Technology Integration and Operational Efficiency in Ready-Made Garment Production: Evidence from Dhaka Division, Bangladesh

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Abstract—The ready-made garment (RMG) industry plays pivotal role in Bangladesh economy, and is under immense pressure to reduce cost, time of production, bring up quality improvement and satisfy buyers requirement. The aim of this study is to investigate the effects of the Internet of Things (IoT), enterprise resource planning (ERP) and automation on improving operational efficiency in RMG production. A survey was taken on a quantitative basis from 720 employees and operational managers of 40 factories in Gazipur district. The data obtained were analyzed using descriptive statistics, correlation analysis and structural model. The findings indicate that the use of IoT, ERP, and automation all positively and significantly affect operational efficiency. ERP has the strongest direct effect ($\beta = 0.229$), followed by IoT ($\beta = 0.189$) and automation ($\beta = 0.173$). The variance of operational efficiency is accounted for by the three technologies and is 72.5%. The results demonstrate the potential to enhance coordination, accuracy, speed and decision-making via connected information systems, real-time monitoring, and automated production support. The study suggests a phased implementation, training of workers, and greater technical assistance in particular for smaller factories.

Keywords—automation, enterprise resource planning, Internet of Things, operational efficiency, ready-made garments.

I. INTRODUCTION

The ready-made garment industry is one of the main drivers of the Bangladeshi economy. It generates foreign exchange, provides employment for millions of people and has helped the country establish a good brand reputation in the international clothing market. Bangladesh is the second largest exporter of RMG after China and is the leading supplier to the buyer of Europe and North America [1, 2]. It is also a major contributor to national export income, particularly in the sector [3]. Hence, fluctuations in the performance of the RMG industry have direct impacts on employment, trade and economic growth.

Competition is evolving. The prime benefit of Bangladesh was “low labor cost”. However, that benefit is reduced now as other Asian countries can provide the same level of cost, the same delivery speeds, or better technical systems. Short lead times, small batch sizes, product diversity, traceability, product stability and strict social and environmental compliance are also key expectations of buyers. If a factory fails to provide reliable information and cannot respond quickly, it can still lose orders even if it has low basic production costs.

Production is also a connected process in the case of RMG. Fabric and accessories are due on time. Cut, sew, wash and iron, inspect, pack and ship items should be done in an orderly manner. Any late delivery can impact the entire order. Planning and co-ordination of the supply chain are important as many raw materials are imported. Slow communication, data duplication and decision mistakes can arise when using manual records or individual departmental files. The gaps can be reduced by the technology as it can connect people, machines, materials, and information.

There are three areas of technology that are particularly relevant. Firstly, IoT devices and sensors can monitor the movement, materials, machines, production status and real-time. Secondly, ERP system can integrate procurement data, inventory data, production planning data, finance data and delivery data into a single platform. Third, automation can assist with repetitive and accuracy-critical processes like cutting, material handling, sewing assistance and quality checks. These technologies are not a substitute for management. They provide managers and workers with improved information and tools to support day-to-day decision-making.

There are also risks and barriers to the adoption of technology. The initial cost can be high. The factories may have few skilled workers, inadequate digital system, and lack of software, or may not have management support. Staff could have concerns with additional work regulations or about losing their jobs. Adoption for small-medium factories can be challenging compared to large export-oriented factories [10] [11]. Hence, the role of technology must be evaluated using field evidence rather than taking a dogma that any new system will yield similar outcomes.

Previous research focuses on ERP, IoT, garment automation, lean production and supply-chain improvements in the garment industry [4]– [9]. But fewer number of studies have compared the direct impacts of these three technology areas in one model with the Bangladesh factory level respondents. This study seeks to fill that void. It sets out to gauge the extent of IoT, ERP, automation and operational efficiency, to validate the relationship between these technologies and test the impact each one has on the other, and to determine which has the greatest direct impact. The results can be useful in the decision-making process of investment in the factory and can be useful for future research on digital transformation in RMG production.

II. LITERATURE REVIEW AND HYPOTHESES

A. Operational Efficiency

Operational efficiency is the utilization of available time, labor, materials, machines and information in a manner that will produce the desired output in a minimum amount of time, with a minimum of waste, error or unnecessary cost. It can be seen in RMG factories in the following aspects: production speed, line balance, less rework, accurate inventory, quick procurement, timely delivery, and coordination. Efficiency isn't just a machine matter. It relies on the integrity of the information and how fast departments can respond to it.

There are a number of ways technology can increase efficiency. It can provide information earlier, minimize data entry, highlight production issues, provide a standardized workflow, and aid in quicker decision making. But the actual outcome is dependent upon the matchup of the technology to the factory process. A large system that isn't cost-effective if employees are not using it adequately or if the data provided are not accurate or if the system is not connected to daily production decisions.

B. Internet of Things

IoT is the term used for a network of sensors, tags, devices and machines that can gather and pass on information. For garment manufacturing, IoT can be utilized to track inventory, monitor machine status, monitor energy, control work-in-process and shipments visibility. RFID tags can indicate the location of materials or products. Sensors can also alert the manager to machine issues or abnormal situations. This helps to minimize manual reporting time [6].

The visibility of the supply chain is crucial in its fast-paced flow. Managers have certainty of stock levels and production status, so they can alter schedules, shift resources or reach out to suppliers in advance of real delays. Additionally, IoT data can be used to help with predictive analysis. A factory might discover reoccurring trends of machine stoppages or material shortages, for instance. Thus, improved monitoring should facilitate quicker response, less waste and better process control. From this perspective, H1 argues that IoT positively and significantly influences operational efficiency.

C. Enterprise Resource Planning.

ERP is an integrated information system which has the ability to bind major business functions. Purchase, inventory, production planning, quality, finances, human resources and delivery can be connected with a single platform. Many factories have separate departments and information is conveyed between them by calls, messages or printed paper. ERP minimizes this divide by providing a common database and common work process [5].

The primary benefit of ERP software is coordination. Purchase teams have the ability to view production requirements. Production teams is able to view material status. Plans can be compared to actual output and delay can be identified by managers. Having your information in one place also eliminates duplicate work and inconsistencies in records. These benefits are significant for RMG companies as customers modify orders on quantity, style and delivery dates. The best ERP system will maximize planning, utilization of resources, and decision making. Therefore, according to H2, there is a positive and significant relationship between ERP and operational efficiency.

D. Automation

Automation is the use of machines, software and control systems to do less work manually. There can be some level of automation. Simple automated cutting, digital pattern systems, conveyor movement, production counters or automated quality tools can be used by a factory. In more advanced factories, the use of robotics or computer-controlled equipment may be used. Automation can be used to improve consistency, to avoid repeated mistakes, and to speed up the production process [7].

There is more to the effect of automation than an increase in output. Automated systems can increase the accuracy of measurement, minimize material waste and ensure greater product consistency and stability. Meanwhile, there needs to be an investment, maintenance, training and job redesign process involved in automation. Inadequate automation can generate dead time on machines or issues with workers' resistance. The benefit to be gained is then greatest if the technology is suitable to the product and production volume. According to H3, automation has a positive and significant impact on operational efficiency.

E. Adoption Barriers and Research Model

Adoption of technology in RMG sector in Bangladesh is still uneven. The larger factories can invest in ERP systems, sensors and in advanced machines. Smaller organizations may experience restricted finance, less infrastructure, software customization expenses, and a lack of technical personnel [10, 11]. Another source of resistance may be employees who lack understanding of the new system, or those who are afraid of losing their jobs as a result of automation. The reasons for this are these barriers, as technology can be seen as a positive thing but not as widely adopted in all factories.

The model in Fig. 1 is a theoretical approach to the problem, which assumes that IoT, ERP, and automation are all independent, but interdependent variables that influence operational efficiency. Real time monitoring, integrated information and automated task support are assumed to have different ways of increasing efficiency. Meanwhile, the three technologies can be complementary to each other. For instance, once the IoT data is tied to an ERP system, it becomes more useful, and automation is more manageable with reliable production information.

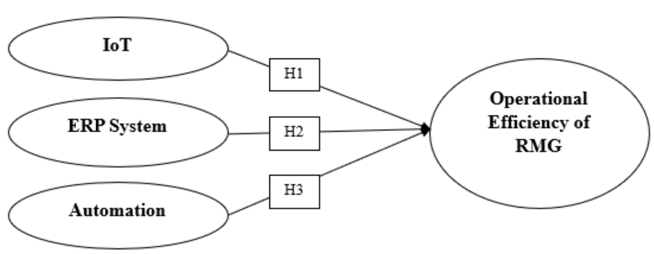

Fig. 1. Conceptual framework linking IoT, ERP, and automation with operational efficiency.

The hypotheses are stated as follows: H1, IoT positively and significantly affects operational efficiency; H2, ERP positively and significantly affects operational efficiency; and H3, automation positively and significantly affects operational efficiency.

III. METHODOLOGY

B. Management Plan and Strategies

This study employed quantitative and cross-sectional survey research design. The design chosen was due to the research tests that determined relationships among measures of constructs that could be measured. The fieldwork was directed to RMG factories of Gazipur district as it is an important production area in Dhaka Division. The study engaged direct workers and operational-level managers to gather their opinions on the factory processes.

C. Response to Intervention (RTI) Services

The sampling was done in multi-stage random sampling. In the first stage, factories were sampled as primary sampling units. A factory sampling frame of 60 factories was created. The number of 40 factories were selected by simple random sampling from this frame. The production schedule, permission rules, cost and time are the major factors that often restrict access to the RMG factories. The chosen factories were approximately 2/3 of the accessible frame.

During the second phase, 720 respondents were randomly sampled from the 40 factories or approximately 18 persons per factory. The sample was made up of 483 sewing operators and 52 quality inspectors. Other respondents were engaged in cutting, washing, ironing, packing, and support work. This blend proved beneficial because the operation is a chain of departments. The sample also included workers who had varying ages and job tenure.

C. Instrument & Data Collection.

The four constructs measured in the questionnaire were IoT, ERP, automation and operational efficiency. IoT was Assessed using three items, ERP four items, automation four items and operational efficiency was assessed using five items. The items were presented using a Likert-type response format. The questionnaire was designed in local language and was easy to understand. When necessary, explanations were given to ensure that respondents of varying levels of education could comprehend the questions.

Data was collected in a factory like manner, according to the production schedules. The researchers were gender sensitive and were respectful of the hierarchy of workers and supervisors in the workplace. The respondents were talked to formally and they volunteered to participate. No worker had to respond due to pressure from management in the factories. Confidentiality and anonymity were ensured. Questionnaires that were not completed or contained errors or inconsistencies were checked off before analysis.

D. Data Analysis

SPSS and Microsoft Excel were used to manage and analyze the data. Frequency and percentage were used to describe the respondents. Mean and standard deviation were used to summarize the constructs. A correlation matrix was created to illustrate the direction and intensity of the relationships. The three hypotheses were tested using the structural model, which included path coefficients, standard errors, t statistics and p values. To demonstrate the percentage of operational efficiency that was explained by IoT, ERP and automation, the coefficient of determination, R^2, was used.

IV. RESULTS AND DISCUSSION

A. Respondent Profile

Table I shows that the sample is composed of 77% female and 23% male. It is noticed that women play a significant role in the production of RMG that is why this distribution is included in the process. A youthful workforce is also found. Fourteen percent of the respondents are below 20 years, 53% are between 20 and 30 years, and 26% are between 31 and 40 years. There are only 7% with an age greater than 40. While the younger workforce might give factories the opportunity to put in place new systems, it can also mean that they will need to be constantly developing their skills.

Most fabric sewers (67%) work in the same industry as the respondents. Cutting workers and helpers each make up 6% of quality inspectors, and 7% are quality inspectors. Washing and ironing workers make up 5% of the workers and packing workers make up 4% of the workers. As for tenure, 49% of respondents work for 5 to 10 years, 29% for less than 5 years, 17% for 11 to 15 years and 5% for over 15 years. The sample, therefore, is an amalgamation of newer and experienced workers, who know the factory routine. The tenure pattern also validates the significance of employee retention and job satisfaction in the production industries [12].

TABLE I
RESPONDENT DEMOGRAPHIC PROFILE

Group	Category	n	%
Gender	Male	166	23
	Female	554	77
Age	Below 20	102	14
	20–30	376	53
	31–40	189	26
	Above 40	53	7
Position	Sewing operator	483	67
	Cutting worker	44	6
	Quality inspector	52	7
	Washing worker	36	5
	Ironing worker	35	5
	Packing worker	28	4
	Helper	42	6
Tenure	Below 5 years	208	29
	5–10 years	354	49
	11–15 years	124	17
	Above 15 years	34	5

Source: Primary data and authors' calculations.

B. Descriptive Statistics

Table II shows the means and standard deviations. The mean values range from 6.092 to 6.435. The mean value of operational efficiency is the highest at 6.435. The overall result indicates that the respondents are mostly confident that their factories are making improvements in the daily operation. ERP has a mean of 6.237, and IoT has a mean of 6.191. The values are high and reflect a high degree of agreement that integrated systems and real-time technologies are available and applied in the factories that were surveyed.

The mean of automation is 6.092, but is at the lowest level. This could result in a situation where employees experience benefits, while automation is not as prevalent as ERP or IoT. It can also be a sign of the more expensive, more complicated technology that is required for automated equipment. The standard deviations are relatively small (0.475 to 0.536). As such, there is some uniformity in the responses among the participants. The most variance is for automation, which makes sense since the level of automation varies significantly depending on factory size, product type and investment potential.

TABLE II
DESCRIPTIVE STATISTICS OF CONSTRUCTS

Construct	Items	Mean	SD
IoT	3	6.191	0.492
ERP system	4	6.237	0.475
Automation	4	6.092	0.536

Construct	Items	Mean	SD
Operational efficiency	5	6.435	0.533

Source: Primary data and authors' calculations.

C. Correlation Analysis

All the correlations are positive as seen in the Table III. There is a correlation of 0.473 for IoT and ERP, 0.567 for IoT and automation, and 0.511 for ERP and automation. The values indicate that all three technologies have some relationship but are not the same. The more a factory invests in one technology, the more they'll invest in another, but they're all a different subset of digital production.

The strongest correlation is with operational efficiency ($r = 0.678$) for IoT. This highlights the need for real-time monitoring and process visibility. ERP has a correlation of 0.603 with operational efficiency. This finding agrees with the shared information / integrated planning principle of decreased coordination issues. Automation has a correlation of 0.567 with operational efficiency. This is also a positive relationship that is meaningful and that will support the value of the automated tasks.

Initial support of H1, H2, and H3 are found in the correlation results. But correlation does not distinguish between the impact of one predictor and other predictors. As these are related to each other, namely IoT, ERP and automation, a structural model is required to estimate direct impacts to both of these at the same time.

TABLE III
CORRELATION MATRIX

Construct	1	2	3	4
1. IoT	1.000			
2. ERP system	0.473	1.000		
3. Automation	0.567	0.511	1.000	
4. Operational efficiency	0.678	0.603	0.567	1.000

Source: Primary data and authors' calculations.

D. Hypothesis Testing

Results of the structural model are presented in Table IV. The three path coefficients are all significant and positive. In H1, the value of β is 0.189. The number of t is 4.636, which is greater than the commonly used t value threshold of 1.96, and the number of p is less than 0.001. H1 is thus supported. IoT makes a significant direct contribution after ERP and automation are included in the model.

In the case of H2, the relationship between ERP and operational efficiency is 0.229. The t value for this path is 5.385 (the greatest of the three paths) and p is less than 0.001. H2 is supported. ERP has the greatest direct impact. The result indicates that the efficient operation of an RMG depends on the integrated information and coordination between departments. ERP could also boost the importance of IoT and automation by integrating their data into a unified planning system.

The value of β for H3 is 0.173 from automation to operational efficiency. The t value is 3.961 and p is below 0.001. H3 is supported. It is worth noting that the direct coefficients are smallest for automation, yet this effect is still significant. The reason for its lower value could be the uneven adoption, high cost, technical difficulty, and/or the possibility that certain factories automate only certain tasks. Standard errors of all paths are small (between 0.041 and 0.044) and indicate that the estimates are precise.

A noteworthy finding is that the highest simple correlation is IoT with efficiency and the highest direct effect in the structural model is ERP. It does not contradict one another. The correlation indicates the overall association between two variables. Path coefficient is the amount of variance in the dependent variable that is accounted for by the independent variable, controlling for the other independent variables. ERP can thus account for more efficiency than IoT and automation.

TABLE IV

STRUCTURAL MODEL PATH COEFFICIENTS

Hyp.	Path	β	SE	t	p
H1	IoT → efficiency	0.189	0.041	4.636	<.001
H2	ERP → efficiency	0.229	0.043	5.385	<.001
H3	Automation → efficiency	0.173	0.044	3.961	<.001

Source: Primary data and authors' calculations.

E. Explanatory Power and Overall Discussion

The coefficient of determination is shown in Table V. The value of operational efficiency is R^2- 0.725. This equates to 72.5% of the difference in operational efficiency being linked to IoT, ERP and automation. It is high and indicates that the chosen technology factors have considerable explanatory power for the observed factories. The remaining 27.5% could be due to management support, worker skills, organizational culture, buyer pressure, supply conditions, product complexity, etc., not captured in the model.

TABLE V

COEFFICIENT OF DETERMINATION

Dependent construct	R^2
Operational efficiency	0.725

Source: Primary data and authors' calculations.

The overall results support the main argument of the study. Technology is effective to the efficiency of RMG if it facilitates the flow of information and production control. IoT supports visibility. ERP facilitates integration and planning. Automation facilitates speed and uniformity. The technologies are not interchangeable, the roles are different and factories should not consider the technologies as direct substitutes. The best results will be achieved with a connected system where machine and inventory information feeds into ERP systems to enable timely action.

The results are also in line with previous research. Improved coordination and resource management are reported by ERP research [5, 10, 14]. Tracking, monitoring, and responding based on data are highlighted in IoT research [6, 13]. Research of automation shows that production speed and accuracy are improved, but also suggests issues in training and cost and job change [7], [15]. The current research provides the first direct comparison and confirms that each technology is important in the context of the other two technologies.

V. PRACTICAL IMPLICATIONS, LIMITATIONS, AND FUTURE RESEARCH

A. Practical Implications

Managers are provided with clear guidance on the results. ERP is not about just accounting software; it is an information system at its core. The system must be integrated with purchasing, inventory, production planning, quality and delivery. If data is entered, who is doing it, who is checking it and how it will be used in the daily meeting should be defined by managers. Even a costly ERP solution will not be worth the investment if it has poor data quality.

The first step with IoT investment should be to focus on specific operational challenges. First, in factories, RFID or sensors could be used to monitor high value materials, work in process, machine stoppage or energy usage. With a limited pilot, the data gathered can determine if the data is accurate and useful and will determine if the system needs expansion before that. The information that can be gathered through IoT should be connected to clear decisions. There will be no improvement in efficiency if a lot of data is collected without a response process.

Technical and human planning should be done for the introduction of automation. Managers should choose tasks that warrant the expense for speed, repetition, accuracy, and/or safety. Before the new system being integrated into the production targets, workers must be trained. There can be shifts in roles from manual labor to setting up, running, maintaining, or even checking the quality of machinery. The method helps to minimize resistance and thus maximize return on investment [15].

A step-by-step approach might be necessary for small and medium factories. Cloud based systems, common technical services, vendor support and industry training can reduce entry barriers. Government agencies, industry associations and buyers are able to help establish common standards and skills development. Along with sustainability aspects like reduced waste, more efficient energy consumption, transparent supply chains, and safer working environments, technology investments should also be correlated with them [11], [13].

B Limitations and Future Research

There are a number of limitations of the study. One, it is a sample of factories that are accessible. The results may not be representative of all factories in other regions, or of very small factories. Secondly, the study is a cross-sectional survey study. Although the results reveal strong relationships, these do not constitute proof of long-term causality. Third, the measures are grounded in the ideas of the respondents. The survey responses can be compared with actual measurements of lead time, defects, machine down time, order completion, inventory, and cost in future studies.

Future studies are needed that cover additional factories and incorporate a comparison with large, medium and small factories. A longitudinal design can be used to assess performance (before and after technology use). Interviews with owners, senior managers, IT staff, supervisors and workers may be included. These interviews can describe the reasons for a system's success or failure and how the staff members feel about the change.

Management support, digital readiness, worker capabilities, organizational culture, buyer needs, sustainability performance, and transparency of the supply chain are other items that can be incorporated into new models. Researchers can investigate if ERP has an impact on the value of IoT data or if training alters the impact of automation. The latter would give a more comprehensive understanding of digital transformation in RMG industry [16].

VI. CONCLUSION

The study aimed to understand the impact of IoT, ERP, and automation on operational efficiency in the RMG industry in Bangladesh. The results of a survey of 720 respondents from 40 factories indicate that all three technologies have positive and significant impacts. ERP has the highest direct impact and IoT has the highest direct correlation with efficiency. The contribution of automation, though not direct, is clear, though less significant.

The model accounts for 72.5% of the variation in operational efficiency. The result demonstrates the role that technology plays in the performance of the factory. But they have to be linked up and have the right people, the right information, the right processes, and the right management response. The full benefit of purchase of software or machines will not be obtained without process changes.

Hence, a progressive and strategic approach by the RMG companies to digitalization is necessary. They are expected to improve ERP integration, incorporate IoT for real-time operational requirements and implement automation while training workers and redesigning jobs. The steps can enhance the production speed, coordination, and quality as well as the competitiveness of Bangladeshi factories in the international garment market.

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