

Monitoring the Efficiency of Fabric Production

Technical Report

Written by: Sophia Watts

For: Melin Tregwynt

Date: March 2022

Supervisor: Jaymie Phillips

Abstract

Industry 4.0 methods can produce increased operational efficiency. Measuring fabric production output indicates department performance, which impacts the cost margins of the company's subsequent products. Enhanced data capture will increase transparency on inefficiencies, enabling agile decision-making. This report focuses on two elements of the process; for each, data capture methods are discussed. Part 1 explores methods to identify value-added and non-value-added activities, introducing Time and Motion Study, Value Stream Mapping, and digital data-capture. Part 2 explores digitising information relating to the flow of inventory, exploring Cyber-Physical Systems, Dynamic QR codes, and RFID tags. The conclusion is that incremental steps towards digitisation and developing an improvement culture will likely achieve greater viability and success, than investing in a radical technology change. This report recommends that existing knowledge concerning the company's needs, operations, and culture, are considered in assessing method suitability.

1. Introduction

Businesses that embrace advantageous Industry 4.0 methods will maintain competitiveness, with benefits including increased efficiency, and improvement of product/service offering to customers (Gilchrist, 2016, p. 205-206; Martinez, 2019). This report aims to identify methods of data capture to increase availability of valuable information, enabling the company to highlight, monitor, and improve on inefficiencies in fabric production, yielding increased output and reduced costs.

The fabric production output metric is an indicator of department performance, impacting the cost margins of all subsequent products. Figure 1 shows an overview of this production process. Average lead times for each stage are defined, however enhanced data capture and analysis of individual elements will enable stakeholders to identify trends and inefficiencies, on which improvements can be actioned.

This report focuses on two elements of the process, and is split into two parts respectively. Part 1 proposes recording downtime in "Step 9" (Figure 2) to reveal the hidden costs through inefficiencies at this stage (Nash and Poling, 2009; White and Cicmil, 2016). Part 2 proposes digitising fabric logs in "Step 11" (Figure 4), identified as a bottleneck, to enable efficient and communicable monitoring of fabric movement, improving quality control and agile decision-making (Gilchrist, 2016, p.206). For each part potential methods are discussed, followed by the conclusion and recommendations.

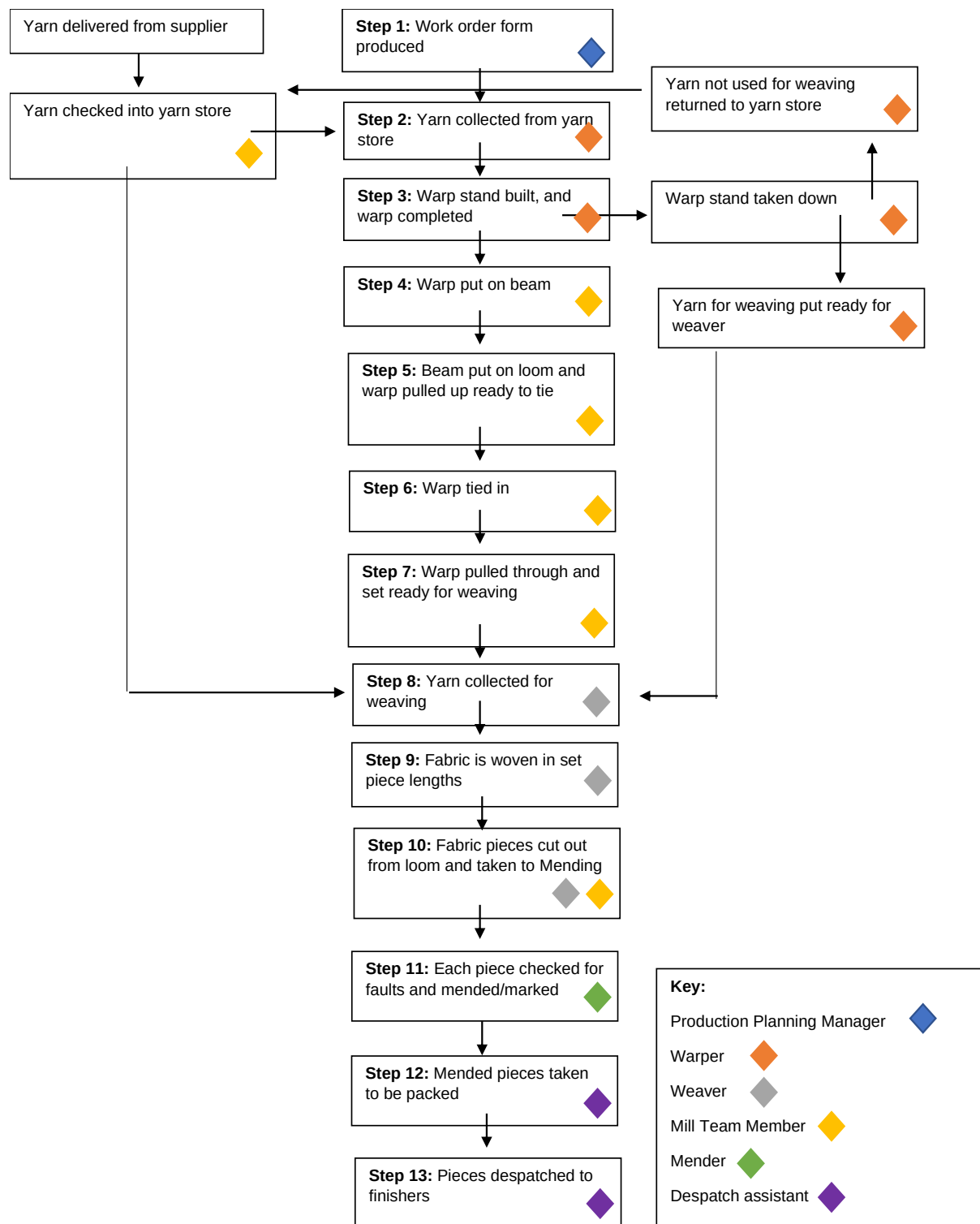


Figure 1: The Fabric Production Process

2. Part 1 (“Step 9: Fabric is woven in set piece lengths”)

2.1. Implementation Methodology

Observation of “Step 9” (Figure 2) reveals operational subtasks undertaken, identified as weaving-operation related and non-weaving-operation related (Table 1). Recording the frequency and duration of these subtasks can identify value-added (VA) and non-value-added (NVA) activities (Nash and Poling, 2008, p. 42), creating a form of Current State Map (Nash and Poling, 2008, p. 2), making this visible to stakeholders for analysis and planning (White and Cicmil, 2016).

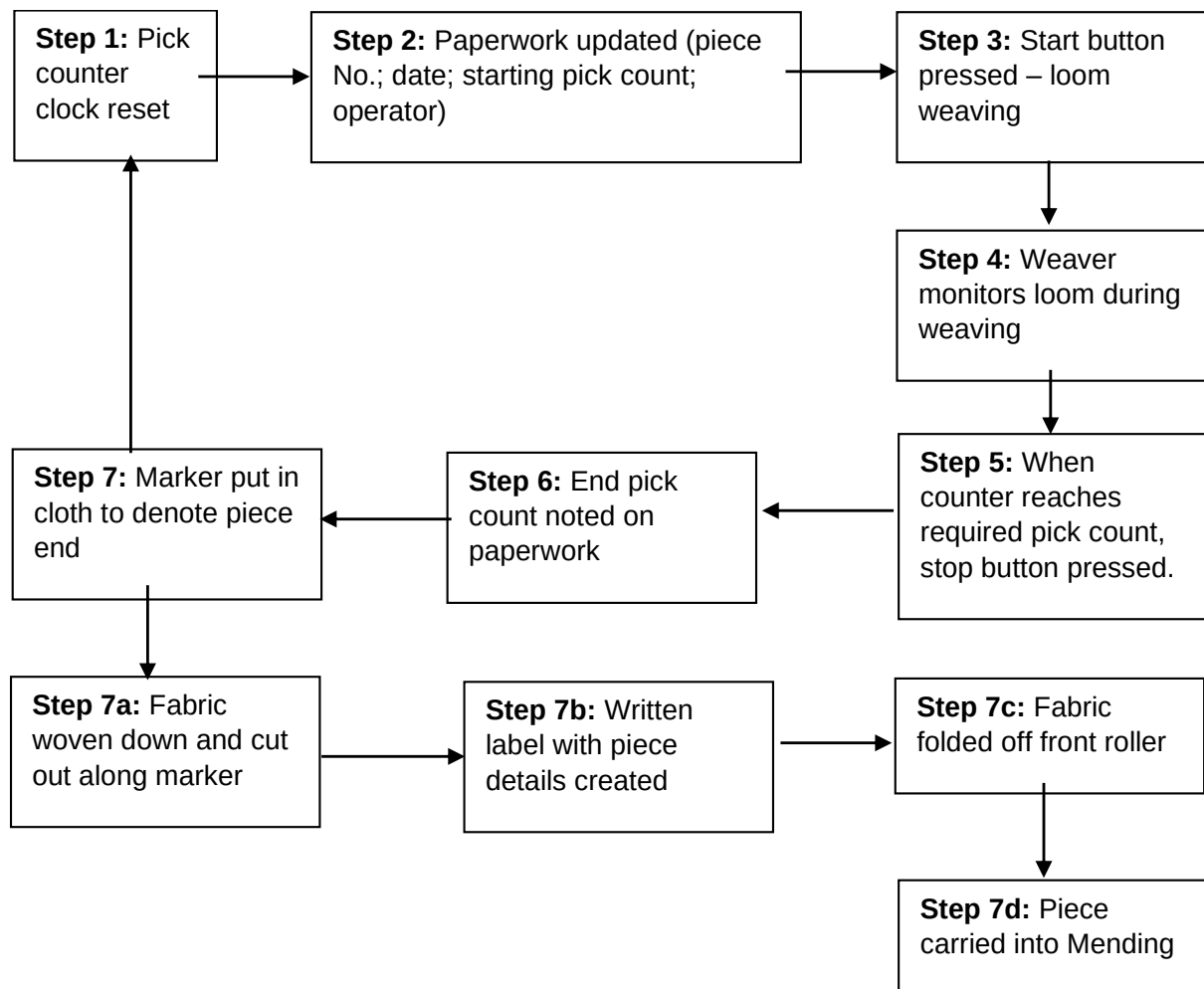


Figure 2: “Step 9” Expanded Process Map

Weaving-Operation Related Subtasks	Non-Weaving-Operation Related Subtasks
Checking fabric for faults	Beam-off from warp
Feeding weft yarn	Putting beams on looms
Fixing warp and weft breaks	Carrying fabric pieces
Making running adjustments, e.g. yarn tension.	Team problem-solving/helping colleagues
	Miscellaneous department/site tasks
	Scheduled breaks
	Comfort breaks

Table 1: Operational Sub-tasks

A time and motion style audit is suggested to capture data, for developing a more informative process map (outlined in Figure 3). An actionable, adaptable plan should be established prior to the mapping process, allowing for unexpected deviation (Nash and Poling, 2008, p. 222). The process could be undertaken manually, or by employing elements of technology. A discussion on possible methods to conduct the mapping process now follows.

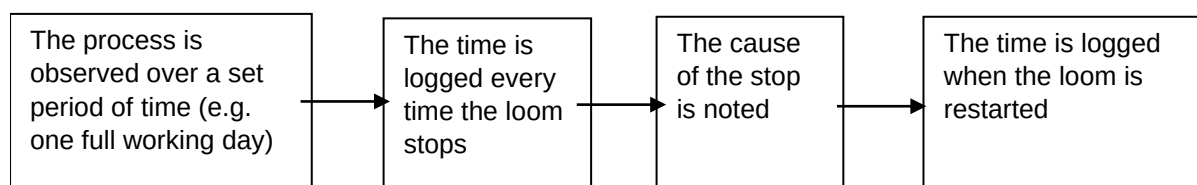


Figure 3: Outline of Time and Motion style audit process

2.2. Background Research

Value Stream Mapping creates a communicable tool depicting the operational flow of processes and their value, enabling greater transparency and a holistic approach to decision-making concerning efficiency. (Nash and Poling, 2008, p. 1). Stakeholder receptivity is required to explore solutions for inefficiencies identified, to achieve objectives (White and Cicmil, 2016). Involving team members in the process provides an opportunity for learning, and to ensure they feel both valuable to the process and instrumental in its development (White and Cicmil, 2016). It is advisable to employ an individual from a different department to undertake the mapping task to facilitate greater objectivity (Nash and Poling, 2008, p. 30; White and Cicmil, 2016). Additional benefit could be gained through knowledge transfer between departments, and socialisation, improving cross-departmental cohesion. (White and Cicmil, 2016).

Traditional time and motion studies (TMS) – whilst effective – are time-consuming to undertake, and risk bias and inaccuracy through human nature. (Faccio, *et al.*, 2019). Accurate data capture in TMS can be aided through video recording for enhanced post-observational analysis (Nash and Poling, 2008, p. 32; Faccio, *et al.*, 2019). Sophisticated technological systems digitally capturing human movements have been developed (Ferrari *et al.*, 2018; Faccio *et al.*, 2019) improving TMS time-efficiency. However, specific actions

must be digitally mapped for automatic detection, requiring expertise and investment for setup and digital analysis programming; unmapped actions would be undetected.

The observed process should be monitored over time to capture myriad variation on the activities involved, accumulating enough data for accurate analysis (Gilchrist, 2016, p. 19; Chuang *et al.*, 2019). Therefore, being able to record the data digitally would be beneficial. A low-cost device to capture the data could be created by combining a Raspberry Pi with a microcontroller, to convert the captured analog data to digital (Chuang *et al.*, 2019); for example, sensing the 'stop-start' motion of the machine, recording the frequency and duration of stops. Capture of contextual information is also required to identify the NVA activities encountered, for example a manual log or by creating an interface, activated by the weaver, to record established delay activities.

Due to the lack of software-programming capabilities in the business, in-house training or external expertise is required to develop technological systems. Therefore, this report advises creating a simple TMS system to keep investment costs low initially, with a view to build on this over time for positive continual improvement as results are achieved. A reiterative mapping strategy will widen the data pool and facilitate process improvement.

3. Part 2 (“Step 11: Each piece checked for faults and mended/marked”)

3.1. Implementation Methodology

Digitising information relating to the flow of inventory in “Step 11” (Figure 4) makes that data more transparent and accessible for analysis (Nash and Poling, 2008, p. 34; Moeuf *et al.*, 2018). A first step in creating a more streamlined and efficient process could be achieved by utilising existing IT software (Martinez, 2019), reducing paper consumption. Replacing paper records by inputting information directly into an Excel spreadsheet (Figure 5) provides a low-cost solution, requiring a device to access the software and basic training on the process. Methods to digitise information are discussed further below.

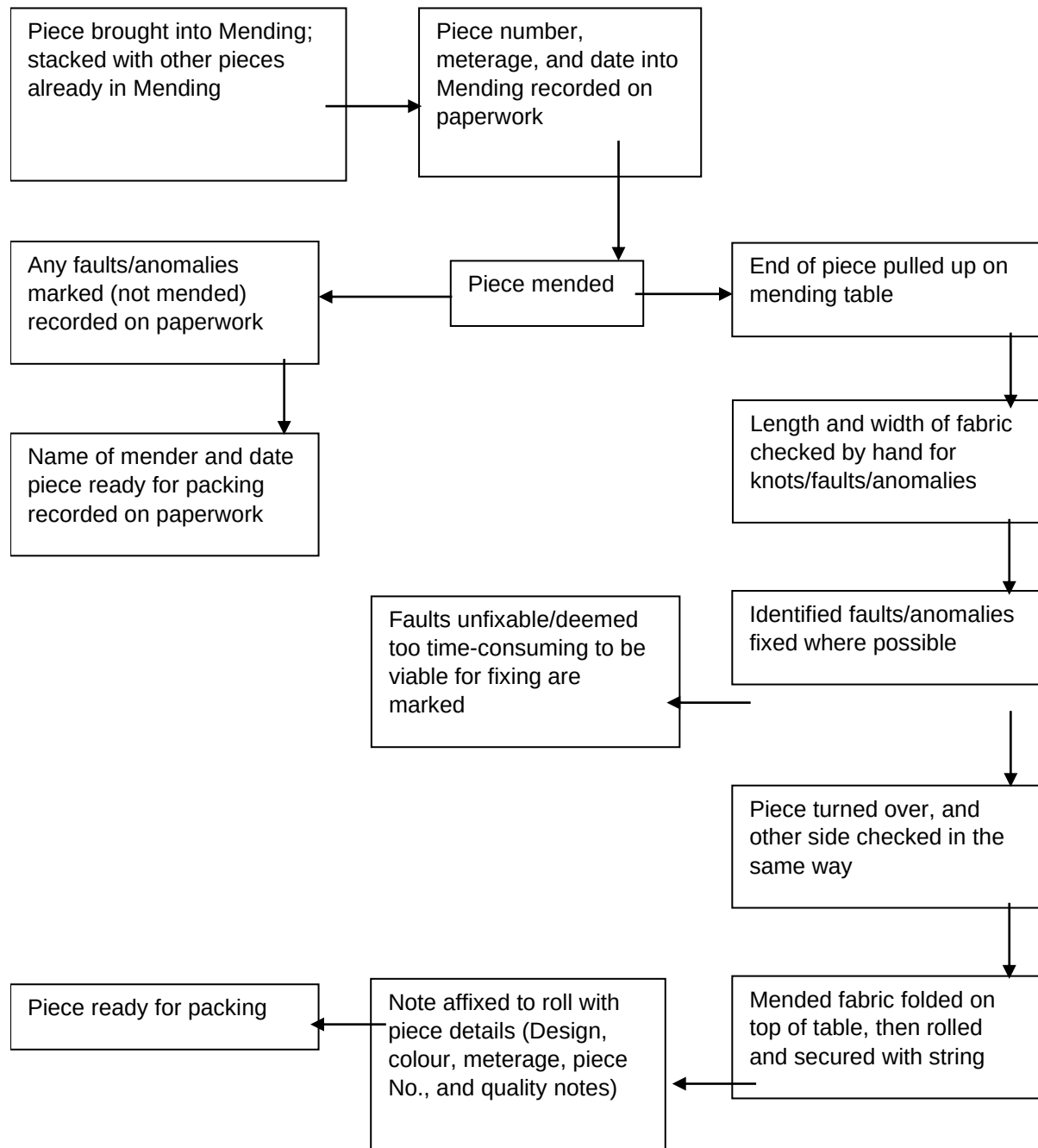


Figure 4: “Step 11” Expanded Process Map

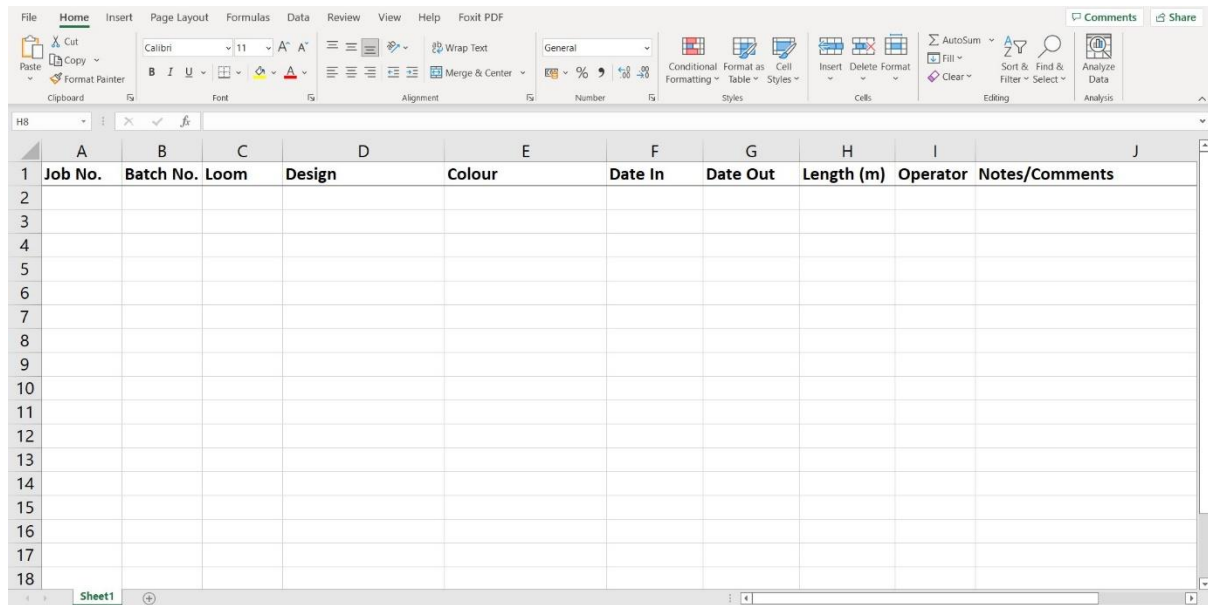


Figure 5: Example of Excel spreadsheet Mending Log

3.2. Background Research

Industry 4.0 technologies facilitate data communication throughout the organisation, creating data transparency for agile decision-making (Moeuf *et al.*, 2018). A Cyber-Physical System (CPS) is an amalgamation of digital and analog worlds; networking embedded computational systems and sensor technologies within physical processes (Gilchrist, 2016, p.36; Taha, Taha, and Thunberg, 2021, p. 5). In operating with CPSSs, the communicability of data across the organisation must be considered to create a reliable and accurate network. (Taha, Taha, and Thunberg, 2021, p. 11).

In developing the most suitable solution within the organisational context, even relatively simple introductions to digitisation can have a positive impact in process and organisational efficiency (Martinez, 2019). The company's existing cloud-based computing system can be utilised for sharing data through software and communication platforms, enabling clear, cohesive analysis and planning (Ghobakhloo, 2018) across departmental silos. Wider organisational impacts can be highlighted, discussed, and actions targeted promptly (Moeuf *et al.*, 2018). A further move towards digitisation could be explored through use of QR codes or RFID tags, affixed to each piece label at weaving completion.

Dynamic QR codes directly access a specific URL, containing data which can be updated (Madsen, Santos, and Jørgensen, 2021). This would facilitate a reciprocal flow of information, both within the production process and between departments. To utilise QR codes beneficially, an operational process – involving manual activities, devices, and processing software – needs to be established to perform the required function (Vukićević *et al.*, 2021). Additionally, if the printed code became damaged during operational processes, this could impact effectiveness (Vukićević *et al.*, 2021).

RFID (Radio Frequency Identification) tags can hold multiple bits of information, individual to each item (Gilchrist, 2016, p. 219), communicated wirelessly (Gilchrist, 2016, p. 106). This information could pertain to the manufacturing process and further throughout its useful life,

by continually updating tags with current information (Gilchrist, 2016, p. 24). RFID readers can scan multiple tags in range simultaneously - visible, and non-visible (Gilchrist, 2016, p. 23-24) - although recent concerns surrounding prolonged radiation exposure may limit distance scanning in the future (Vukićević *et al.*, 2021). Despite the benefits of the technology there are challenges posed. New processes are likely required to fully utilise RFID data (Miles, Sarma, and Williams, 2008, p. 13), plus a supportive software system (Miles, Sarma, and Williams, 2008, p. 20).

Creating a CPS across the business could be a beneficial future development. The practicalities and benefits gained of implementing an advanced system for the environment should be assessed. Due to the complexity and expense of implementation, this report suggests exploring improved organisational communication through full utilisation of existing technology opportunities in the short term. Further research on longer-term technology investments could be explored.

4. Conclusion

In implementing Industry 4.0 technologies, the aim is not purely to introduce digitalisation; the aim is continual improvement, and the implication is that an element of digitisation will aid development of improvement culture (Gilchrist, 2016, p. 206; Martinez, 2019). Diligently considered Industry 4.0 methods, if implemented successfully, should see beneficial long-term gains on initial investment costs (Gilchrist, 2016, p. 205). Developing a system for increased data capture of operations is complex but if successfully achieved can yield greater efficiency improvement (Faccio, *et al.*, 2019). For this company, taking small steps towards digitisation and developing a reiterative improvement culture will likely have more impact, and achieve greater viability and success initially, than investing in a radical technology change.

5. Recommendations

Introducing elements of digitisation, alongside development of a culture of adaptability, may provide adequate efficiency improvements in certain processes (Martinez, 2019). Therefore, methods should be assessed in relation to company context, utilising the existing knowledge concerning the company's needs, operations, and culture (Martinez, 2019). The company should create a communicable roadmap conveying their strategic path between short-term and longer-term goals for clarity and cohesion (Ghobakhloo, 2018). The strategy should consider the resources, competencies, knowledge, and implementation costs required to action the strategy at each stage, highlighting any shortfalls and identifying solutions (Ghobakhloo, 2018). Involving key team players in developing the system is advised for ease of implementation and positive engagement (Moeuf *et al.*, 2018; Martinez, 2019). Creating a coordinated system, alongside utilising, and developing team skills and expertise, can create a system of continuous improvement (Martinez, 2019). A key consideration in digitising data and creating smart systems is mitigating any risks associated with cyber security (Moeuf *et al.*, 2018). This not only relates to external breach of data, but also ensuring the reliability and accuracy of information recorded (Ghobakhloo, 2018).

References

- Chuang, s. *et al.*, (2019) 'Predictive Maintenance with Sensor Data Analytics on a Raspberry Pi-Based Experimental Platform', *Sensors*, 19 (18). DOI:10.3390/s19183884.
- Faccio, M. *et al.* (2019) 'Human Factor Analyser for Work Measurement of Manual Manufacturing and Assembly Processes', *International Journal of Advanced Manufacturing Technology*, 103, pp. 861-877. doi.org/10.1007/s00170-019-03570-z.
- Ferrari, E. *et al.* (2018) 'Motion Analysis System for the Digitalization and Assessment of Manual Manufacturing and Assembly Processes', *IFAC Papers Online*, 51 (11), pp. 411-416. <https://doi.org/10.1016/j.ifacol.2018.08.329>.
- Gilchrist, A. (2016) *Industry 4.0: The Industrial Internet of Things*. 1st edn. New York: Apress.
- Ghobakhloo, M. (2018) 'The future of manufacturing industry: a strategic roadmap toward Industry 4.0', *Journal of Manufacturing Technology Management*, 29 (6), pp. 910-936. DOI:10.1108/JMTM-02-2018-0057.
- Madsen, S.S., Santos, A.Q., and Jørgensen, B.N. (2021) 'A QR code based framework for auto-configuration of IoT sensor networks in buildings', *Energy Informatics*, 4 (2). <https://doi.org/10.1186/s42162-021-00152-w>
- Martinez, F. (2019) 'Process excellence the key for digitalisation', *Business Process Management Journal*, 25 (7), pp. 1716-1733. DOI:10.1108/BPMJ-08-2018-0237.
- Miles, S.B., Sarma, S.E., and Williams, J.R. (Editors) (2008) *RFID Technology and Applications*. [Online]. Available at: DOI: <https://doi.org/10.1017/CBO9780511541155> (Accessed: 24th March 2022).
- Moeuf, A. *et al.* (2018) 'The industrial management of SMEs in the era of Industry 4.0', *International Journal of Production Research*, 56 (3), pp. 1118-1136. <https://doi.org/10.1080/00207543.2017.1372647>.
- Nash, M. A. and Poling, S. R. (2008) *Mapping the Total Value Stream: A Comprehensive Guide for Production and Transactional Process*. New York: Productivity Press.
- Nash, M. A. and Poling, S.R. (2009) 'Process Mapping for the 21st Century', *Quality*, 48 (8), pp. 24-25. <https://www.proquest.com/scholarly-journals/process-mapping-21st-century/docview/235256637/se-2?accountid=130472>.
- Taha, W.M., Taha, A.M., and Thunberg, J. (2021) *Cyber-Physical Systems: A Model-Based Approach*. [Online]. Available at: <https://doi.org/10.1007/978-3-030-36071-9> (Accessed: 24th March 2022).
- Vukićević, A. *et al.* (2021) 'A smart Warehouse 4.0 approach for the pallet management using machine vision and Internet of Things (IoT): A real industrial case study', *Advances in Production Engineering & Management*, 16 (3), pp. 297-306. <http://dx.doi.org/10.14743/apem2021.3.401>.
- White, G.R.T. and Cicmil, S. (2016) 'Knowledge acquisition through process mapping Factors affecting the performance of work-based activity', *International Journal of Productivity and Performance Management*, 65 (3), pp. 302-323. DOI 10.1108/IJPPM-01-2014-0007.