we could not take into consideration all sizes of bottles produced, we conducted the experiment on the most produced and heaviest at the factory which is the Persil 3L bottle. This means that the most common weight the workers must handle is a box weighing an average of 18 kg.

Since the processes involved bending and lifting, we decided to focus on the negative effect on the workers' lower backs. To study the effect that this task could cause, we simulated the scenario at the factory in the AUB Ergonomics lab with the help of participants. We took the measurements necessary to be able to simulate a scenario that best replicates the physical task.

The experiment included two extremities of the palleting process. The lower extremity being box placement at bottom of the stack and the high extremity being box placement at the top, which is 120 cm high (taken from a full pallet of Persil 3L at the site). We chose five male participants, since all the workers in the factory are male, to perform the task to evaluate them using ergonomic tools. We depended on the previously mentioned mixture of tools that evaluate the correctness of the work done by the workers. These tools would then help us improve the task and come up with evaluations. We also used the EMG device in order to provide more insight on the muscle activity of the workers performing this task.

B. Simulation:

The data collected from our visits to the factory were based on a time study that was conducted for one of the machines. The study initiated by observing the production process of one batch of detergents per machine to further understand the process. After that, we reassured the breakdown process that was done in our time study previously for our arena simulation. We decided to use a triangular distribution for all the machines except for one. After the time study was done, we plugged the data into ExpertFit to find the most accurate distribution for the processes. The labelling process of bottles, for example, was found to follow an Erlang distribution. After several visits, we managed to get the data for the five machines. Some ExpertFit data obtained for the filling process is shown in Table 1. Due to constraints in data collection, we based the triangular distribution on the bottle sizes that each machine can process. This means that the heaviest bottle filled per machine was allocated the maximum time, while the lightest was allocated the minimum time. This ideology was applied to all machines that followed the triangular distribution.

Table 1- Sample Arena Distributions for Filling Process

Machine	Distribution
Thomasson 2	Triangular (2,5,10)
Thomasson 3	Based on expert fit: 0.067273 + 38.925888 * BETA (2.936914,3.617303)
Thomasson 4	Triangular (1.67,5,10)
Thomasson 5	Triangular (2.5,7.2,15)
AVE	Constant (3.5s)

C. Facilities Planning:

After several visits to the factory, we noticed a few space inefficiencies and decided to apply facilities planning methods to optimize the overall space. To be more specific, the workers were unnecessarily involved in a significant amount of backtracking. It appears some machines were more advantageous than others in terms of location. This is mainly because 4 out of the 5 available machines were part of the original layout and the fifth machine (being the largest) was later added without a re-consideration of department flow.

We sat down with the factory manager Mr. Raymond to learn more about the chronological order of things and the overall resulting inter-departmental flow. He also shared with us data depicting Henkel's daily demands for detergent output and explained in detail exactly how a product is transported throughout the facility. It is important to note that the facility is a process layout; the departments are divided on the basis of the processes that take place (mixing is separate from the packaging, which are both separate from the maintenance department and so on). The main challenge we faced is that the factory, and hence the departments, spans across three floors. In our facilities planning course, the methods we learnt to optimize layout planning are all only applicable to a single-floor facility. For that reason, we decided to study the factory floor by floor.

We began with a breakdown of the departments. In general, there are a total of 10 departments if we combine all the floors of the facility. These departments are: old machines, box storage area, bottle storage area, mixing, quality control, new machines, maintenance, finished product warehousing, wrapping station, and warehouse offices.

Henkel's physical plant department was kind enough to share the AUTOCAD layout of the facility, shown in Fig. 1. We divided the departments in white, keeping in mind that "maintenance" and "bottle storage" are departments that are on elevated platforms. Fig. 1 shown only the first floor of the facility. This floor is the main processing floor since it is where the machines and storage boxes reside. To preliminarily understand the importance of departments with respect to one another, we decided to use the SLP method. To gather the necessary information, we used a combination of daily demand worksheets, observations, and communication with the heads of the departments. After SLP, we plan to develop alternative layouts and simulate them on ARENA to gather performance measures such as average transfer time and completion time and compare the layouts to reach the optimal design.

Fig. 1- Floor Department Distribution

V. Results

A. Ergonomics:

So far, we had four participants perform the task in AUB labs but unfortunately, we are not able to access the results now due to the current situation. However, with the given data, a peak in the EMG plots was observed when the participants were bending over and performing the palleting task. This is an indicator of a need for improvement. One of the suggestions is to have an adjustable pallet that begins at a suitable level for the first set of boxes and drops down after finishing each layer. In this way, the workers will not need to engage in excessive vertical movements, since the pallets could facilitate easier transfer of boxes. This suggestion was tested in the labs as well and a flatter EMG result was observed.

NIOSH Lifting Equation:

In order to analyze the results, calculations were carried out on the lifting analysis worksheet, specifically focusing on two liftings tasks: the lower and upper extreme previously mentioned. We computed averages for all the components of the equation for both extremes and chose the RWL of the destination since it is the lower value. We then computed the LI and got the smallest value at the destination (for both extremes). Both values are greater than 3, as seen in Table 2, meaning that the lifting task should be revised immediately.

Table 2- Average of all Participants (NIOSH Results)

	Upper Extreme		Lower Extreme	
	Origin	Destination	Origin	Destination
RWL	8.742	4.660	7.766	4.451
LI	2.063	3.868	2.324	4.121

Musculoskeletal Discomfort Rating:

The MDR tool allowed us to rate the level of discomfort on a scale of 1 to 10, with 10 being high discomfort and 1 being very little. This tool was first used on the workers in the factory. Unfortunately, when we attempted to ask the required questions, they displayed signs of worry that the supervisor would punish them since they knew they were being watched. That is why we decided to use this tool on the participants in the ergonomics lab to get an idea of the level of discomfort. This allowed us to back up our claim of task revision. We then computed the average of the five participants for each task to have a bigger picture which can be seen in Table 3. The results show that there is not any extreme discomfort felt by the participants, but that is only because they performed the task once. The workers in the factory, however, perform this task for 12 hours.

Table 3- Average of all participants (MSD Results)

	Upper Extreme		Lower Extreme	
	Shoulder	Back	Shoulder	Back
Average of the 5 participants	4.4	3	4	5.8

Rapid Upper Limb Assessment:

We used RULA to assess the posture of our participants and see if it needs any improvements. For placing the 18 kg box on the bottom layer of the pallet and the top layer of the pallet, the main body parts that received the highest scores in the worksheet were the trunk, upper arm, and wrist. The results are shown in Fig. 2. We calculated a RULA score of 7 which means that the palleting task needs to be revisited for it to be safer for the worker.

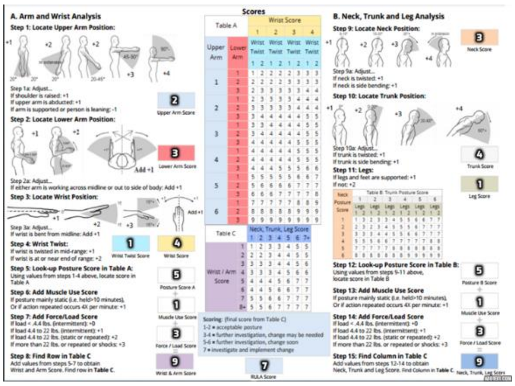

Fig. 2-RULA Worksheet Scores

Simulation:

The model created for the simulation is complete, however there are still some compiling errors that are restricting us from observing the results that will be tackled during the remainder of the semester. While running the simulation, you can observe a long queue at the workstations. Fig. 3 is a visual of Machine 3. In Fig. 3, there are long waiting times at the capping, labelling, and packing stations. This mimics the real-life observations we viewed during site visits.

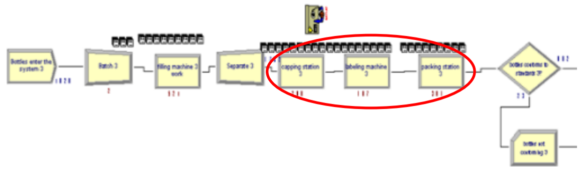

Fig. 3- Bottlenecks along Machine 3

B. *Facilities Planning*

To solve this issue, we proceeded with an activity relationship diagram that combines all the departments across all floors, to better understand the significance of their locations. The most important things that were learned but were not obvious by observation were the that the machines and offices have an undesirable relationship due to noise annoyance as well as that quality control and mixing departments have a very important interaction (related to inspection of the product). The final activity relationship diagram, based on qualitative measures solely, is found in Fig. 4.

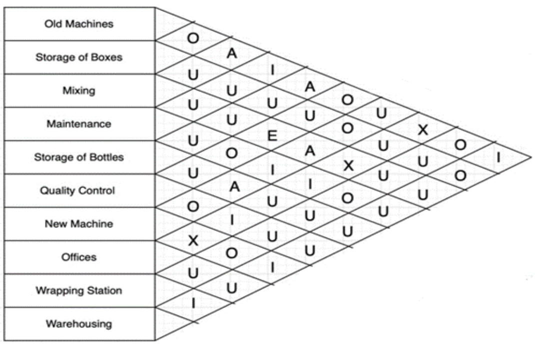

Fig. 4- Developed Activity Relationship Diagram

The machines. whether new or old, all have the same goal, and have almost the same exact interactions with all the other departments. After discussing our activity relationship diagram with Mr. Raymond, he informed us that despite the interactions we observed, some departments are highly fixed and cannot change location. These departments are the ones that span across the second and third floors. Therefore, it became clear to us that what we need to improve is the layout of the first floor, mainly attempting to optimize the interaction between the new machine and the other departments.

We decided to construct a flow diagram to show the backtracking on the first floor, as seen in Fig. 5. Our focus, now being mainly the first floor, was to improve that which put the new machine at a disadvantage. In other words, to decrease the amount of worker backtracking to and from neighboring departments.

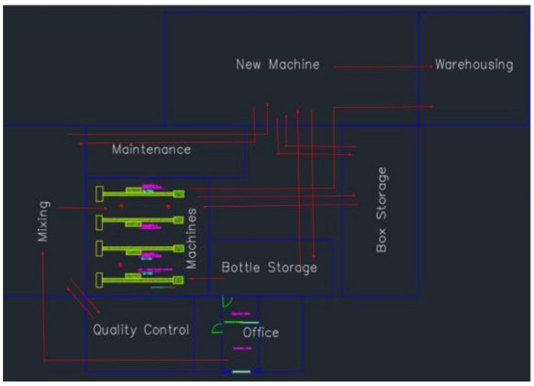

Fig. 5- Flow Chart on the First Floor

VI. Discussion and Conclusion

Interpreting the results obtained so far, it can be concluded that the factory lacks focus on worker safety and has several bottlenecks in the machines used which slows down the process of production. According to all the ergonomic tools we have used (NIOSH, MDR, and RULA), the palleting process can cause harm to the workers' lower backs. For that reason, we concluded with a couple of suggestions as a solution for the factory. Our main suggestion includes having an adjustable pallet to reduce the angle of vertical twist of the worker from a 90° angle to a 0° angle. Reducing the angle when placing the boxes on the pallet, by simply moving the pallet closer up minimizes the chance of injury. Along with that, the workers should be given more breaks to rest and move around in order to avoid concentrated muscle activity. Lastly, since it is obvious that the tasks that are required from the worker are ones that demand a certain ability of physical activity, Henkel should consider having certain criteria of the worker's physical characteristics before hiring its employees and should provide relative training for them. Following through these suggestions, Henkel is expected to increase worker safety.

We are currently working on facilities planning since the manager wants to move the machines in the factory to another building. For that reason, we will be forming alternative layouts based on activity relationship diagrams. We will be simulating alternative layouts on ARENA to compare and get the optimal design. Moreover, if conditions allow, we intend on obtaining more quantitative results by gathering more on-site data.

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