

**A Big Data Approach to Evaluate and Improve Productivity
and Workers Performance in the Clothing Manufacturing
Industry: Case Study from Bangladesh**

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Abstract: The goal of this article is to examine opportunities and show the approach of using big data analytics to evaluate and boost worker's performance and productivity in the case of the clothing manufacturing factories. Manufacturing industries in Bangladesh are mainly dominated by the apparel and textile sector for a long time now. While this sector has seen a hefty growth throughout all these years, it is still far from using the available latest technologies to improve further in productivity and worker's performance. As garments manufacturing is a labor-intensive industry, there is actually not much opportunity to automate the work. But, what we can do is make the work easier for the operators involved in each process which will increase their performance and overall productivity. Usually, manufacturing operations involve generation of a large amount of structured or unstructured, useful or non-useful data on a daily basis. This huge amount of information is known as big data which is difficult to handle by using traditional data management and analysis tools. However, with the help of big data analytics used in a proper method, the information collected by different types of sensors, logs or records, and computerized machines can be used to track insufficiencies in different areas of manufacturing operations. This research is conducted based on problems identified from primary production data collected from a garments manufacturing plant of Bangladesh and extensive literature review and with the help of big data the paper will suggest a way to identify and evaluate deficiencies of worker's performance quickly by using the resources available in the factories compared to the usual time consuming method which in turn will have a big impact on the overall productivity.

Keywords: Big Data, Smart Manufacturing, Industrial Innovation, Productivity, Workers Performance

1. Introduction:

The apparel and textile manufacturing industry might not seem too prominent from the engineering automation perspective till now but there are many who think that it is the single most prominent industry from the economical prospect (Godley, 1997). Now-a-days with the increase in demand for apparel worldwide especially in western countries, this sector is experiencing exponential growth every day (Moorhouse, 2020). Bangladesh as a key player of textile and clothing manufacturing is covering a major demand for a long time by maintaining proper quality and currently ranked as second in clothing export after China. As a result, this sector has become the leader in terms of employment, GDP and foreign exchange earnings since its inauguration in the country's economy (Nabi, Mahmud, & Islam, 2015; Farhana, Syduzzaman & Shayekh, 2015). Technological growth and automation in this sector has not reached its full potential yet though. Only in some cases of spinning, weaving, garment manufacturing and dyeing, the automation has reached almost full potential (Carr & Latham, 2008; Choubey & Agrawal, 2016).

Industry 4.0 after its first display in the Hannover fair of 2011 brought a lot of new technologies such as Internet of Things (IoT), Cloud Computing, Big Data, Augmented and Virtual Reality, Additive Manufacturing, 3D printing, Autonomous Robots (János Viharos, Soós, Nick, Várgedő, & Beregi, 2017; Alcácer & Cruz-Machado, 2019). All these technologies could bring about a full scale manufacturing automation for garment manufacturing and related sectors. With advanced technology arriving, machines can increasingly handle difficult tasks such as stitching pockets, attaching belt loops to the garments, handling pliable fabrics (Emont, 2018).

But, most of these are still in the development stage and not being used to their fullest. As an example, fabric as a limp material is very difficult to grasp and handle by robots. Moreover, some of the sewing operations are very critical which requires precision and sometimes need to be done in a small space which can be increasingly difficult for an autobot (Emont, 2018; Molfino, Zoppi, Carca, & Avvenente, 2010). That is why, human workers are one of the core elements of garment manufacturing. But, unlike robots the humans have the requirements of taking proper rest, have fatigues and make errors while doing the work which in turn creates bottlenecks and affects the final output and these can be seen as limitations of humans. These limitations frequently affect the productivity, efficiency of manufacturing and overall performance of an operator (Molfino et al., 2010; Nabi et al., 2015).

Now-a-days, in a modern clothing manufacturing environment, lots of manufacturing data is being gathered everyday by different sensors, computerized sewing machines and RFID's which are coming from machines, workers and contains loads of information related to performance, operation, statistics, goals (Shah, Wang, & He, 2020; Cui, Kara, & Chan, 2020). Big data analytics can be extensively used to analyze these huge volumes of data gathered from different parts of the manufacturing sector and provide useful insights (Azeem et al., 2021). Proper analysis of these structured and unstructured data can increase productivity and efficiency of clothing manufacturing processes by finding new insights, marking errors into the processes and as a result can increase workers performance as well by making the data analysis automated. As a result, it helps the manufacturer to save money and time, run operations smoothly by reducing waste and inconsistency of production (Mishra, Upadhyay, & Sharma, 2020). In this paper, some primary production data collected from garment manufacturing industries of Bangladesh related to real situations of poor productivity and worker's performance will be presented. These data had a major contribution in identifying the problems in combination with the conducted literature review. At the end of this research, a big data based approach will be suggested to evaluate and solve productivity and performance related problems quickly which will help to improve overall productivity and efficiency of the plant alongside worker's performance. Moreover, some visual illustrations of problems and solutions related to big data analytics implementation will be presented and an estimated cost-benefit analysis with return on investment will be shown as well.

2. Research Questions:

How can big data reshape the manual operational data collection and analysis to an automated process in clothing manufacturing industries and how it can impact the workers performance and productivity? What can be the estimated total cost of ownership of big data analytics and what might be the calculated return on investment?

3. Research Methodology:

The research started with defining the research goal. To have better visualization and to understand and identify the problems properly, real case studies from the industry were collected and an extensive literature review was conducted. Later on, the research followed thorough data analysis and based on that an optimal solution has been suggested to solve the problems. The process flow of the research is shown below in Figure-1:

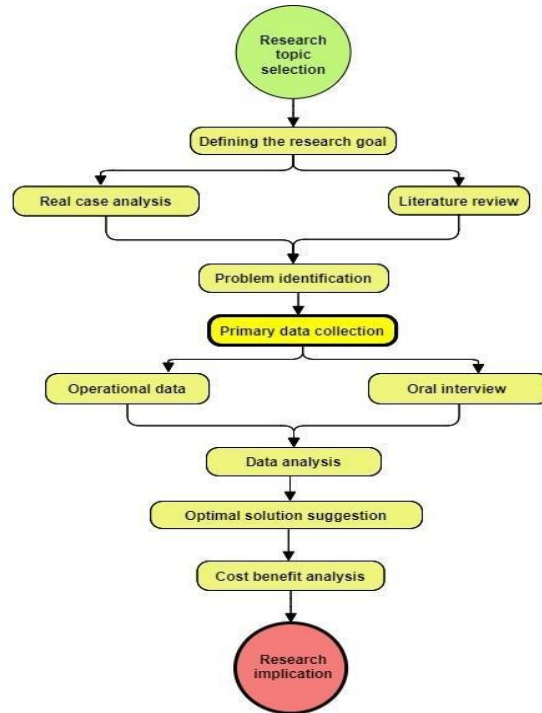


Figure-1: Flow of the research

4. Literature Review:

The readymade clothing industry had a huge impact on the economy of the western countries for a long time. For example- in Britain during the 1st industrial revolution clothing manufacturing and trade was one of the most important sources of mass employment. Back then, even in the United States the clothing industry had a decent impact on the overall economy. But, still there was not enough motivation among industry researchers to examine the methods of transforming cotton, wool or any sort of fibers into textiles and how to improve the industry even more and that is why the industry had a poor legacy in terms of industrial development (Godley, 1997). But with the constant improvement as the time went, the demand of the people changed and increased drastically. A lot of improvements took place and several industrial revolutions have passed. We have entered into the modern era and people around the world are thriving for more fashionable clothes. As a result, the industry has seen an exponential growth and in the last 15 years, clothing production has doubled, accounting for more than 60% of the total textile production. Fast fashion

has become a major player behind this boost and people's willingness to follow celebrity culture increased the demand for fast fashion (Moorhouse, 2020).

Bangladesh as a major manufacturer and exporter of clothing and fashionable garments has been fulfilling this demand for a long. The inauguration of the export capable textile industry in the country has only gone past four decades as the very first shipment was made back in 1978 and the country got its independence in 1971. Since that very first shipment, the country started to raise itself in a new industrial sector (Nabi et al., 2015; Farhana et al., 2015). There were several factors behind this growth as well. Quota system which was implemented by both the European Union and the United States was designed to import a large proportion of clothing from Bangladesh and the countries within the same rank and this was abolished by 2004. But, Bangladesh made a strong ground in the world market of textile and clothing by then. On top of the quota system mentioned above, favorable trade policies, easy loan facilities and duty-free import facilities of textile raw materials from the government made the country a heaven for textile and clothing industry (Rahman, Habibullah, & Masum, 2017).

It's a well-known fact that Bangladesh is not a producer of cotton, but now it has a large industry to manufacture and meet a major portion of the worldwide demand of clothing and holds the place right after China in terms export of clothing and textile. Thanks to the readymade garments industry, Bangladesh has made it from being a least developed country to a lower middle income country not long ago. Moreover, since the last 10 years more than 80% of the total exports are coming from the textile sector according to a report published by Bangladesh Garment Manufacturers and Exporters Association (BGMEA) and in the last fiscal year of 2020-21, the percentage was almost 84%. In recent years, the contribution of the clothing manufacturing industry in the GDP of Bangladesh is around 20%. Every day the number of export orders are increasing, new buyers are coming with orders as well and there are several factors which are influencing this increasing number of orders (Yunus & Yamagata, 2012).

Huge population is one of the main reasons behind this drive. The RMG industry requires a good number of manual workforces and a vast female workforce of the country is working in this sector to fulfill this need. As a result, the RMG industry has become the largest sector in terms of creating enormous employment opportunities for females. Cheap labor force is another reason. The average monthly wage of the workers in Bangladesh in this sector is really low and the buyers want to take

this opportunity to minimize the unit price of the garment as well to serve retail customers at a lower price. All of these made Bangladesh a favorite location of readymade garments manufacturing for the buyers across the globe (Farhana et al., 2015).

But, on the contrary the overall happiness among the workers in the RMG manufacturing is not so good and many see the work of this sector as slavery. There are several issues related to the worker's job satisfaction in this sector which is directly connected to the productivity of a plant and efficiency of an individual as it affects the performance. The job satisfaction actually illustrates the worker's happiness with their job and the surrounding environment (Khan, Moudud, Huq, & Islam, 2019). There were many occasions throughout all these years when strike, unrest broke out. There are several factors behind this unrest and one of the most pressing factors is poor salary structure. As most of the workers are uneducated and unskilled, they get very poor salaries in contrast to the ever-increasing expense of livelihood. There are many factories where working time is long with one short break during the whole day. This affects the worker's performance which has a direct impact on productivity. Improper treatment towards workers by mid-level factory executives is another reason (Yunus & Yamagata, 2012).

Assembling apparel is indeed a labor intensive process which includes a huge number of machines and workers in each garments assembling line. Sometimes due to longer working hours and shorter breaks, the workers lose their focus which hampers their performance, overall productivity of the line and creates bottlenecks (Nabi et al., 2015). Moreover, most of the factories do not comply with the appropriate labor law and ILO conventions on the inside though on the outside they act like they do. Job security, lack of hygiene in the workplace, and leave policy, proper medical facility acts together towards an improper environment for the operators and impacts directly upon the performance (Yunus & Yamagata, 2012; Khan et al., 2019). Though there are these factors which can affect the employee's performance, the overall productivity of an apparel manufacturing and export plant, the situation is improving now-a-days. Many factories are focusing on improving the surrounding environment of an operator as a whole (Rahman et al., 2017).

But, still as clothing manufacturing is a labor-intensive process, workers develop fatigue during their work which also has a huge impact on the reduction of efficiency. Hence, the industrial engineering department of the factories uses time study techniques to balance a sewing line by solving the bottleneck issues and they take different ergonomic and other factors, and conditions

to calculate the standard time for an operator to carry out the specific task at a defined rate of performance (Nabi et al., 2015). As this is just a calculation of time, it doesn't always click and the factory engineers always find bottlenecks after a certain amount of time and take other initiatives to solve the bottlenecks. But, this manual finding of bottlenecks is time consuming and by the time it gets found out, worker's performance gets affected which leads to overtime to fulfill the production target (Nabi et al., 2015; Farhana et al., 2015).

The world is far more advanced now in terms of technology than it was before. An Atlanta-based firm called Software Automation introduced "sewbots" which can help in sewing to some extent and is being used in a Chinese owned garments factory in Little Rock, Ark. But still unlike electric or mechanical manufacturing industries, the huge apparel manufacturing industry seems much protected to complete automation as fabric is a lump material which is difficult to work with and some operations are really difficult to automate (Emont, 2018). Even if there is any chance in the near future to automate the garment manufacturing as a whole to get higher productivity and efficiency, it shouldn't be the only solution to solve problems related to workers performance, line efficiency and the overall productivity. Because, once automated there is a higher probability that a large number of people will lose their livelihood (Jony Moin & Sohailud Doulah, 2013; Hayes & McLoughlin, 2008). A study in 2016 by the International Labor Organization (ILO) predicted that more than 80% of people related to apparel manufacturing jobs might lose their jobs if automation spreads widely. With some garment factories adopting automation in sectors other than the apparel manufacturing, the number of people who were working there in before has been cut down in half (Emont, 2018; Jony Moin & Sohailud Doulah, 2013).

That's where industry 4.0 comes in with a lot of options. It didn't come only with the option of labor automation. There is a collaborative robot which can work alongside humans. Cyber-physical systems to carry out the risky manufacturing processes whereas the human will take care of the more result-oriented production processes. Cloud computing, cyber-security, Internet of Things (IoT) all came just not to replace humans but to help humans work faster and efficiently. And, one of the most important technologies that industry 4.0 brought is Big Data (Ma et al., 2020). According to a paper written by Belhadi, Zkik, Cherrafi, Yusof, & El fezazi (2019), big data involves datasets which are bigger in size and the usual database software has limited capacity to capture, store and analyze these data. Big data is usually described as 4V's which works with

Volume, Variety, Velocity and Veracity. In 2011, the McKinsey Global Institute published a report headlined “Big Data: The Next Frontier for Innovation, Competition and Productivity” which meant that big data is going to have a huge impact in production which we have started seeing now in different manufacturing sectors.

Big data is being used in remanufacturing operations by establishing a quality valuation system to acquire big data of used products. The remanufacturer evaluates quality of the used products with the help of big data analytics, can exclude used products with poor quality and can offer a suitable price of the product (Xu, Li, & Feng, 2019). In manufacturing, machines like CNC, meters, sensors and controllers can gather a lot of data during operations. Moreover, data from other different devices with various sampling frequencies, formats leads to a lot of structured and unstructured data which is difficult to handle by conventional tools and big data analytics have proven to be useful for dealing with the increasing volume of data gathered from machines and sensors. This data can be used for manufacturing excellence after certain analysis with the help of Big Data (Corallo, Crespino, Lazoi, & Lezzi, 2022).

In a study done by Yadegaridehkordi et al. (2018), it has been shown that big data adoption has a significant influence in manufacturing companies’ performance. With the help of a developed method called DEMATEL-ANFIS and based on collected data from managers of Malaysian manufacturing companies, big data can influence performance on technological factors of a firm greatly compared to organizational and environmental factors though the adoption of big data on manufacturing performance improvement is still in an early stage. Faheem et al. (2021) developed a cross-layer platform called CBI 4.0 based on big data for active monitoring and control of unexpected changes in the manufacturing processes where big data will play a crucial role of constant gathering, monitoring and analysis of data to find any uneven pattern in the process. In manufacturing, big data can extract relevant and useful information from real-time data to support decision making with the help of a wide range of statistical methods and artificial intelligence techniques. In logistics planning and scheduling, RFID gathers a lot of real time data while working and can convert them into useful information with the help of big data (Souifi, Boulanger, Zolghadri, Barkallah, & Haddar, 2021). Ye, Wang, Yao, Jiang, & Liu (2019), have developed a big data processing framework to predict the quality by analyzing data via big data analytics.

Same can be used for productivity and worker's performance analysis and improvement. Now-a-days, a lot of industrial sensors are being used in garment manufacturing industries. Moreover, due to technological evaluation, the manual sewing machines have been replaced by computerized sewing machines which can collect a lot of sewing related data. These machines can collect and remember sewing patterns for future use, and can count the number of stitches and intervals. With the help of big data, the individual data collected from sewing machines can be analyzed to find most bottleneck operations, worker's fatigue time and unproductive time and actual interval between each successive sewing operation which can be used to find the bottleneck operations right in that instant. Hence, the production executives can make decisions such as to replace the workers with someone else for the time being or giving a short break to reduce the fatigue and work with full efficiency (Jana, 2018; Li, Chen, & Shang, 2022).

Moreover, with the help of computerized sewing machines, IoT sensors and RFID associated with the material handling devices in the garments manufacturing floor, the gathered data can be stored in a central big data analytics platform which can be used to analyze manufacturing data, worker's performance ratio and provide appropriate and instant decisions where to improve (Ye et al., 2019; Wang, Xu, Zhang, & Zhong, 2022). Usually, in garments manufacturing the correction of bottlenecks are manual and time consuming. By time study technique, the IE executive sets an overall daily and hourly production target. Once the actual manufacturing starts, there is no actual computerized manufacturing tracking system to track production status and at the end of the day, they see that the production was not met for the day and then only tries to find the reasons or bottleneck operations. This leads to improper worker's performance, reduced productivity, working overtime and shorter breaks which ultimately leads to job dissatisfaction and lower efficiency (Nabi et al., 2015; Farhana et al., 2015; Khan et al., 2019).

If the production bottlenecks could be monitored, tracked and corrected immediately with the help of raw data gathered from sewing machines, RFID and sensors and analyzed by big data analytics, the production problems can be solved instantly leading to a better productivity, efficiency and higher worker's performance (Ye et al., 2019; Jana, 2018; Wang et al., 2022).

5. Problem Identification:

In the paper, the identification of problems took place as a combination of two different strategies.

1. Some real situations that textile engineers face in clothing manufacturing plants were collected to find out the difficulties. In addition to these, some more recent cases from industries were gathered as well. While these cases were being thoroughly analyzed, it had been seen that the worker's performance was not constant throughout the whole day and bottlenecks were being created frequently because of that. But, the attempt to identify the bottlenecks were really slow because of the manual storage, analysis and calculation of production data at the end of each day which was leading to overtime the next day and this was repetitive.
2. During the extensive literature review (Azeem et al., 2021; Belhadi et al., 2019; Xu et al., 2019; Yadegaridehkordi et al., 2018; Zhong, Newman, Huang, & Lan, 2016; Zhang, Ming, & Yin, 2020; Majeed et al., 2021), it has been noticed that even though big data actually works with a huge volume of information, there was not enough attempt to process manufacturing data in a way that can work for the operators. Moreover, there was not a single literature related to big data which could have shown its use in a labor intensive manufacturing industry such as garments manufacturing to improve worker's performance by making the data processing and analysis quicker and suggesting which process needs immediate attention and improvement.

The Ishikawa Diagram below in Figure-2 is showing the causes in detail which worked as factors behind operator's improper performance, lower rate of productivity found as effects.

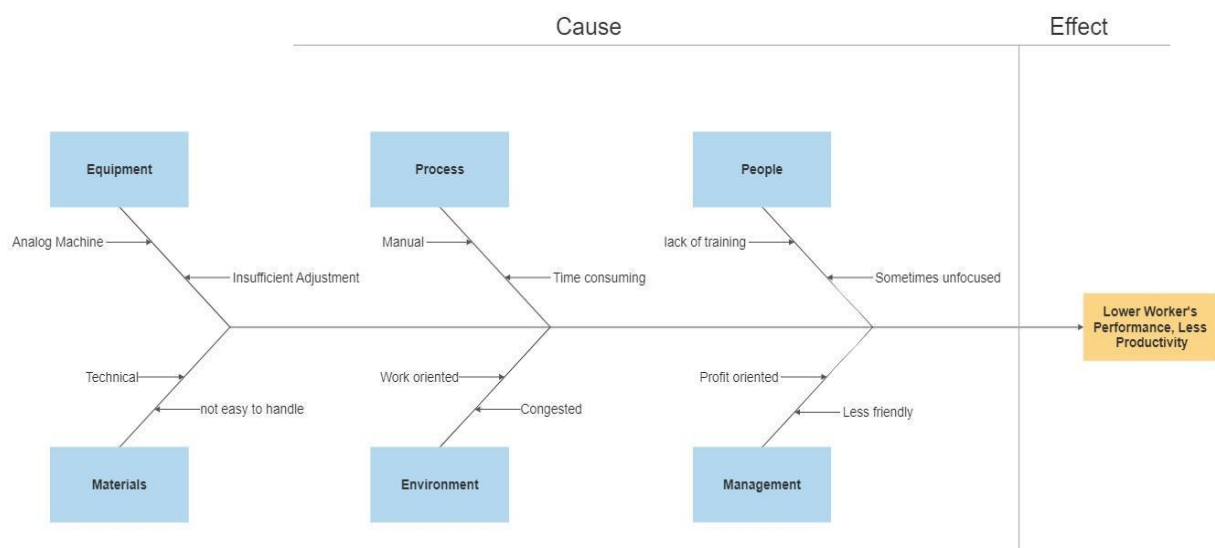


Figure-2: Ishikawa diagram for causes and effects identification

As “Application of big data” was selected as the research topic prior to the start of writing this paper, it came as a thought of making an attempt to solve worker’s performance and productivity related issues through a hypothetical big data approach in garments manufacturing industry which is much labor-intensive and where the introduction of latest technologies is slower than the other industries. As big data works with a huge volume of raw information, the attempt of improving the performance and productivity will be based on making the information flow instant and faster so that the industrial engineers can take care of the bottleneck operations immediately.

6. Primary Data Collection and Analysis:

The primary data to find the actual research opportunity and to search for the area of improvement was collected from two different sources. First, several real production data was collected from a garment manufacturing factory of Bangladesh. Secondly, oral interviews with industrial engineers of that factory were performed and recorded based on some open ended questions.

6.1 Production Data Analysis:

Operational data of several purchase orders were collected from the factory to gain an idea about the differences between calculated and actual daily production status.

STYLE NO:	2015149	BUYER	KB Asia	MP	43
ODR QTY	3500 Pcs			M/C	40
ITEM :	Extreme Motion-Reg Fit-Bootcut-Lewie	FABRIC	Denim	SMV	19.40
				BPT	0.49
DATE:	27-Feb-22	LINE	66 A+B	TGT/HR (80%)	106
				ACTUAL	100

Table-1: Production data collected from the factory

Here, in Table-1, it can be seen that during production planning for style no- 2015149, the engineers have calculated the hourly target as 106 pcs and based on the hourly calculation, they also calculated the daily production target. At the end of the day when the daily production count took place, they saw that the actual hourly production rate is 100 pcs which is 6 pcs less compared to the calculation. It gets recorded in the IE bulletin and production chart for the bottleneck

operation identification and correction the next day. It is to mention that, the actual working hours per day is 9 excluding the 1 hour lunch break.

NO :	OPERATION	GRADE	MC Type	SM V	OP	ASST. OP	IRON MAN	TG T	Remarks
ASSEMBLY									
27	FRONT & BACK WITH LOOP MATCH & GASSET PLACEMENT MARK	N/A	H/P	0.45		1		133	
28	INSEAM JOINT	A	5TOL	0.48	1.0			125	
29	INSEAM TOP STITCH	B	FOA	0.47	1.0			128	
30	SIDE SEAM JOIN	A	5TOL	0.60	1.0			106	Balance with 28
31	SIDE CORD STITCH	B	SN	0.50	1.0			120	
32	ELASTIC CUT & MOUTH PATCH JOIN WITH MARK	C	SN	0.42	1.0			143	
33	W/B JOINT PLACEMENT MARK & MATCH	N/A	H/P	0.40		1		150	
34	WB JOINT	A	CS	0.70	1.5			129	
35	MOUTH TACK	B	SN	0.38	1.0			158	
36	W/B TACK	B	SN	0.70	1.5			129	
37	W/B TOP STITCH	A	KAN	0.38	1.0			158	
38	SIDE SEAM IRON & BODY TURN	N/A	IRON	0.42			1	143	
39	LOOP MAKE & PLACEMENT MARK	C	F/L	0.43	1.0			140	
40	LOOP JOIN & CHAIN SECURITY TACK		SN	0.40	1.0			150	
41	LOOP TACK WITH SECURITY TACK	B	SN	0.40	1.0			150	
42	BOTTOM HEM WITH T-CUT	A	SN	0.45	1.0			133	
K/S=1,F/L=1,S/N=8,5T OL=2,CS=1,FOA=1,				7.58	14.0	2.0	1.0		

Table-2: Detailed production data with operation sequence collected from factory

*K/S= Kansai, F/L= Flatlock, S/N= Single needle, 5T O/L= 5 Thread overlook, C/S= Cylinder sewing, FOA= Feed of the arm, H/P= Helper, SMV= Standard Minute Value, MC type= Machine type, OP= Operator

Here, Table-2 is showing the assembly (final) part of the whole sewing process after which each finished garment exits the sewing line. The manufacturing process starts with an assistive operation to make the following processes easier. The whole process follows a predetermined sequence. As the garment starts to pass through each process, the final shape of the garment starts to show up. The stitching processes are not too technical but fabric as a lump material is difficult to handle which makes the operations time consuming. Moreover, some operations such as mouth tack, waistband tack need to be performed in a small space which is difficult and makes it time consuming. As per above table, side seam joining is the most time consuming task as it involves closing both left and right side of the garment from top to bottom and hence calculated individual

production target is the lowest here. The overall garments manufacturing follows a unit production system which means a single piece of garment comes out every time after finishing all the operations involved.

In the table, it can be seen that each individual operation has its own hourly calculated target. The industrial engineers of the factory compare the actual average production rate with this calculated individual hourly target and that's how bottleneck operation gets identified. A comparison between table 1 & 2 shows that the calculated production rate of operation no-30 is the same as the calculated overall production rate. It is because operation 30 is a complete individual operation and without completing it, a garment can't exit the sewing line. As the production target is the lowest here among all the others, this is also fixed as the overall hourly production target. But, it still gets affected for several reasons and the actual production gets down to 100 pieces per hour.

After analyzing the actual and calculated production data, the engineers suggest some line balancing techniques (the most frequent rule is to balance the work with another work where a similar machine is working) to improve the hourly output. Above, in Table-2 we can see that they have recommended to balance operation 30 with operation 28 as the machines used in both operations are the same.

In addition to these, engineers also follow another technique to fix the productivity or to balance the sewing line in order to improve the overall productivity and worker's performance which is called learning curve.

STYLE NO:	SOLANG SKINNY	BUYER:	H&M	M/P	61
ODR QTY	20700 PCS			M/C	53
ITEM :	BASIC 5 PKT	FABRIC:	TWILL	SMV	17.58
STUDY BY:	IE DEPT			BPT	0.29
DATE:	20-Jan-22	LINE:	ALL	TGT/HR (85%)	177

Table-3: Production data of a critical style collected from the factory

Here, the calculated hourly production target is 177 pcs. The style- Solang Skinny mentioned above is a critical design and for these kinds of special designs, the factory uses a learning curve to find optimum quality, reduce bottlenecks or any mistakes. Below in Figure-3, it is showing that

the very first day of starting production of these kinds of critical styles, the sewing line didn't run with full capacity, only with 20% capacity.

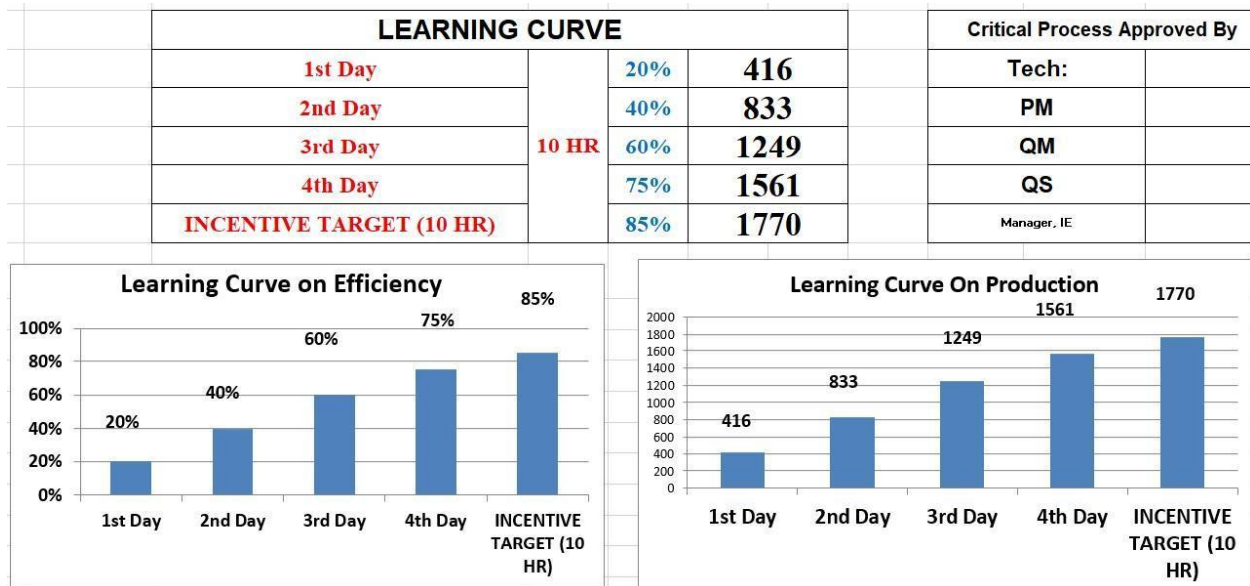


Figure-3: Learning curve of a critical style garment

The line started with 20% efficiency to adjust the style even though the target efficiency is 85% and then slowly they were increasing the efficiency. This learning period went on like this for four days and then they had to work overtime which is the fifth day (designated as Incentive target here) to cope with the production schedule. This overtime work is bad for the workers as well as for the company. Because of the overtime work each week, the workers don't get proper rest to heal their body, to get out of the fatigue which affects their performance badly and creates a negative impact on their productivity. Moreover, the factory owners also have to pay additionally for the overtime work (usually, overtime payment is double than the regular salary) which affects the profit.

But, none of these (lower efficiency, productivity and workers performance) would have happened if the responsible department could access the actual production data and monitor the production status continuously. If they could have seen real time production data right in that moment when the problems are being created, there is a higher possibility that immediate corrective actions could take back the production status to what it was supposed to be making the productivity and working efficiency higher.

6.2 Oral Interview:

Besides the actual production data, an oral interview was conducted as well to identify and have clear ideas about the lacking at the factory. Five different industrial engineers were interviewed via Facebook messenger service based on a set of questionnaires and their responses were recorded to have a full understanding. The interview was done based on some open ended questions. The summary of the answers received is listed below:

Data collection- The factory uses excel charts and wall board (hand written) to collect and store the operation data. Usually, the engineers prepare the IE and operation bulletin and line arrangement takes place accordingly. Each new purchase order runs for a day and at the end of the day, manual count of the products take place. The engineers calculate the hourly actual production status from it.

Analysis- After finding out the actual hourly production rate, the engineers compare the data against the calculated production rate to find out whether the production status is okay or not. They also check it against each individual operation to see if there is any further scope for improvement or not.

Correction- Factory engineers compare the actual production rate against each individual operation and if they find any bottleneck operation, the next day they take corrective actions to solve it. Usually, they try to balance the line by sharing the bottleneck operation with a process of higher productivity that uses the same type of sewing machine.

Automation- The factory has computerized sewing machines in different lines but there is no attempt to use the machines to their fullest potential. The work in the factory is mostly manual. Material handling activities are also manual. The human centered manual method of work leads to overtime frequently because of the productivity issues and weekly it is around 20 hours.

Remarks- As the industrial engineers are responsible only for the production side to make operation bulletin and perfect production sequence, to show operational excellence, to find out deficiencies in production, identifying and correcting the bottleneck processes and last but not the least to maintain the prepared production plan, they work with a lot of data. But, this data collection, scrapping, analysis and all the other processes are manual and time consuming. This indirectly affects the productivity of the factory and negatively creates an impact on the workers

performance. If the data collection, analysis was automated, the engineers could have identified the process deficiencies a lot faster which could improve the productivity, efficiency and workers performance.

To sum up, it can be said that the information gathered through both production data and oral interview indicated that one of the real problems behind less productivity and efficiency, lower workers performance is data management. That is to say, the manual collection, scrapping, untimely and lengthy processing of the production data makes it hard for engineers to identify production deficiencies and workers performance related issues instantly and marks a huge negative role in the whole process.

7. Big Data Approach as a Solution:

Big data refers to the information or data sets that are usually too large to handle with usual data processing tools mainly because of its volume and variety. Usually, in manufacturing industries each process involves a lot of operational data (Belhadi et al., 2019). Likewise, in each garment manufacturing industry a lot of production data is generated each moment from every individual process. This data involves different structured, unstructured necessary information. For example- in garment design, there is information related to color, material, design sketch, body data and technical design (Jain, Bruniaux, Zeng, & Bruniaux, 2017)]. In garment manufacturing, there is information related to the number of stitches, sewing machines, sewing pattern and design, processing time, SMV, calculated output and many more. Most of these data come out together as accumulated from sewing machines or other logs and sensors. Some of these data are useful as they can give some valuable insights if processed professionally and big data analytics can play a very important role in processing these information in a particular manner to identify, analyze and suggest improvement in productivity, efficiency and performance (Jain et al., 2017; Ji & Jiang, 2020). Proper use of big data analytics in a garment manufacturing plant can help to discover patterns which can be used later on to improve the manufacturing processes which in turn helps to minimize process faults, save money and time, increase workers performance. Results achieved through big data analysis can be used to reduce waste and inconsistency in the production process (Ji & Jiang, 2020; Jain & Kumar, 2020).

7.1 Suggested Big Data Tools:

As a first step of implementing big data analytics to optimize productivity and solve operators' performance related issues, some tools which can be exceptionally helpful have been suggested below:

Data storage- the very first step of implementing big data analytics is stockpiling the data. A data storage tool works like a data warehouse which can be used to store and preserve any incoming information from equipment or operations (Mishra et al., 2020).

Data cleanup- generated data comes in different formats from several type of sources. These data can be both structured and unstructured. To ensure integrity and quality of unstructured data, a cleanup tool is required to convert unstructured data into an understandable form (Zhang et al., 2020).

Data profiling- profiling tool is required to perceive the maximum and critical information as it can reach the core of the data set. It is required to get a clear idea about each operation involved in a whole manufacturing process (Sharma, Kumar, & Kumar, 2021).

Data mining- data mining can be one of the most important tools to use in big data analytics. It can extract required information and help to make the right decision at the right time for manufacturing processes (Majeed et al., 2021).

Data mapping/grouping- data comes in accumulated form. Data mapping tools can group the data in different sections and improve the understanding about information flows in manufacturing processes (Mishra et al., 2020).

Data analysis- the most important part of big data analytics. Helps to find valuable, hidden meanings by analyzing the gathered data properly. The data analysis tool can identify patterns, calculate impact and provide prediction for an event that is yet to happen. Also, helps to make a better decision (Li et al., 2022).

Data visualization- data visualization tool helps to present the data graphically in a clear form. Hence, helps to understand the results better (Ye et al., 2019).

Data Monitoring- this tool helps to monitor the equipment performance or health, data quality and manufacturing processes constantly and informs right away if something goes wrong (Li et al., 2022).

7.2 Proposed Framework of Big Data Application:

In the proposed method, data will come from different sources as log files or direct usable data from the processes. With some machine learning techniques or advanced data cleanup tools, unstructured data can be processed to use while structured data can be readily handled by the system. A detailed working process of proposed framework is given below in Figure-4:

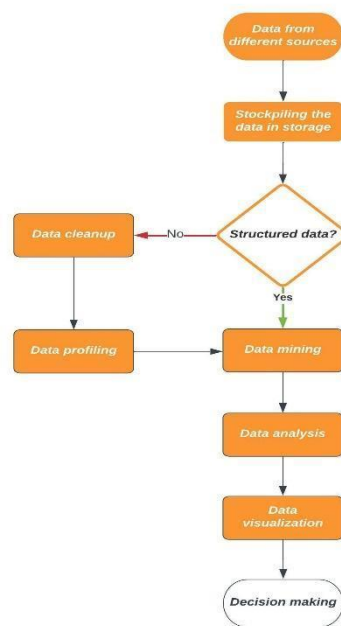


Figure-4: Proposed big data application framework

7.2.1 Detailed Working Process of the Proposed Framework:

Step 1: In this step, data is going to come from different sources and stages of the manufacturing processes. These data are going to be stored in the storage for further processing.

Step 2: The system is going to check whether the accumulated data is structured or not. If the data is not structured, a data cleanup tool is going to scrap this data and process it with multiple algorithms. Then, important information out of this dump of free and unstructured data is going to

come out as structured useful data after going through profiling. After completion of this step, further enhancement in existing knowledge is achieved.

Step 3: The raw data includes both structured and unstructured form. The structured data goes through data mining directly from the storage and the unstructured data after completing step 2 goes through the data mining process. Here, detailed mining of the data with several algorithms takes place to filter irrelevant concepts and to keep the precision high.

Step 4: The mined data goes through a thorough analysis to find out the accurate information that each production processes need to improve further. The analysis gives only that information which is asked for to make it easier for the user to utilize the data.

Step 5: Capture and graphical or written visualization of the data takes place in this step. Moreover, proper organization of the dispersed knowledge into categories takes place in this step.

Step 6: The final results come into display and based on the results, the user can make appropriate and time-worthy decisions to improve or reorganize the process. Based on the results, the user can also decide which operator is having problems with performance or where the productivity is being hampered currently.

In the process of data collection, different scraping techniques can be used. Irrelevant data is left out. Only those data will be kept that can affect different parameters of the predicted system. If there are any missing values, different techniques of feature engineering will be used. A machine learning based proposed system will classify frequently used data and show the appropriate result by visualizing the effect of those factors which have a role in manufacturing excellence. As the proposed system will be taking data generated in the manufacturing processes to process the historical data in order to get results, the data storing and gathering will take place in such a manner so that no data loss occurs.

7.3 Operational Data Collection:

There are several techniques to collect information to use for manufacturing excellence via big data analytics. Industrial Internet of Things (IIoT) sensor integration, Programmable logic controller, Remote terminal units, Radio frequency identification integration, Robot and AGV, CNC and other computerized machine integration (Faheem et al., 2021).

7.3.1 Data from Computerized Sewing Machines:

In the factory from where the case study was collected, all the sewing machines are computerized. The computerized sewing machines in the factory actually have several capabilities related to data collection and saving for their own benefits. The capacities of the computerized sewing machines include-

1. Automated control of stitching, threading and movement. The micro-computer inside the machine can control the motor and determine how fast the machine can run.
2. The machines have a downloadable feature which allows different stitch patterns to be downloaded into the sewing machine's computer allowing any sort of garments to be produced by anybody.
3. As the computerized sewing machines come with a memory, it is possible to store the number of stitches per operation and the time consumed by each operation. That's why it is possible to collect hourly numbers of successful individual process completion.
4. Moreover, each computerized sewing machine has an LCD display. It is possible to see each of the sewing related data visually in each machine.

If all these available features can be used properly to collect data from all the sewing machines via an IIoT network, they will be valuable for big data analytics to set a benchmark for each production process and to detect any sort of anomaly immediately.

7.3.2 Data Collection via Integration of Industrial Internet of Things (IIoT):

Industrial Internet of Things (IIoT) sensors are the latest addition to technology which came once the Industry 4.0 concept was introduced in the market. These sensors are quickly becoming a reality of the modern digital workplace. Sensor technology has the power to unlock information which is hard to track usually. The IIoT sensors can gather several manufacturing floor data and by using sensor technology can improve efficiency, productivity, quality control and maintenance.

With passive infrared sensors connected to an IIoT network, workers motion and heat generation can be detected. These data can be collected by the network constantly and go under proper analysis after setting the benchmark. With proper analysis, it is possible to determine each worker's performance. When they are performing with full capacity, when they are not and hence

it will be easy to detect fatigue time of the worker's. Moreover, based on the observation the factory engineers will be able to decide when the workers need a break.

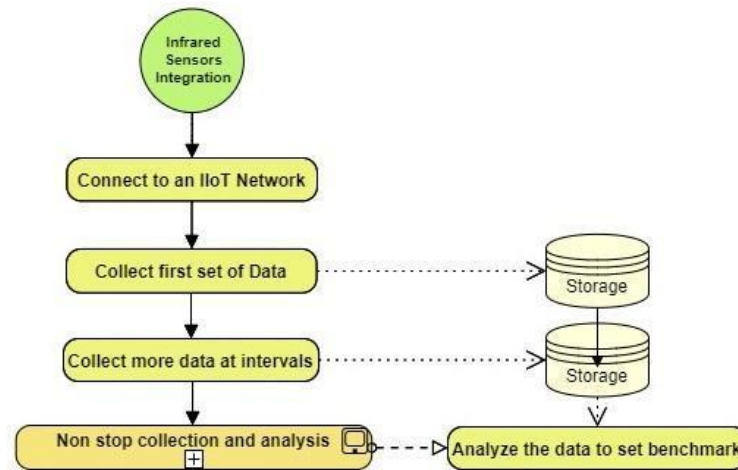


Figure-5: Data collection via passive infrared sensors integration

The small battery powered passive infrared sensors can be affixed to seats or desks to detect produced heat and motion of the workers. If someone crosses the benchmarked parameter at any time, it will trigger an alert to the responsible person to take necessary initiative. Thus, the IIoT sensor allows sewing production engineers to monitor the sewing lines efficiently to understand the deficiencies within the sewing line and among the operators and hence the engineers can take certain effective actions immediately improving the overall productivity and workers performance.

7.3.3 Data Collection via RFID:

Radio Frequency Identification (RFID) is a type of wireless communication that uses radio frequency of the electromagnetic spectrum to identify an object uniquely. This simple but powerful tool can be used in garments manufacturing to collect production data more frequently and hence can help to identify production insufficiencies effectively.

In Garments manufacturing, usually to input cut parts into the sewing lines and to take sewn garments out of the sewing line, boxes with predetermined capacity is used. In the factory from where the case study was collected, they also use boxes to carry the cut pieces to the input side of the sewing line and when sewn garments exit the line, those are also carried by boxes to the storage area. If these boxes could be replaced by boxes with RFID tags and each box has a capacity of

carrying a predetermined quantity of garments, the number of sewn garments will be registered automatically each time an output box passes through a RFID terminal. For an example- if a box can carry 50 pieces of sewn garments each time and gets registered into the system via the RFID terminal, the responsible engineers will then have a constant report of production and will be able to compare it with their calculated hourly target which in turn will help to identify production insufficiencies (if any) quickly and more effectively leading to a quick solution of the problem.

8. Proposed Methodology for Evaluation and Improvement:

Two methods have been proposed below. One is to improve and evaluate the workers' performance and the other one is to improve productivity.

8.1 Proposed Framework for Workers Performance Evaluation and Improvement:

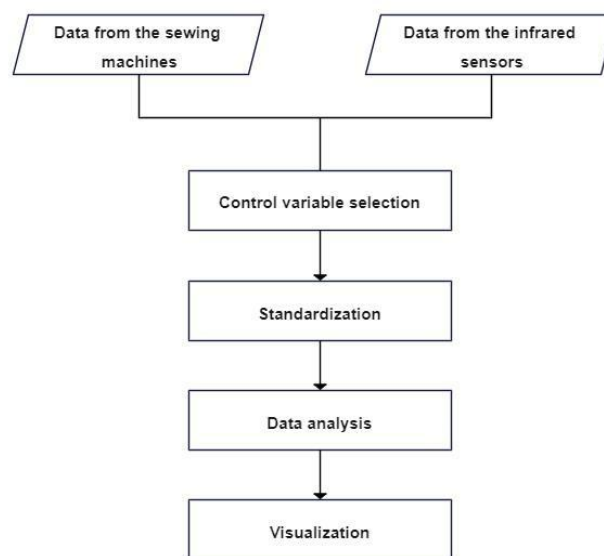


Figure-6: Proposed framework for workers performance evaluation

The proposed system presented above in Figure-6 shows the flowchart of the major procedures. The details are going to be discussed chronologically below.

8.1.1 Proposed Grouping of Accumulated Dataset for the Research:

Data which can be gathered from the sewing machines and infrared sensors are hypothetically classified into several types for the big data analytics to identify and evaluate workers' performance.

- **ID**: A unique ID for each passive infrared sensor.
- **User ID**: An ID generated automatically in the database for each operator via each passive infrared sensor.
- **Location ID**: An ID which will represent a specific sewing machine.
- **Process code**: A unique code used to identify each individual process.
- **Process Sequence Number**: A number which will indicate the sequence of processing.
- **Number of stitches**: A number generated from the sewing machine which indicates the number of stitches for each successive sewing operation.
- **Time stamp**: It will record the start and finish time of each successive sewing operation.
- **Time gap**: It will record the time between each successive operation.
- **Quantity**: Number of successive operations per hour.
- **Heat stamp**: It will record the heat of the surrounding environment of each worker and any changes in it.
- **Motion detection sequence**: A sequence of workers motion during the operation and any sudden changes in it.

8.1.2 Big Data Approach for Evaluation of Workers Performance:

To measure and evaluate workers' performance, there are several steps.

1. Determine the control variable. In this case, the total number of manufacturing processes involved at the same time.
2. For Standardization, time stamp, time gap, and quantity and motion detection sequence will play crucial roles as each of these have direct relation with SMV calculation for each operation. Also, the rate of change in SMV will have to be calculated which can be found below in equation-1:

$$\text{Rate of change in SMV} = \frac{x_2 - x_1}{x_1} \dots \dots \dots (1)$$

Where, X2 and X1 are the current and previous SMV for each operation.

Based on the above calculation, SMV standardization will be sorted out.

3. Once this is fixed, the data can be ranked as below based on the calculation of performance rate.

Performance rate: Standard result of SMV divided by the SMV received on a rolling basis based on constant monitoring of time stamp, time gap, quantity and motion sequence.

- Satisfactory performance: Workers of each operation reaching the production target on time.
 - Unsatisfactory performance: Any worker not reaching the production target on time.
 - Satisfactory case: Operations receiving the performance rate 1 or higher.
 - Unsatisfactory case: Operations receiving the performance rate is below 1.
4. The data can be further grouped at different time scales. Moreover, the number of satisfactory cases and unsatisfactory cases are counted and can be compared at different time scales.
 5. Visual representation via graphs based on the grouped data sets will help the engineers to make decisions on the performance of the workers.

Based on the method described above, the industrial engineers will be able to find the exact process (using the User ID, Location ID and process code) within the whole manufacturing where the workers' performance are being hampered and take corrective actions to solve the problem as well.

8.2 Proposed Framework for Productivity Evaluation and Improvement:

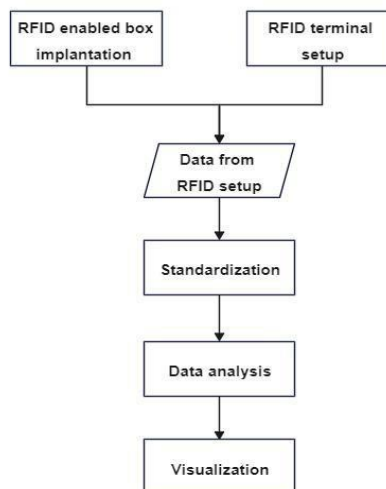


Figure-7: Proposed framework for productivity evaluation

The proposed methodology displayed above in Figure-7 shows the flowchart of the major procedures. The details are going to be discussed below.

8.2.1 Big Data Approach for Evaluation of Productivity:

Several steps need to be followed to evaluate productivity of a garments manufacturing line.

1. In the output side of the garments manufacturing line, there are boxes which are used to carry the sewn garments to the storage area. These boxes have to be replaced with RFID enabled boxes of predetermined capacity. An RFID terminal needs to be set up in the factory to collect RFID data. Each time when a box is full, it will pass through an RFID terminal and data related to production status will be recorded.
2. For standardization, accumulated quantity data generated from sewing machines based on the number of stitches data will play a crucial role. The quantity data comes on an hourly basis. To find the standard, the rate of change in quantity will have to be calculated as well which can be found by using equation-2 written below:

$$\text{Rate of change in quantity} = \frac{y_2 - y_1}{y_1} \dots \dots \dots (2)$$

Where, Y2 and Y1 are the current and previous quantity respectively.

Based on the above calculation, standard quantity will be fixed.

3. Once the standard quantity is fixed, it will be compared to hourly quantity received from RFID data and productivity rate can be calculated from it.
 - Satisfactory case: If the productivity rate is 1 or higher.
 - Unsatisfactory case: If the productivity rate is below 1.
4. The data found can be grouped in different time scales (half-hourly/hourly/daily). In addition to these, both the satisfactory and unsatisfactory cases are counted and can be compared at different time scales.
5. Graphical representation of the grouped data sets will help the engineers to see and make decisions on productivity.

Based on the method described above, the industrial engineers will be able to find the problem with productivity quicker than before and will be able to mark the main problem by tracking each operation in the big data system using the process code.

9. Comparison between Existing Method and Proposed Big Data Approach:

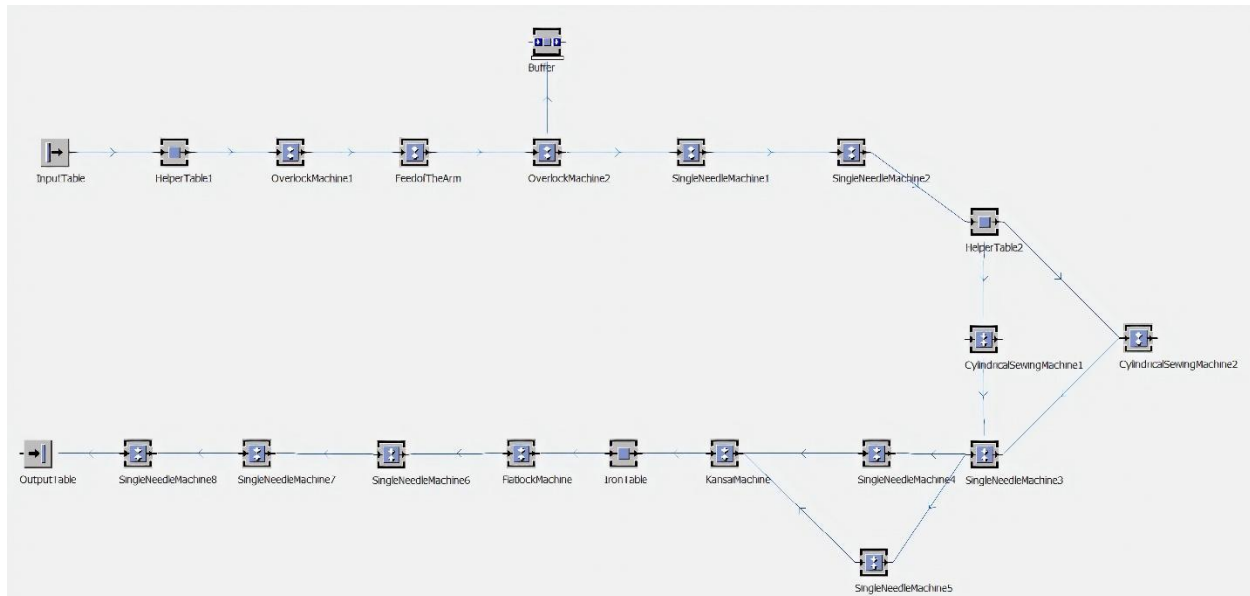


Figure-8: Visual representation of existing method

In the existing method, the cut pieces come in bundles and the bundles stack up in the input table (left most station in Figure-8) ready for feeding in the sewing machines to be assembled into the final garment. The whole sewing process follows a predetermined operation sequence. The sewing machines are computerized and have the ability to capture and generate a lot of sewing related data. The cut pieces pass through different sewing machines and supporting workstations and the complete garment starts to get ready. Once all the parts of a garment passes through all the sewing operations, the complete garment exits through the output table (right most station in figure-8) and the initial quality check takes place there. The finished garments are stored in a temporary storage carried via boxes. No real time production data exchange takes place in the existing process. The counting of the sewn garments is manual and usually it takes place at the end of each day to check whether the daily production target has been met or not. The industrial engineers prepare a production excel chart based on time study which includes individual and total SMV calculation, individual and accumulated production target calculation based on a predetermined efficiency. When the counting of the sewn garments is finished at the end of the workday, the engineers compare the actual quantity with the calculated quantity and check whether the actual quantity is less or not. If it is less, then the engineers check it against the individual operations with lower production quantity from the chart and find the inefficient operations. This whole process is time

consuming and by the time, the overall productivity is affected which leads to overtime. After finding out the inefficient processes, the engineers then take corrective actions. In most cases, the corrective action is balancing the process with a similar machine of higher productivity.

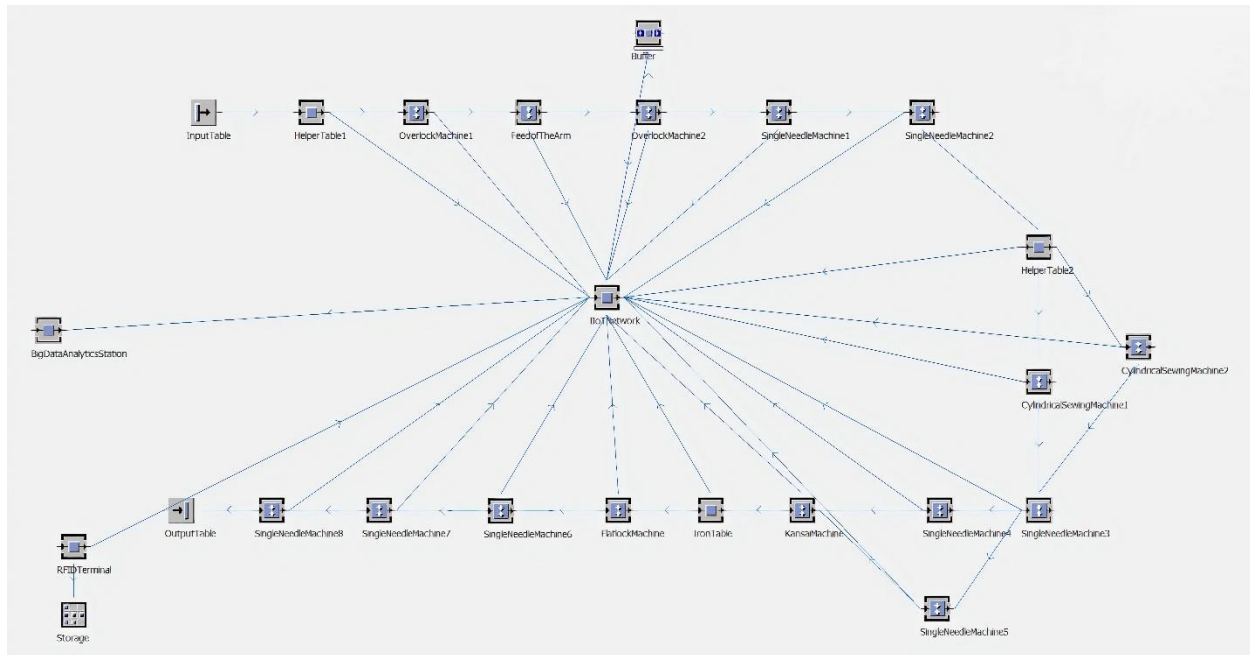


Figure-9: Visual representation of proposed big data approach

In the proposed big data approach, the garments manufacturing sequence is the same as before. There is no change in it. But, big data analytics will play a big role with the help of passive infrared sensors, RFID technology and using the full advantages of computerized sewing machines. Each machine will have a passive infrared sensor which will collect workers' heat and motion data. The computerized sewing machines are already collecting sewing related data which includes quantity, number of stitches, time and so on. The usual sewn garments carrying boxes will be replaced by RFID enabled boxes of predetermined capacity. Once the boxes are full, they will pass through a RFID terminal to the temporary storage and the data will be recorded. All this data will be continuously collected via an IIoT network set up in the factory and will be transferred to a workstation where all accumulated data will be analyzed and grouped into different categories for setting standards and non-stop comparison of continuous incoming data with the help of big data analytics. Based on the analysis, the industrial engineers will be able to identify the production deficiencies a lot quicker than before and take rectifying actions instantly which will help to improve the overall productivity and make the workers performance a lot better. The visual

representation of the analyzed data will provide clear views for the engineers to make speedy decisions.

10. Estimated Total Cost of Ownership and Benefit Analysis:

The total cost of ownership (TCO) and benefit analysis usually takes place to calculate the feasibility and impact of a suggested solution from the economic perspective. Here, in this case a similar cost and benefit analysis has taken place below to show such comparison which will act as a determiner for the factory owner to decide whether to go for implementation of the suggested big data approach or not.

10.1 Estimated Total Cost of Ownership:

As per amazon, usually a passive infrared sensor costs around \$8 to \$10 that makes it cheaper to install one passive infrared sensor per machine. (<https://www.amazon.com/HiLetgo-Pyroelectric-Sensor-Infrared-Detector/dp/B07RT7MK7C/>)

According to the latest market price, the average development and setup cost of an IIoT network is within \$10,000 to \$50,000. For manufacturing, the approximate cost is around \$30,000 where the cost of restructuring the network architecture is included as well. (<https://lanars.com/blog/how-much-does-it-cost-to-develop-an-iiot-app>)

Based on the information available on the internet, big data analytics software package, installation cost ranges from \$150,000 to \$180,000 depending on the area of usage and the software capacity (<https://www.cooladata.com/blog/true-cost>).

Based on the current market price, now-a-days an RFID tag might costs around \$20 to \$30 (<https://www.advancedmobilegroup.com/blog/the-true-price-of-rfid-tags>). A RFID tag reading terminal cost usually ranges from \$400 to \$700 (<https://www.rfidjournal.com/faq/how-much-do-rfid-readers-cost-today>). For the factory of this paper, 4 output boxes with RFID tags are enough per sewing line.

In addition to these, there are initial training costs involved as well and the training cost varies according to company and software installed and the estimated price is around \$7000 for a duration of 8 months (<https://careerfoundry.com/en/blog/data-analytics/best-data-analytics-certification-programs/>).

In the factory from where the operational data was collected, there are 30 sewing lines. Each sewing line consists of 40 sewing machines on average. The factory has two temporary storage facilities for sewn garments. Based on this information, the estimated total cost of ownership is shown below in table-4:

Factory information	30 sewing lines. 1200 sewing machines. 2 sewn garments store.	-
Estimated price of a big data analytics station	-	\$180,000
Setup cost of an IIoT network	-	\$30,000
Cost of passive infrared sensors	\$10/pc	\$12,000
RFID installation cost	\$25 for each tag. 4 boxes will be used per sewing line. \$700 for one RFID terminal. 2 terminals for 2 stores.	$(30 * \$25 * 4) + (\$700 * 2)$ =\$4,400
Training cost	8 months duration	\$7,000
Total		\$233,400

Table-4: Table showing estimated total cost of ownership

If rounded up, it can be said that the estimated cost of transforming manual and time consuming data collection, storage, and analysis to big data analytics will be around \$240,000.

10.2 Benefit Analysis and Return on Investment Calculation:

The factory exports on average 1 million pieces of denim long pant per month. The average price per piece is \$10. Due to the manual data interchange, storage and analysis of the manufacturing processes as well as implementation of learning curve for newly introduced designs, the overtime work is more like a recurring event. The hourly overtime payment is double than usual. In addition to these, excessive workloads because of the overtime affects the workers resting time as well which has a huge impact on the performance mostly because of the fatigue issue. Moreover, if the workers are able to finish the production target well within the scheduled time, the factory can avail more incoming purchase orders than before which have a great influence on the overall profit.

The salary range of an operator usually ranges from \$130 to \$150 as in Bangladesh the salary structure is determined on a monthly basis not on hourly basis. The workers have to work 9 hours a day with 1 hour as lunch break in the middle. The factory operates 6 days a week. So, usually the factory runs 25 or 26 days a month in general which means the average monthly working hours are about 150. That indicates that the hourly rate is about \$1. The hourly rate of overtime work is about \$2. Data found based on the oral interview conducted initially, the average overtime is 20 hours per week to meet the production target. The information are summarized below in table-5:

Current monthly export	1 million pieces
Average price per garment	\$10
Monthly work days	25 days
Daily working hours	9 hours
Average hourly salary	\$1
Average hourly (overtime) salary	\$2
Average overtime per week	20 hours
Average weekly overtime payment	\$40

Table-5: Summarized information of the factory

With the implementation of big data analytics and hence because of the faster data exchange, the bottleneck operations will be identified and corrected faster which will reduce the number of overtime hours per week. This will reduce the cost to some extent shown below in Table-6:

Estimated overtime hours per week	10 hours
Average hourly (overtime) salary	\$2
Estimated latest weekly overtime payment	\$20
Cost reduction per week	\$20
Estimated cost reduction per month	\$80

Table-6: Overtime reduction summary due to proposed big data approach

Moreover, the workers will be more productive than before because reduced overtime will lead to more rest time after each working day which will directly affect their performance by making it more positive. Hence, there is a probability that the factory will be able to receive and execute more purchase orders per month. The average real efficiency of the factory is 75% now. If the

current efficiency increases a little more because of the improved performance of the workers and the monthly production capacity of the factory increases even by 10,000 pieces than before, the Return on Investment (ROI) will be real quick. This is shown as a summary below in Table-7:

Current average efficiency	75%
Current production capacity	1 million pieces per month
Estimated increase in quantity per month	10,000 pieces
Average price per piece	\$10
Estimated increase in earnings per month	\$100,000
If the factory needs 1 more Big data analytics and IIoT network setup each (because of the area coverage), the cost will be-	\$210,000
The new TCO of big data analytics will be-	$(\$240,000 + \$210,000) = \$450,000$
Average profit per piece of garment	\$2
Monthly estimated increase in profit=	\$20,000
Roughly calculated Return on Investment (ROI)=	$\$450,000 / \$20,000 = 22.5$ months

Table-7: Data table on estimated return on investment

The profit achieved after this time will be counted solely as the profit for the company which will help the company to grow further.

11. Conclusion:

Clothing manufacturing industry is the highest contributor in terms of export earnings of Bangladesh. But, still this industry is one of the most neglected in terms of technological advancement just because it is labor intensive and the operators' performance are affected mostly because of the intensity of work. Hence, the overall productivity of a garments manufacturing plant gets hampered often. But, the huge operational data generated in this sector can play a bigger role in improving the worker performance and productivity if analyzed properly as there is a possibility that many useful insights might be earned.

Big data analytics as a technology that came from Industry 4.0 can be the perfect solution for this kind of analysis. It has the ability to work with large amounts of structured and unstructured

information and find useful meanings from it making the manufacturing process perform at a higher level by finding and correcting the process deficiencies.

The paper also showed a similar but hypothetical big data approach to evaluate and solve garments production process insufficiencies based on a case study collected from Bangladesh. The paper focused on using the meaningful information obtained by the suppositional implementation of big data analytics in a controlled manner to evaluate workers performance and productivity by finding the flaws faster than before and correcting it immediately. The whole framework proposed here will act as a vanguard for further research and practical implementation of big data analytics in larger manufacturing industries such as garments manufacturing.

Even so, this research has some limitations as well. The whole research is hypothetically developed as there was not a single scope of implementing the proposed approach even on a limited basis. So, there might be some flaws or problems that might arise if any attempt is made to implement the solution. But, there is a hope that it can be solved via trial and error. The reference architecture of big data analytics was not discussed in depth as the paper was focusing mainly on suggesting the approach for evaluation and improvement of workers performance and productivity. The costs of big data analytics, IIoT network, sensors and RFID are estimated as these were collected from the internet. Hence, the calculated return on investment might not be the same in real life.

Above all, it can be said that the undermined clothing manufacturing industries should be introduced with the available technologies as soon as possible because in the longer run these might help the owners to gain higher profit even if the initial investment is high. The technologies available from industry 4.0 can act as nails to fix the clothing manufacturing industry and the suggested approach here can be one of these nails.

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