CHEMICAL ENGINEERING TRANSACTIONS

VOL. 107, 2023

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Petar S. Varbanov, Bohong Wang, Petro Kapustenko

ISBN 979-12-81206-07-6; **ISSN** 2283-9216

DOI: 10.3303/CET23107075

A Big Data Approach to Improve Productivity and Sustainability in the Clothing Manufacturing Industry: Case Study from Bangladesh

Md. Abdullah Al Mamun, László Buics*

Széchenyi István University, Department of Corparate Leadership and Marketing, 1. Egyetem tér, Győr 9026
buics.laszlo@sze.hu

The goal of this article is to examine opportunities and show the approach of using big data analytics to boost productivity in the case of clothing manufacturing factories in a sustainable way. The Bangladeshi manufacturing industry is mainly dominated by the apparel and textile sector for a long time now, and this has seen a large growth over the years. However, this industry is still far from using the latest technologies to improve productivity even further and bring sustainability. Usually, manufacturing operations involve the 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 collected information can be used to track insufficiencies in different areas of manufacturing operations. This research is conducted based on a similar idea where problems are identified, and production data collected from a garments manufacturing plant in Bangladesh are analyzed. Based on real factory data, several hypothetical frameworks were developed to implement and analyse the production data with the help of big data analytics, computerized sewing machines, radio frequency identification (RFID) tags and passive infrared sensors. The paper also shows an estimated implementation cost and return on investment of the suggested approach.

1. Introduction

Textile manufacturing is a prominent growing industry (Moorhouse, 2020), and the demand for apparel is increasing worldwide (Choubey and Agrawal, 2016), especially in western countries (Nabi et al., 2015). Bangladesh as a major manufacturer and exporter of clothing and fashionable garments has been fulfilling the increased demand for a long time (Farhana et al., 2015). However, technological growth and automation in the clothing sector have not reached their full potential yet (Carr and Latham, 2008). But, Industry 4.0 can offer a lot of new technologies such as the Internet of Things (IoT), Cloud Computing, Big Data, Augmented and Virtual Reality, Additive Manufacturing, 3D printing, and Autonomous Robots, which can be used in the clothing sector as well (Alcácer and Cruz-Machado, 2019). There have been a few attempts to implement some of these within garment manufacturing. Uttam (2013) showed that the automated material handling system can be used to move the garment parts implemented without the manual intervention of the operators on the line. According to Emont (2018) “sewbots” in the Chinese garment manufacturing industry are in progress to replace human workers, aided by cameras and sensors to enhance production.

But compared to it’s competitors, Bangladesh is still far behind in implementing such technologies within the clothing sector (Rahman et al., 2017). As assembling apparel is a labour intensive process, workers often lose their focus, affecting efficiency and creating bottlenecks (Khan et al., 2019). These problems can lead to lower productivity and sustainability level within the plant (Cui et al., 2020). Some previous works attempted to minimise some of the above stated problems. Chowdhury et al. (2013) combined a progressive bundle system (PBS) with a modular production system (MPS) for low volume-high product mixture, which showed lower implementation cost, production cost, and lead time leading to higher productivity. Hawlader and Halim (2017) showed in research that using sewing aids within the garment production processes can significantly reduce the production time and hence increase the worker's efficiency. However, Industry 4.0 can offer several new

Paper Received: 09 March 2023; Revised: 19 June 2023; Accepted: 22 October 2023
Please cite this article as: Al Mamun M.A., Buics L., 2023, A Big Data Approach to Improve Productivity and Sustainability in the Clothing Manufacturing Industry: Case Study from Bangladesh, Chemical Engineering Transactions, 107, 445-450 DOI:10.3303/CET23107075

technological solutions. Collaborative robots can work alongside humans. Cyber-physical systems can carry out risky manufacturing processes whereas the human will take care of the more result-oriented production processes (Ma et al., 2020). But, one of the most important technologies that industry 4.0 brought is big data analytics (Belhadi et al.,2019). Currently, big data is being used in many manufacturing operations by establishing a quality valuation system to acquire big data of used products and can exclude used products with poor quality (Xu et al., 2019). In a proper manufacturing environment, machines, meters, and sensors can generate and store a lot of data and these data can be used for manufacturing excellence, improved process safety (Goel at al., 2019), sustainability (Theng et al., 2021) and performance (Corallo et al., 2022) after certain analysis with the help of Big Data analytics

Nowadays, in a modern clothing manufacturing environment lots of manufacturing data is being generated 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, and target goals (Shah et al., 2020). Big data analytics can be extensively used to analyse these huge volumes of data gathered from different parts of the manufacturing sector and provide useful insights (Azeem et al., 2021). Different type of industrial sensors can be used in garment manufacturing industries to monitor the manufacturing condition and environment constantly (Ye et al.,2019). RFID can gather a lot of real time data during operation and can convert them into useful information with the help of big data (Souifi et al., 2021). Computerized sewing machines has the ability to collect sewing related data such as sewing patterns, count of the number of stitches and intervals and with the help of big data, all these can be analyzed to find most bottleneck operations, worker's fatigue time, unproductive time and the differences between the inputs and final outputs (Li et al., 2022). After combining all the above stated technologies, the gathered data can be linked and synced into a central analytics platform which can be used to analyze manufacturing data, worker's performance ratio and provide appropriate and instant decisions where to improve (Wang et al., 2022).

However, almost none of these technologies are common within the garment factories of Bangladesh and hence there is no way to know whether inclusion of these technologies can lead to proper tracking of worker's performance, productivity and waste level (Khan et al., 2019). But, if the technologies can be made available within the plants of Bangladesh and a proper implementation approach is developed, the production bottlenecks could be monitored, tracked and corrected in real-time with the help of big data analytics, leading to a better productivity and, higher sustainability (Ye et al., 2019).

In this article, several hypothetical approaches are developed to implement big data analytics in a clothing manufacturing environment with the help of data gathered from sensors, computerized sewing machines and RFID tags in a proper manner which can help to improve productivity and bring sustainability.

2. Materials and Methods

The research was performed to figure out a way to handle negative effects (such as less productivity, lower performance and sustainability) within the plant with the help of big data analytics. The selected factory is one of the biggest woven garments manufacturing plants in Bangladesh exported denim bottoms worth of US $500 million worldwide in the year of 2022. Moreover, plant authorities provided access to all the required set of primary information needed to carry out this research and gave approval to find out and analyse some real situations that the engineers face in that clothing manufacturing plant in order to identify the common negative effects. To investigate further, the styling details of a chosen product from the factory and related production data were collected.

Table 1: Styling Details of the Selected Product

Style	Order Quantity	Item	Buyer	Fabric	Line	Man power	Machine	Standard Minute Value (SMV)	Basic Pitch Time (BPT)	Target hour (80 %)	/Actual
2015149	3500 Pcs	Extreme Motion-Reg Fit Bootcut-Lewie	KB Asia	Denim	66 A+B	43	40	19.4	0.49	106	100

In Table 1, it can be seen that the calculated production target per hour at 80 % efficiency is 106 pcs, but in actuality, it was 100 pcs. Also, Table 2 shows the operational data of the assembling part of the whole sewing process including the hourly calculated target of each operation. In the table, each row starts with the name of the required assembling operation to make a product ready, then the grade of the operator, the machine being used to carry out the operation, the standard time to carry out each successive cycle of the operation, number

of operator / operator assistant / iron operator needed and most importantly the calculated hourly output from the specific task. According to this information, side seam joining is the most time consuming task affecting the overall production of the sewing line. We can also see that the engineers then suggested a line balancing technique showed in the remarks column to improve the final overall output. But, this type of solution is really old and contributes little to the actual improvement of the production situation.
Machine description: H/P= Heat Press Machine, 5TOL= 5 Thread Overlock Machine, FOA= Feed Of the Arm Machine, SN= Single Needle Machine, CS= Cylinder Stitching Machine, KAN= Kansai Machine, IRON= Iron Machine, F/L= Flatlock Machine

Table 2: Operational Data of the Selected Product

No.	Operation	Worker's Grade	Machine Type	SMV	Operator	Assistant Operator	Iron Operator	Target	Remarks
27	Front & Back with loop match & Gusset 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	W/B 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 turn	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=7, 5TOL=2,FOA=1, CS=1, KAN=1				7.58	14.0	2.0	1.0		

Moreover, when a new style is introduced within a sewing line, it goes through a process called "Learning Curve" so that the workers can get used to the new style. In this way, the operation starts with a lower efficiency and gradually the efficiency increases over time. This leads to overtime work and payment and indirectly lower efficiency, productivity and workers' performance. But, none of these would have happened if the responsible department could access the actual production data and monitor the production status continuously.
In addition to all these, there were oral interview with the plant engineers where they pointed out that they work with a lot of data which helps with the improvement in overall production situation. 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. In the research, Technomatix Plant Simulation (version 15) was used to find the appropriate layout and a simulated result.

3. Solution

After studying the existing processes, and carefully reviewing the problems, it was determined that the proper analysis of big data in a garment manufacturing plant can help to discover patterns that can be used to improve the existing manufacturing processes in order to minimize process faults, save money and time, increase productivity and bring sustainability. Hence, several application frameworks were developed in this study to apply the same.
In the frameworks, three different ways were prescribed to collect operational data. There are computerized sewing machines which can control stitching, threading and movement, have micro computer and a memory that can store different sewing related data. These machines can sync these data via an Industrial Internet of Things (IIoT) network, which can be analyzed to set a benchmark for each production process.

As explained in Figure 1., small battery powered passive infrared sensors can be affixed to seats or desks of each operator to monitor heat and motion generated by the workers. These data can also be collected by the IIoT network constantly for analysis and to set a benchmark in order to determine each worker's performance. Finally, RFID tags can be attached to the input and output boxes to keep automatic count of the input pieces and final outputs. Data captured from all these (Computerized Sewing Machines, Sensors and RFID tags) will be stored in a central data warehouse and constantly analyzed with the help of a big data analytics platform to set benchmarks, find out production related deficiencies.

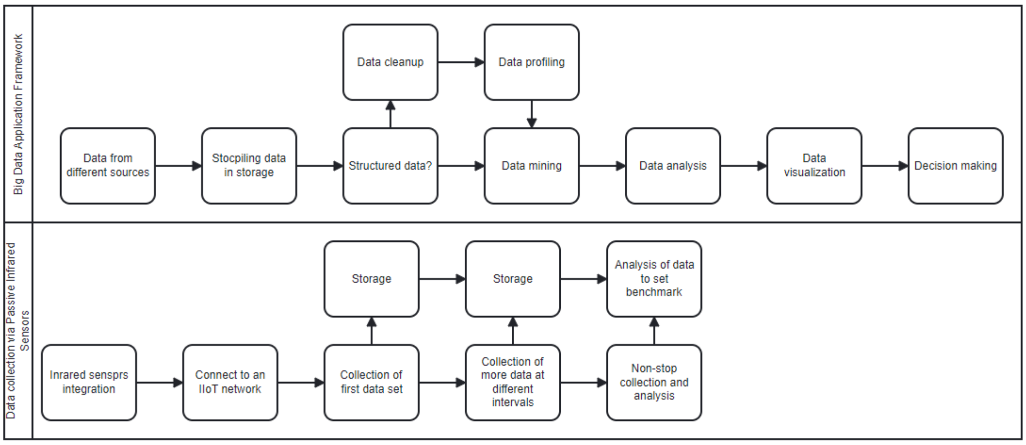

Figure 1: Proposed Big Data Application Framework and Data Collection via Passive Infrared Sensors

But, there are some potential limitations in this application as well. The initial setup and infrastructure reorganization cost will be high. In reality, clothing manufacturing environment is not too technical from the engineering perspective. So, implementing such technical solutions into a semi-technical manufacturing environment will require proper integration assessment and good governance. Moreover, in the case of Bangladesh, that is even more true as the manufacturers as well as the workers are comfortable in their existing approach of work. Thus the implementation of such technologies will likely face initial resistance and will require fast and proper return on investment to show its benefits. In terms of privacy the datasets will be collected and used within the proposed frameworks. These are all manufacturing related information to determine hourly inputs and outputs, to find out workers fatigue level, productive and required break times. There will not be any camera to track worker movements or whereabouts. So, the data privacy will not be a concern in implementing these frameworks. Also proper security will be in place to protect the collected production datasets from leakage.

4. Results and Calculation

A framework was developed to evaluate the performance of workers and productivity within the plant.
Data received from different sources will be grouped for analysis as stated below:
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 motions during the operation and any sudden changes.According to Figure 2. in both the frameworks, a standard hourly target will be set based on the aforementioned procedure with the help of the control variables. For workers' performance, these will be time stamp, time gap, quantity, and motion detection sequence and for Productivity these will be the quantity and number of stitches. At the same time, the continuous analysis of the workers' performance and productivity will take place based on incoming real-time data and rate of change in SMV and quantity. After that, there will be

comparison between standard and real-time data and the productivity, operations and performance will be divided into satisfactory and unsatisfactory level. The workers reaching the production target on time will be marked as satisfactory, otherwise unsatisfactory. This will be calculated as a comparison between standard SMV and SMV received on a rolling basis. Also, the operation which receives performance rate higher than 1 will be satisfactory case, otherwise unsatisfactory. Moreover, a comparison between standard hourly output and continuously received output information will be done to find out the productivity rate. If the rate is higher than 1, the productivity will be deemed as satisfactory, otherwise unsatisfactory.

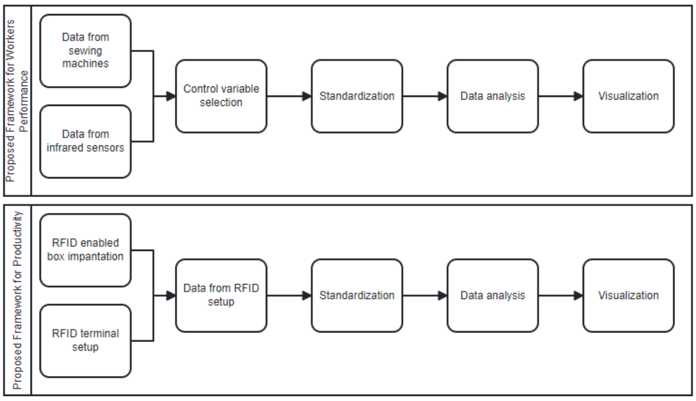

Figure 2: Proposed Framework for Workers Performance and Productivity

As per calculation and based on the information received, the total cost of ownership of one big data analytics platform including setup & training cost is about $240,000. Table 3 below shows the estimated return on investment.

Table 3: Data table on the Estimated Return on Investment (Authors' creation)

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 (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

Moreover, the estimated weekly overtime working hours will be reduced as an improvement indicator of the big data analytics implementation which will help to reduce an estimated overtime payment cost of $80 per month.

5. Conclusion

The paper, based on real factory data, showed a hypothetical approach of using the meaningful information obtained by the suppositional implementation of big data analytics in a controlled manner within a clothing manufacturing factory of Bangladesh to evaluate and improve workers' performance and productivity faster than before. As a first step, the factory can attempt to assess the whole existing infrastructure and prepare a preliminary workout from where to start the feasibility test of the suggested approach. If successful, the plant can move forward on implementing the approach on a pilot basis within a production line. But, this research has some limitations as well. The whole process is hypothetically developed, supported with discrete event simulation, as there was no scope of implementing the proposed approach yet. In case of hypothetical frameworks, real time problems are not counted as there is no way of knowing them beforehand which can also vary based on products, cases and plants. Once implemented, the approach can be modified based on the practical requirements. Regardless, it can be said that, the whole framework proposed here will act as a vanguard for further research and practical implementation of big data analytics in a larger scale within clothing manufacturing industries to assess and improve productivity and manage the flow of waste effectively.

References

Alcácer V., Cruz-Machado V., 2019, Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems, Engineering Science and Technology, an International Journal, 22(3), 899-919.

Azeem M., Haleem A., Bahl S., Javaid M., Suman R., Nandan D., 2021, Big data applications to take up major challenges across manufacturing industries: A brief review, Materials Today: Proceedings, 49, 339-348.

Halim A.F.M.F., Hawlader M. R., 2017, Significance of the use of sewing work aids in garments production, American Journal of Engineering Research (AJER), 6(7), 267-279.

Belhadi A., Zkik K., Cherrafi A., Yusof S., El fezazi S., 2019, Understanding Big Data Analytics for Manufacturing Processes: Insights from Literature Review and Multiple Case Studies, Computers and Industrial Engineering, 137, 106099.

Carr H., Latham B., 2008, Sewing, In D. J. Tyler (Ed.), Technology of Clothing Manufacture (4 ed.), Oxford: Blackwell Publishing Ltd., pp. 152-157.

Choubey N., Agrawal M., 2016, Automation in Textile Industry, International Journal on Textile Engineering and Processes, 2(1), 30-33.

Chowdhury J. M., Ferdous S., Doulah A.B.M.S., 2013, Investigation of a hybrid production system for Mass-customization Apparel Manufacturing, Journal of Textile and Apparel, Technology and Management, 8(3), 1-10.

Corallo A., Crespino A., Lazoi M., Lezzi M., 2022, Model-based Big Data Analytics-as-a-Service framework in smart manufacturing: A case study, Robotics and Computer-Integrated Manufacturing, 76, 102331.

Cui Y., Kara S., Chan K., 2020, Manufacturing big data ecosystem: A systematic literature review, Robotics and Computer Integrated Manufacturing, 62, 101861.

Emont J., 2018, The Robots are Coming for Garment Workers. That's Good for the U.S., Bad for Poor Countries, The Wall Street Journal.

Farhana K., Syduzzaman M., Shayekh M. M., 2015, Present Status of Workers in Readymade Garments Industries in Bangladesh, European Scientific Journal, 11(7), 564-574.

Goel, P., Pasman, H., Datta, A., Mannan, M. S., 2019, How Big Data & Analytics can improve process and plant safety and become an indispensable tool for risk management. Chemical Engineering Transactions. 77, 757-762.

Khan A., Moudud S., Huq U., Islam M., 2019, Job Satisfaction of Garments Industry in a Developing Country, Management Studies and Economic Systems (MSES), 4(2), 115-122.

Li C., Chen Y., Shang Y., 2022, A review of industrial big data for decision making in intelligent manufacturing, Engineering Science and Technology, an International Journal, 29, 101021.

Ma S., Zhang Y., Lv J., Ge Y., Yang H., Li L., 2020, Big data driven predictive production planning for energy-intensive manufacturing industries, Energy, 211, 118320.

Moorhouse D., 2020, Making Fashion Sustainable: Waste and Collective Responsibility, One Earth, 3(1), 17-19.

Nabi F., Mahmud R., Islam M., 2015, Improving Sewing Section Efficiency through Utilization of Worker Capacity by Time Study Technique, International Journal of Textile Science, 2015(1), 1-8.

Rahman M., Habibullah M., Masum M.A., 2017, Readymade Garment Industry in Bangladesh: Growth, Contribution and Challenges, IOSR Journal of Economics and Finance, 8(3), 1-7.

Shah D., Wang J., He Q., 2020, Feature engineering in big data analytics for IoT-enabled smart manufacturing – Comparison between deep learning and statistical learning, Computers and Chemical Engineering, 141, 106970.

Souifi A., Boulanger Z., Zolghadri M., Barkallah M., Haddar M., 2021, From big data to smart data: Application to performance management, IFAC-PapersOnLine, 54(1), 857-862.

Theng, M., Jully, T., Liew, P. Y., Tan, L., 2021, A Review of Manufacturing Sustainability Assessment Tool Selection Criteria: A Quantitative Score-Rating System versus Process-Data Sustainability Assessment, Chemical Engineering Transactions, 89, 523-528.

Uttam D. D., 2013, Material Handling in Textile Industries, International Journal of Advanced Research in Engineering and Applied Sciences, 2(6), 52-66.

Wang J., Xu C., Zhang J., Zhong R., 2022, Big data analytics for intelligent manufacturing systems: A review, Journal of Manufacturing Systems, 62, 738-752.

Xu F., Li Y., Feng L., 2019, The influence of big data system for used product management on manufacturing–remanufacturing operations, Journal of Cleaner Production, 209, 782-794.

Ye Y., Wang M., Yao S., Jiang J., Liu Q., 2019, Big data processing framework for manufacturing, Procedia CIRP, 83, 661-664.