Introducing Radio Frequency Identifation into Lean Manufacturing ; An application in garment industry *

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Abstract— **Applying Lean Manufacturing system in industry has a high impact on increasing the productivity, profitability, reduce costs and improve quality. However, applying this system needs a huge amount of continuous information about the products' path which is very difficult to be achieved in a labor intensive industry. The main objective of this research is to overcome the problem of acquiring accurate and timely data to be used in the different Lean manufacturing tools. This research identifies implementation areas where RFID can have the greatest impact on work-in-process management, manufacturing flow tracking and defects control in lean manufacturing environments. The study specifically focuses on how RFID can help identify, reduce, and eliminate the seven common types of waste identified by Taiichi Ohno. To support this objective, a Radio Frequency Identification (RFID) System is designed and applied in garment industry. Industrial case studies were performed at a garment factory to verify and validate the designed RFID system. The RFID software/hardware is designed and implemented on the manufacturing process. The study expands the knowledge of manufacturing waste reduction through the use of RFID technology.**

The study concluded that the reduction of manufacturing waste can be achieved through the deployment of a well-designed RFID system which can be integrated in the manufacturing process. This study fulfills an identified need to study the implementation areas where RFID can have the greatest impact and add value within lean manufacturing settings in labor intensive industries. The research includes implications for industry practitioners and researchers by providing a better understanding of the benefits of RFID in manufacturing.

Keywords—RFID; Lean Manufacturing; Garment industry; Work in process;

I. INTRODUCTION

Garment industry has a large contribution in the national industry and exchange earning. It represents 26.4 percent of industrial production in Egypt and about 10 percent of the country's exports. After the removal of Multi Fiber Agreement in 2005, local apparel industries have suffered due to the increase in the demand for low cost garments by the customers and the sudden increase of the costs of the raw material by the suppliers. On the other hand new entry of international enterprises into the Egyptian market as those from China and Bangladesh makes it even harder for local garment industries. A lot of mangers are searching for different systems and methodologies to bring down their expense and to boost their benefit. The best way to accomplish such objectives is to seek after operational excellence and to eliminate wastes to accomplish better customer service. Lean Manufacturing with its different strategies and tools was found to be the solution for most of these problems The main goal of implementing Lean Manufacturing is to identify & reduce wastes in an industry or an organizational service .The starting point of implementing lean manufacturing tools is to have huge data measurements and large information about the daily path of the products. In labor intensive industry it is very difficult extract the required data accurately, which means failing of implementing Lean Manufacturing. Introducing Radio frequency identification was the solution for providing all the needed information to improve the performance of Lean Manufacturing implementation

RFID is likely to be among the most important and fastest-growing technologies in terms of scope of application in the next generation of business intelligence and also it was found out that applying RFID in industry could have a great impact [1]
During the period from 1995 to 2005, it was first important to solve the technical problems of RFID after that relating of RFID to business issues would fast grow [2] .Many frame works were proposed to support the selection and deployment of the appropriate RFID-based control strategy in many fields like Automotive, construction industries and service center performing MRO activities [3]
Before implementing RFID in industry, several applications were implemented in all other kinds of fields. Some of them were large scale applications like automobile distribution yard, highway and city toll collection, public library customer service, industrial laundry management, airline luggage tracking, hospital patient identification, prison inmate tracking [4]. Reference [5] introduced other small scale applications such as ATM cash transfer , container yard management ,McDonald's cashless payment, beer keg distribution control ,lab supply vendor-managed inventory , railcar tracking, ocean going container tracking, specialty container identification, fashion boutique management, refrigerated cargo control, MREs (Meals Ready to-Eat) control, theme park visitor location, student location, mine worker identification, mapping of RFID tag readability in relation to the food content in a refrigerated sea container . However these applications were having a great impact but when applying RFID in supply in the recent years it made a great difference in the explosion of RFID [2]. Other deployment benefits include eliminating shipping and receiving errors, improving productivity, establishing traceability, and achieving inventory control and accuracy [6]. RFID is a flow control technology, and tracking is the typical application of RFID in logistics management [7]. When simulating and implementing RFID in inventory management of military, RFID is found to have a great benefits on improving the supply chain process , Monte Carlo simulation is being used to anticipate the benefits of this system implementation[8]. After deploying RFID in supply chain, RFID started to spread in many kind industries; in aerospace industry. [9], RFID in electronics [10] and RFID in manufacturing. [11]

After raising the idea of implementing RFID into lean manufacturing, [12] state that deploying the RFID system could eliminate wastes according to the following sequence: unnecessary inventory (best eliminated), inefficient transportation, overproduction, waiting time, inappropriate Processing, unnecessary motion, defects (least-eliminated). Herath et al. [13] propose a smart factory prototype that doesn't need any human intervention from the ordering of the customer stage till the shipping stage. [14] Present a real time manufacturing execution system (RT-MES) that was applied in MCP Company. Alhas et al. [15] improve the production line of aeronautical industry by integrating a chip in the composites parts during assembling procedures.

This paper contributes to the existing literature by introducing a Radio Frequency Identification (RFID) System which is is designed and applied in garment industry. Industrial case studies were performed at a garment factory to verify and validate the designed RFID system. The RFID software/hardware is designed and implemented on the manufacturing process. The study expands the knowledge of manufacturing waste reduction through the use of RFID technology.

Within the mentioned framework, the paper is organized as follows: in section 2, the case studies upon which the system design was based are presented; section 3 introduces the main steps of system implementation; in section 4 the results are presented and discussed to illustrate the system and section 5 concludes the research work.

II. Case Studies

Three different case studies were conducted in Delta Galil Egypt factory in order to find out the evaluating ways of garment production line, the factors that affect garment production, time & accuracy of these evaluations. Each case study was conducted on a different day, in each of them data for time studies, stoppage times were measured and recorded, the expected work in process, bottle necks, efficiencies and productivity of each station on the production line were calculated.

Time study is a method of measuring the cycle time of every task in an operation. The measurements are being performed manually by stopwatches and video analysis. The goal of the time study is to help defining how much it takes an operator to carry out the task and show the level of his/her performance. Most of the operations consist of two parts; handling time and machine time. The cycle time of each worker on the production time was measured 10 times then it was compared to the standard time of the process.

From the time study, it is important to calculate the expected produced pieces of each station per hour then find the bottle neck station and the work in process before each station.

Down time (Stoppage time) analysis was conducted on the production line to show the common problems which affect the production flow and cause wastes like inventory, defects and waiting which at the end lead in reduction of productivity and increasing lead time. A sheet was designed to record the following information: 1) reasons of stoppages 2) duration of the stoppage 3) stations in which that stoppage occurred .It was concluded that there are 5 main reasons behind stoppage time which are (a) No Work: line starvation one of the main causes of downtime and it can stop the line production for days and maybe weeks. (b) No material: the delay of material is most probably caused by the wrong planning for example sending the

wrong material or loss of the material in the material ware house. (c) Machine breakdown: may stops the station for few minutes or hours but it usually happens frequently, so it is one of the downtimes that should be eliminated (d) Quality issue: when the end line quality rejected a piece its immediately gets back to defected station for rework so it delays the production flow and causes a huge inventory (e) Personal time or absenteeism: when an operator is not on her station, it cause inventory and decrease the line efficiency.

The efficiencies of the production line and the operator was calculated from this equations

$$\text{Theoretical production target per day} = \frac{\text{Total man power per line} * \text{total working minutes per day}}{\text{Standard minute value}} \quad (1)$$

$$\text{Line efficiency} = \frac{\text{Total output per line} * \text{Standard Allowed Minute}}{\text{Total manpower per line} * \text{Total working minutes per day}} \quad (2)$$

$$\text{Operator efficiency} = \frac{\text{Total minute produced}}{\text{Total running time}} \quad (3)$$

Equation (1) is the theoretical capacity of production per day ,it depends on the man power ,working minute and the standard time of the product. Equation (2) is used to calculate the line efficiency of the production line, it depends on the produced pieces, Standard allowed minute, man power and working minutes. Equation (3) is the operator efficiency; it depends on the number of produced pieces, the Standard minute value of the product and the total working hours

Table 1. Shows the results of the three case studies, as it is obvious that the stoppage time and average time is related to the line efficiency. The defective pieces number also is related to the operator's skills.

Table 1. Case study results

Differences	Case study 1	Case Study 2	Case Study 3
Number of operators	12	12	12
Demand (pieces)	1000	860	845
Produced pieces	570	432	320
Defective pieces	10	36	9
Average time (min)	5.6228	6.52	6.6452
Total stoppage (min)	165	256	295
Line efficiency(min)	51.8%	39.3%	29 %

Fig. 1 shows the inconsistency in the efficiencies of the 12 stations of the production line, because each day different labour with different condition works on the station that's why the station performance changes unexpectedly.

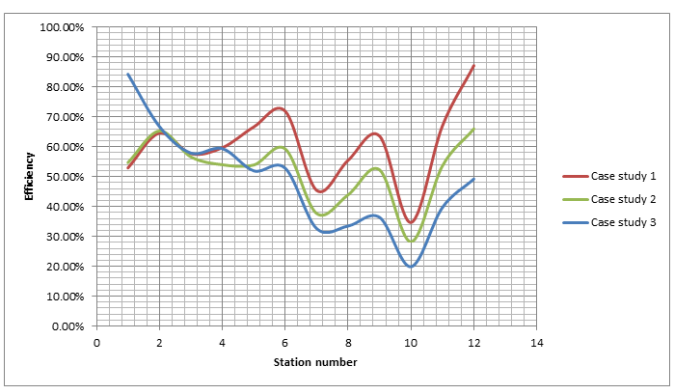

Fig.1. Station efficiencies

Performing the case study took around 3 hours, calculating the expected bottlenecks; work in process, stoppage times and analyzing this data with the other key performance indicators for the 18 production line took days (efficiencies & productivity). Even this data may be misleading due to the possibility of mistakes; data is manually recorded measured and recorded. Another important drawback that was observed during conducting the study the number and frequency of reworked

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pieces, it was difficult to even get a rough number of defective or reworked parts. In the current condition, the rework could be discovered in one of the following stations, sent back to the concerned station for rework without recording these steps. The time consumed in this hidden process affects the flow of the production line, causes more WIP and provide false indication about the output quality of the station. All the of the above mentioned problems together with the lack of a reliable database on the variables affecting the manufacturing process urged the researcher to design a system that can be integrated in the manufacturing system to automatically identify and track the information in every stage of the manufacturing process and keep all information for further use and analysis after production. This objective is only achieved through the adaptation of Radio Frequency identification the manufacturing environment. The proposed RFID system will help manufacturers to constantly control and improve manufacturing performance to remain competitive. The major concern of the system designer is to maintain sufficient up-to-date workflow information to effectively advance manufacturing performance. The workflow information includes, but not limited to; (1) Average time to stay on each station (2) Operator efficiency (3) Efficiency of each station according to the standard time (4) Productivity of each station (4) Stoppages of each station in seconds.(5)Number of rework produced from each station (6) the number of WIP pieces at each station.This system will support the application of the Lean manufacturing tools and thus increase the productivity of the production line as it would give all this data in a real time system to allow the industrial engineers to measure, analyze and modify the production line before any problem could occur.

III. SYSTEM IMPEMENTATION

Fig.2 shows the system architecture. It's composed of hardware and software modules. The hardware consists of the tags which are stuck on the products, the (Near Field Communication) NFC readers that identify the tags, Arduino processor that gather the data and send it through the wireless module to the access point. On the other side, the software consists of python communication (Application Processor Interface) API which receive the data, the processing API that analyze the data and produce the result on CSV file to be represented as excel sheets.

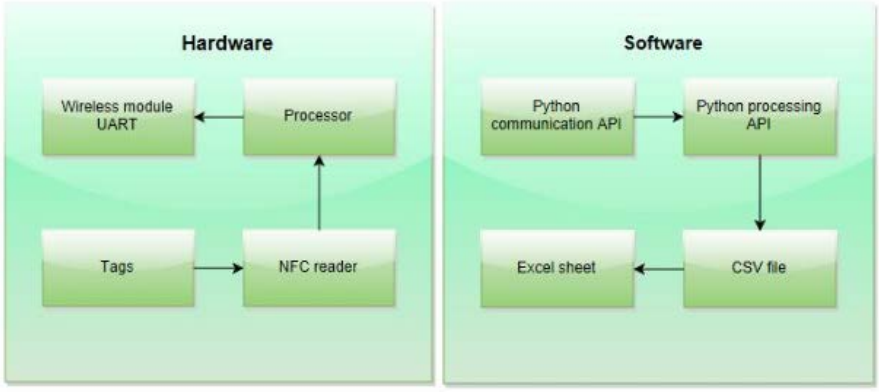

Fig.2. System Architecture

The prototype system works on two machines so each machine has two readers installed before and after it, in order to detect both entrance & exist of the products from station.

Fig.3 Shows the orientation of the reader on the station and also shows the passive tags that were used on the products.

Figure.3. Orientation of NFC/RFID readers on the station

Each check in /check out module consists of near field communication (RFID technology 13.5MHZ), special type of passive tags that can suit garment, Arduino Uno microcontroller, Wireless module serial UART (200M range-433 Mhz) and a power cable. These modules are considered to be the NFC nodes which gather all data of the stations, and then the data is being sent to the data collector which is connected to the software.

Fig.4 Shows how NFC node search for the tag and then it concatenate the station address to the unique identification number of each tag before it send both the time &UID (Unique identification number)to the data collector. After receiving the data, the data collector sends it to the software to analyze.

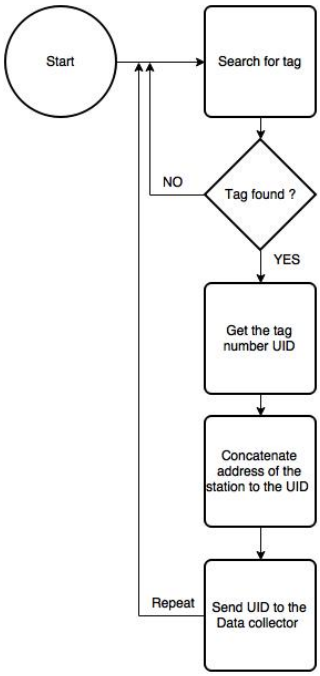

Figure.4. NFC Node

Python language was used in the software part as it is a dynamically typed-language so it's easier to express concepts in fewer lines of code than would be possible in as java and C++. A comma separated values (CSV) file contains different values separated by a delimiter, which acted as a database table or an intermediate form of a database table.

The main task in those scenarios was to give accurate updatable information in second with any change happens in the system either from check in or check out of any product. The needed information is: (1) Average time to stay of each station (2)Operator Efficiency(3)Operator Productivity(4)Station Stoppage time (5)Number of rework (6)The number of work in process pieces.

Fig.5 shows the algorithm of finding out the reworked pieces over each station, the software code starts by removing the noise and saving both the UID and the entrance time of the product at different arrays, if the product UID is repeated on the same station then increment the defective counter. This number could be used to evaluate the skills of the operators.

Time to stay (cycle time) is calculated by getting the difference between entrances and exists of each product on the station, adding the sum for all products and divided by number of product to find of the average time to stay of the operator. On the other hand, the stoppage time of the station is calculating by getting the difference between the products exist and next product entrance on the station. Adding all the stops on a accumulative stoppage time would find out the total stoppages of the machine. Concerning the efficiency and productivity of the operator, it starts to be zero when no product produced after that the efficiency and productivity is being calculated according to equation (4) & equation (5).

$$Efficiency = \frac{\text{No. of pieces} * \text{SMV(Seconds)}}{\text{Worked time (seconds)}} \qquad (4)$$

$$Productivity = \frac{\text{Total pieces} - \text{defective pieces}}{\text{worked time (Second)}} \qquad (5)$$

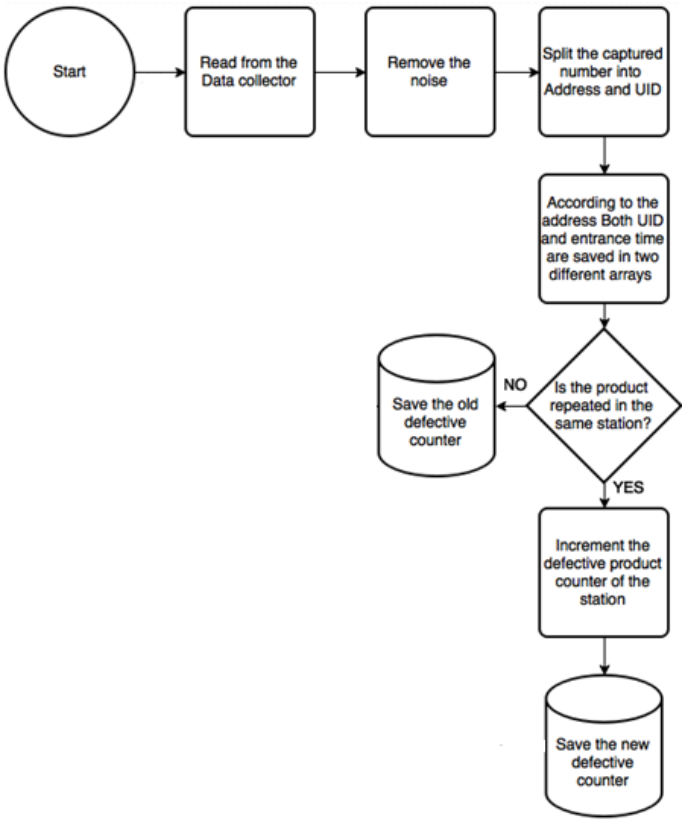

Figure.5. Reworked pieces

Fig.6 shows the work in process algorithm which is the sixth needed workflow information, the product is considered to be works in process if it has been finished by one machine and still not processed by the next machine. The sum of these products is considered to be the total number of work in process before each machine.

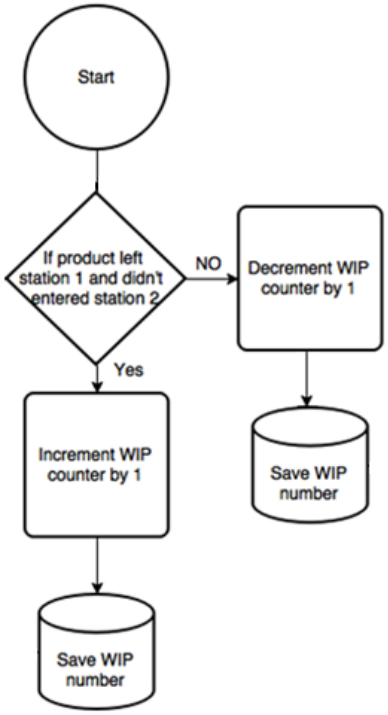

Figure.6. Work in process

IV. RESULTS

Several scenarios were performed as a physical simulation to validate our system in series & parallel work flow; the results of a scenario that worked on both parallel and series work flow together is presented.

The simulation was done on twenty products. The sequence of the simulation is explained as follow: twenty products have passed over the two stations. This scenario was composed of 7 phases. First phase, products from one to five passed by station 1 only and considered as work in process on station 2. Second phase, station 2 started to work in parallel with station 1, so station 2 was producing products from one to five while station 1 was producing products from six to ten. Third phase, both of them were still working in parallel, so station 2 was working on products from six to ten while station 1 was working on products from eleven to fifteen. Fourth phase, station 1 stopped working while products from eleven to fifteen passed by station 2 to decrease WIP number to zero. Fifth phase, products sixteen, seventeen and eighteen passed sequentially over the two stations .Sixth phase, defective product eighteen reentered again on the two stations. Seventh phase, tag 19 and 20 passed sequential over the 2 stations before defective product 20 returned to station 1 again. The standard time was set to be 2.5 seconds for station 1 and 3 seconds for station 2. The simulation took around four minutes during executing.

By the starting of the simulation six CSV files are produced with the date and time of the simulation to distinguish between each working simulation results. Those CSV file are opened as excel sheets and this excels sheets consists of 3 columns time, station1, station2.The system was adjusted to be updated every time a product pass by a reader ,So there was a high frequency of updatable reading (reached to be one second).

Figure.7 shows the results of the time to stay excel sheet of station 1.It started from zero and ended to be 2.6 second, the average time reading second by second reflects the performance of the operator, if it's very high compared to the standard time then there is a problem needed to be solved by the industrial engineer. On the same manner was station 2 the average time was compare to the standard time and each new cycle time was changing the total time to stay.

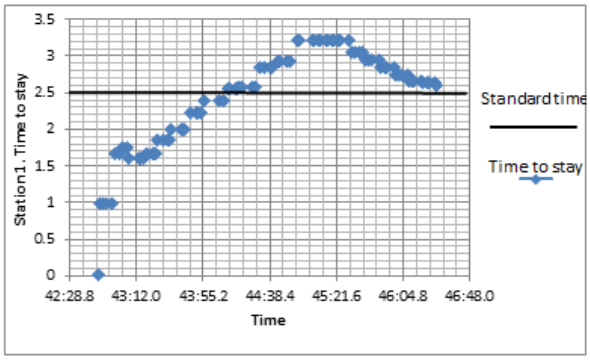

Figure.7. Station one Time to stay

Fig.8 shows the results of station1 stoppage time, stoppage time was an accumulative variable that capture its stop between the products .the stoppage time increased to reach 167 second over the four minutes .while stoppage time of station 1 was found to be 2 was found to be 130 seconds because the standard minutes of station 2 was greater than that of station 1.

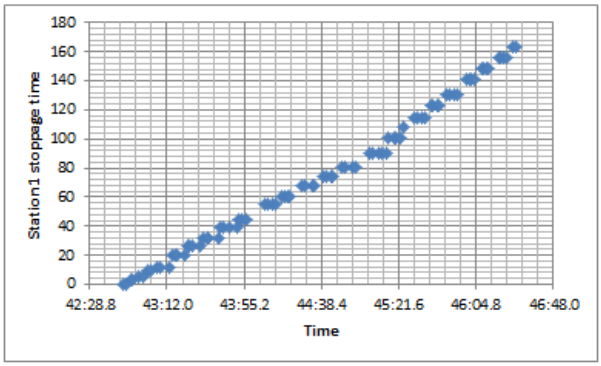

Figure.8.Station one stoppage time

Fig.9. shows the change of work in process over station 2, in the first stage the first 5 products have been produced from station 1 and considered as WIP on station 2 .Then in the second and third stages both station started to work in parallel that's why the WIP were deflecting between four and five .In the fourth stage, station 2 only worked to decrease the WIP to zero. At last stage the 5 products passed in series over the 2 stations which deflected the WIP between zero and one.

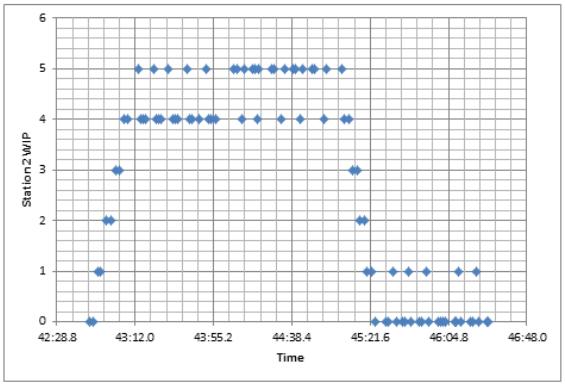

Figure.9.Station two Work in process

The reworked pieces were captured to be 2 pieces on station 1 and only one piece on station 2. Each of them was recorded with the time of entrance and the product tag number.

Figure.10 shows the efficiency of station 1. It was calculated to be 100% after the first piece because the first piece was produced in exactly 2.5 second which is the standard time of station 1,then it decrease by the decreasing of the rate of the produced pieces specially after the first five products till it reach at the end of the simulation to 21 %.

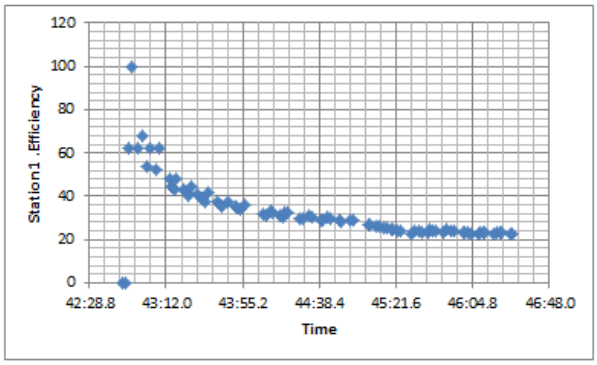

Figure.10.Efficiency of station one

Fig.11 shows the productivity of station 1. After the first product it was found that the productivity of the operator 0.4 products per second then it decreased gradually with to reach 0.09 products per second.

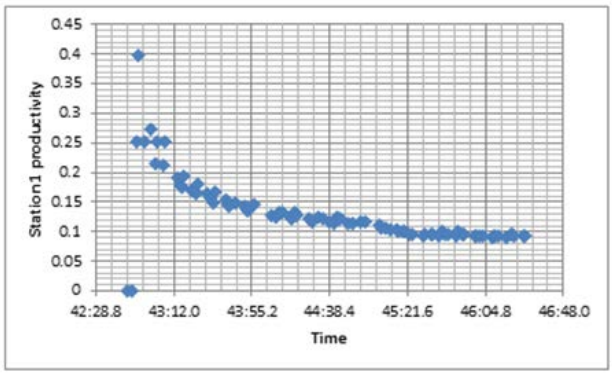

Figure.11.Productivivty of station one

V. Conclusion & Future work

This research supports the use of RFID technology in lean manufacturing settings in labor-intensive industry, especially garment industry. The applications tackled in this research included areas such as work-in-process management, manufacturing flow tracking and defects control. The potential RFID applications that have been supported under work-in-process management scale include: (a) knowing how much of which products are work-in-progress, (b) enabling more effective tracking of materials throughout manufacturing process, (c) knowing where finished products are, (d) managing the location of products during transportation between processes, and (e) eliminating manual data collection and human errors. RFID can be used to improve manufacturing flow through (a) eliminating manual counts and human error, (b) eliminating the need for product queuing – waiting time and assisting in the application of just-in-time methodology, (c) knowing location of backtracking, (d) identifying unnecessary motion of products, and (e) knowing the type of stoppages, their timing and their reasons.

The study also showed that there is a significant relationship between lean manufacturing wastes reduction and the adoption of RFID technologies through the application of the proposed hardware and software systems over a garment production line. This integration :(1) Eliminates the manual and paper based data collection that is error-prone, tedious and time-consuming.(2) Upgrades the production-floor data to a level that is real-time, complete and accurate. (3)Have high influence on the improvement of lean manufacturing generally on the work flow and specially on the work in process (WIP) , number of reworks , waiting time.(4) Converts the production flow data into piece by piece flow data instead of bundles flow data. (5)Fed back the system with the disturbance in the normal plans and schedules which could enables a real time adaptive decision mode.(6) Capture and display any movement of the material to decision makers in order to work out different Lean Manufacturing strategies.

Future work should work on deploying RFID system on a real garment production line, Adapt the system to track the workers if they changed their stations ,also to adapt the system in a way to categorize the stoppage time into one of the five categories of stoppages that where stated in the case study. More over researches should implement RFID system in different labour intensive industry.

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BIOGRAPHY

Michael Magdy is teacher assistant and researcher at the german university in cairo in mechatronics department. He holds a bachelor degree in mechatronics and also a master degreein mechatronics. He has made some robotics researches in mercedes EGA factory & other industrial electronics researches in Delta Galil factory.

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