Making Industry 4.0 relevant to small business – a case study

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Abstract

Despite the much-discussed positive impact Industry4.0 has on organisation, SMEs reported mixed results. Although the recent pandemic has given a big push for SMEs to adopt digital technologies, it appears to fall short of the desired digital innovation in management practices. Adopting the lens of operations management, this paper attempts to explore the relevance of Industry4.0 to small business through theoretical argument and case study. A framework to guide Industry4.0 approach in small business is proposed. It also attempts to explore the relationship and tension between operations management methodology, Industry4.0 technology, managerial capabilities, and operations performance objectives.

Keywords: Operations Management, Industry 4, Small Business

Introduction

It has been more than a decade since the introduction of Industry 4.0 initiative. The adoption of Industry 4.0 has been advocated to have positive impact towards operating performance, such as flexibility, cost reduction, improve productivity, improve quality, and delivery time reduction, creating competitive advantages to businesses (Agostini and Nosella, 2020; Bayo-Moriones et al., 2013; Moeuf et al. 2018; Raymond, 2005). However, recent research has reported mixed results in the implementation of Industry 4.0 in SMEs (Somohano-Rodriguez et al., 2020), and poorly documented (Moeuf et al., 2020).

In the UK, a recent survey by the Department for Business, Energy & Industrial Strategy revealed that only 12% of SMEs engaged in 'the implementation of a new or significantly improved production or delivery method…includes significant changes in techniques, equipment and/or software' (UKIS, 2020). This is the lowest since the 2008 financial crisis. While SMEs have experienced '…a big push forward…' in digital initiatives due to Covid 19 (OECD, 2021), a further investigation shows that the initiatives by small businesses mainly centre around adoption of digital technologies (such as ecommerce or providing laptops to employees to facilitate remote working), with less interest on digital capabilities, and high resistance to digital innovation in management practices (Riom and Valero, 2020).

Drawing from the above observed phenomena in both academia and industry, the small business initiatives to adopt Industry 4.0 risk merely moving the ‘asset frontier’ to the right, without achieving a ‘bettered operating frontier’ (Schmenner and Swink, 1998). The existing less productive management practices usually are embedded and hidden within the new technologies introduced (Land et al., 2021; Thurer et al., 2022). This might form a vicious cycle, further alienating small businesses from Industry 4.0.

Using the operations management’s perspective, through both theoretical argument and observed phenomena from a case study, this paper attempts to explore the relevance of Industry 4.0 to small business from operations management perspective: (i) What is Industry 4.0 and its potential impact on SMEs’ operations management performance? (ii) What is the relationship between operations management related methodology and Industry 4.0? (iii) How could operations management methodology and Industry 4.0 be aligned to achieve operations performance objectives?

Industry 4.0

Industry 4.0 (Germany), Smart Manufacturing (USA) and Smart Factory (South Korea) are some of the examples of digital transformation initiatives by both governments and industries to facilitate the use of technological advancement in manufacturing industries to achieve competitive advantage (Mittal et al., 2020; Oztemel and Gursev, 2020). In this paper, these will be collectively referred as Industry 4.0 (I4).

As the I4 concept is based on emerging technological advancement, it has ‘accumulated’ more than hundred definitions (Moeuf et al., 2018), where researchers such as Culot et al. (2020) and Oztemel and Gursev (2020) have conducted detailed literature review on. In this paper, organisations are seen as value delivery systems (Cimini et al., 2019). With this perspective, I4 will be viewed as ‘*…a set of initiatives for improving processes, products and services allowing decentralised decisions based on real-time data acquisition*’ (Moeuf et al., 2018).

Various frameworks have been proposed to review these technologies. For example, the Nine Pillars of technological advancement by Rüßmann et al., (2015), the Front-end (smart manufacturing, smart products, smart supply chain and smart working) and Base-end technologies (internet of things, cloud services, big data and analytics) by Frank et al. (2019), and the nature of technological innovation by Culot et al. (2020). Adopting management lens, attempts have also been made by researchers such as Fettermann et al. (2018) and Moeuf et al. (2018), to map I4 technologies based on the technological impact on managerial capabilities proposed by Porter and Heppelmann (2014): Monitoring, Control, Optimisation, and Autonomy, which has been widely adopted as I4 maturity level.

These technologies include but not limited to autonomous robots, simulation, big data and analytics, augmented reality, additive manufacturing, the cloud, cybersecurity, the industrial internet of things and horizontal and vertical system integration. While each technology achievement is cutting edge on its own, it is posited that the main driver is communication related technologies, such as the Internet of Things (IoT), which enables real-time information flow between processes and between physical and cyber world (Bayo-Moriones et al., 2013; Hansen and Bogh, 2020; Porter and Heppelmann, 2014; Somohano-Rodriguez et al., 2020).

Apart from technology, Culot et al. (2020) highlighted the equally important yet neglected *non-technological enablers* of I4: *organisational enablers* and *new business* *models*. Adopting the sociotechnical system theory, it is argued that I4 is not achievable via *plug-and-play* of technologies. Rather, it requires innovative changes in management practices and business processes. Similar perspective is also supported by researchers who advocate a human-centred approach to I4 technology adoption (Bauer et al., 2019; Tortorella et al., 2021; Yeong and Stratton, 2018).

Industry 4.0, Operations Management and Performance in Small Business

Attempts have been made by researchers to explore the relationship between I4 and Operations Management and Performance (OMP). A review on both academic and non-academic literature by Culot et al. (2020) unveils common themes on potential positive I4 impact on organisation: productivity, flexibility, mass customisation, environment sustainability, time and cost to market, quality, and lead time. This coincides with the six operating performance objectives in the field of operations management: quality, speed, dependability, flexibility, cost, and sustainability (Slack and Brandon-Jones, 2019: 37-71). Although this suggests possible correlation between I4 and Operations Management, researchers have warned against the assumption of absolute causal relationship between I4 and Operations Performance, calling for further research and investigation (Culot et al., 2020; Fettermann et al., 2018; Liao et al. 2017; Moeuf et al., 2020).

To support the above calls, researchers have attempted to further understand the relationship between continuous improvement 'best practices' in Operations Management with I4. For example, Lean Practices (Buer et al., 2018; Kamble et al., 2020; Rosin et al., 2020; Tortorella and Fettermann, 2018), Lean Six Sigma (Chiarini and Kumar, 2021), and World Class Manufacturing (D'Orazio et al., 2020). These researchers have attempted to explore and map each I4 technology with tools and principles within the 'best practices', and the anticipated impact on Operations Performance. To achieve the benefit of both I4 and 'best practices', these researchers advocate an integral implementation approach, with the use of 'best practices' as lens to guide continuous improvement: '*Methodology before Technology*'. This could potentially address the issue of lack of procedure in I4 implementation experienced by organisations, particularly in small businesses (Fetterman et al., 2018). Although positive impact on operations has been reported, the evaluation has primarily been done on relatively repetitive environment, prompting further research on non-repetitive environment (Buer et al., 2018).

'Methodology before Technology': What is the question?

Researchers have long warned against blindly copying 'best practices' in operations management (Done et al., 2011; Schmenner and Swink, 1998; Stevenson et al., 2005). Instead, the underpinning operations management theories and assumptions used in 'best practices' should be challenged to achieve alignment with the contextual dependencies, including human factor (Boer et al., 2015; McLean et al., 2017; Sousa and Voss, 2008).

According to Boer et al., (2015), various 'high-level' theories have been proposed to explain phenomena observed in operations management. For example, Theory of Swift and Even Flow by Schmenner and Swink (1998:102): "*the more swift and even the flow of materials through a process, the more productive that process is*". In other words, the productivity of a system depends on how well the variation and uncertainties associated with the flow are managed. Variation and uncertainties can be managed via the coordinated strategies: reduce, buffer, and separate/postpone (Fisher, 1997; Stratton, 2018). This has been demonstrated in 'best practices', for example Lean, Total Quality Management (TQM), Theory of Constraints (TOC), and others. In Lean, various tools such as Heijunka, Waste Reduction 5S and others, have been introduced to reduce variability. However, the primary objective of these ‘best practices’ is to improve flow, and not reduction itself.

Adopting the lens of the Theory of Performance Frontier, these ‘best practices’ are innovative approaches to achieve ‘bettered operating frontier’ (Schmenner and Swink, 1998:107). Organisation has two performance frontiers: the asset frontier (the optimal performance inherited from the assets and infrastructures deployed, including I4 technologies), and operating frontier (the resulting achievable performance due to management strategy and policies adopted). Within this performance space, two types of ‘*beneficial movements*’ are proposed: ‘*improvement*’ and ‘*betterment*’.

‘*Improvement*’ efforts include ‘*increasing utilisation or efficiency … has only to do with removing inefficiencies in transformation processes and nothing to do with changing the substance of either operating policy or physical assets*’. Such efforts bring an organisation to its operating frontier: optimised, after which improvement ceases. On the contrary, ‘*betterment’* efforts ‘*is about altering manufacturing operating policies in ways that move or change the shape of the operating frontier*. Once ‘*bettered operating frontier*’ is created, ‘*improvement can start anew … to achieve its full potential within its new operating frontier*’.

Based on the above arguments, this paper suggests viewing I4 efforts from three perspectives: *Asset*, *Improvement*, and *Betterment*. Under *Asset* effort, organisations invest in I4 technologies without adequate consideration of its impact on the system throughput/flow. Using an example from the book: ‘*The Goal*’ (Goldratt and Cox, 1996), the introduction of ‘*robot*’ into a production line failed to increase system throughput. Instead, it increases work-in-progress (WIP) due to its existing ‘push’ and ‘cost paradigm’ related organisation practices and policies.

The *Improvement* efforts refers to the use of I4 technologies to reduce inefficiencies in current practices. Apart from going paperless, such as digitisation of information (Jedynak et al., 2021), digitalisation of ‘best practices’ such as Lean or TOC falls under this category. For example, digital value stream mapping (VSM) and digital Kanban in Lean (Buer et al., 2018; Sanders et al., 2016) or digital buffer management in TOC (Stratton and Yeong, 2018). Under this category, it is argued that I4 technologies have positive impact on existing ‘best practices’ (Rosin et al., 2020).

Betterment efforts goes beyond jumping onto the bandwagon of ‘best practices’, or I4. Instead, both ‘best practices’ and I4 are considered integrally and contextualised. In contrast to short term gain, this effort is incremental, cyclical and involves all employees (Nonaka et al., 2000; Tortorella et al., 2021; Yeong and Stratton, 2018). To achieve *betterment*, this paper posits the adoption of an overarching concept: the four *concepts of flow* (CF) proposed by Goldratt (2009) to guide the *betterment* effort:

- CF1: *Improving flow (or equivalently lead time) is a primary objective of operations.*
- CF2: *This primary objective should be translated into a practical mechanism that guides the operation when not to produce (prevents overproduction). Ford used space; Ohno used inventory*.
- CF3: *Local efficiencies must be abolished.*
- CF4: *A focusing process to balance flow must be in place. Ford used direct observation. Ohno used the gradual reduction of the number of containers and then gradual reduction of parts per container.*

Relevance of CFs with operations management has been explored in Alsharief and Stratton (2022) and Stratton et al. (2022).

A Proposed Framework

Based on the above theoretical discussion, this paper proposes a framework (refer to *Figure 1*) with the attempt to represent the relationship between operations management and I4. With reference to *Figure 1*, starting from the bottom, underpinned by operations management law and theories, the four concepts of flow are used to underpin the design and implementation of both 'best practices' and I4. 'Best practices' – the methodology, and I4 technologies acts integrally to realise the managerial capability areas: *monitoring*, *control*, *optimisation*, and *autonomy*. These capability areas, with each build on the preceding, can be used to demonstrate or evaluate the I4 maturity level in an organisation. The realised managerial capabilities will translate into competitive advantage, represented by the operational performance objectives.

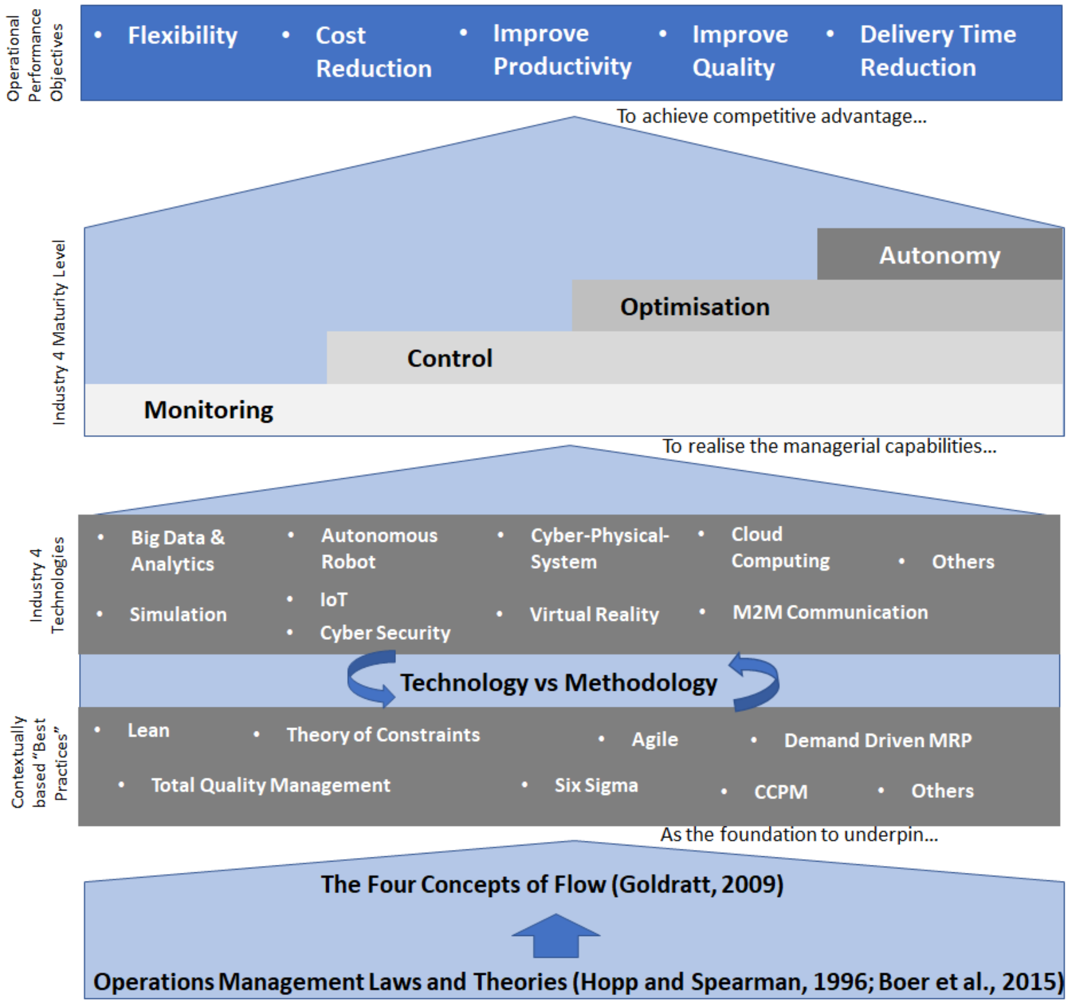

Figure 1: Relationship between Operations Management and I4
(Adapted from Moeuf et al. 2018; Potter and Heppelmann, 2014)

A Case Study

Having developed a framework based on theoretical argument, through a case study (Voss et al., 2016; Yin, 1994), this paper attempts to demonstrate how the framework proposed could potentially be used to underpin and evaluate the I4 journey in a small business. Both formal and informal data are collected, which includes company data, minutes of meetings, semi-structured interviews, conversation, observation, and field notes taken.

The case company, company A, is a bespoke make-to-order (MTO) mobility furniture manufacturer in the UK. Supported by a workforce of 40, the production process labour intensive and relies heavily on craftmanship. The company struggles to meet existing market demand, resulting in unsustainable financial performance.

In the year 2019, a new senior management has been brought in to introduce strategic change to turnaround and grow the company. To improve its operations performance, the senior management is determined to introduce a new digital platform to replace the dominantly manual, paper-based, and non-integrated multi-system management software. The new digital platform will support the end-to-end customer journey: pre-sales, sales fulfilment, and post-sales.

While company A has many experienced employees, it lacked staff with relevant digital skills and knowledge. The senior management adopted the 'outside-in' approach, engaging external expertise from both the industry and university. The first phase of this project spanned for one year, from March 2020 (just before Covid pandemic lockdown) till February 2021. This phase includes (i) pre-sales: enquiry, consultation, customer order and requirement capturing and confirmation; (ii) sales fulfilment: production planning and control, and delivery; (iii) post-sales: customer relationship management and product after sales service and maintenance.

Pre-sales

A cloud-based platform is put in place to improve customer's experience with company A. This includes an interactive website with modular and prescriptive consultation process, enabling customer to build own chair in the virtual space provided. Due to Covid lockdown, the system has integrated video capability for consultants to interact with customers remotely. This replaces the original outdated and non-interactive website, where main purpose was to display information. This platform allows a triage process, decoupling customer request into standard and those requires consultation.

As every chair is custom built to each customer's requirement, the standardised customer information and requirement input reduces information error in the making of the furniture. For example, in building a chair, customer information is needed to ensure right hip position, seat width and height, arm position, seat depth, neck, head and lower back support, etc. This replaces the need to manually re-enter similar information into various independent systems which were maintained separately: commercial system, accounting system, purchasing and stock system, manufacturing system, and customer relationship management system.

Sales Fulfilment

A cloud-based production planning and control (PPC) module is designed and implemented to increase its productivity. Adopting an agile approach, the development and deployment of this system can be largely divided into two major phases. As the original tool used was a manually maintained spreadsheet with minimal experience and knowledge about digital PPC system, the purpose of first phase is proof of concept, setting a stage for employees to be engaged in the development process. Due to the relatively high variation and uncertainty associated with the production environment, TOC methodology is adopted (Yeong, 2019). Underpinned by TOC, the standard concepts such as planned load management, constraint management, and buffer management are embedded as heuristic algorithm.

In the second phase, based on contextual input from shopfloor personnel and the management, PPC is further developed into a decision support system (DSS). The planned load simulation feature in DSS supports *Pre-sales* by accepting orders based on system capacity. Once confirmed orders are received, buffer management enables management to make decisions related to *prioritise*, *expedite*, and *escalate* orders. This enables management to proactively plan and control production related activities.

In the initial design, a relatively detailed level of resource loading was made. However, due to the move by management towards multi-skilling shopfloor personnel, DSS moves away from displaying overly detailed and complex resource planning. Rather, resource pooling (resource bucket) is used, resembling the Simplified Drum-Buffer-Rope TOC concept introduced by Schragenheim et al. (2009).

As the company has its own logistic resources for domestic delivery, a dispatch and logistics module is developed, embedding standard management consideration in the form of heuristic algorithm, and incorporating information from Google map API, an algorithm is developed to provide suggested delivery route. The original company practice is to fulfil all domestic deliveries using own vehicles and drivers. Unknowingly, the availability of transportation dictates the priority of orders on the shopfloor. This self-inflicted constraint was later removed by the new senior management. Instead, utilising own transportation capacity to fulfil priority orders, changing a constraint resource into a strategic resource.

I4 Maturity Level and Operation Performance

This I4 initiative has increased the managerial capabilities of the company in the areas of monitoring, control, optimisation, and arguably autonomy. With the *methodology*, *technology*, and *people* aligned, senior management is relieved of day-to-day fire-fighting activities. Instead, company has been empowered to autonomously engage in continuous improvement.

At the end of this project, the company achieved an overall 1% increase of net profit; 40% reduction in remedial work; 50% increase in production throughput per week. This project has become catalyst to the overall change management in the company. The managing director of the company commented: "*The new senior management inherited entrenched negativity from the workforce in general. People didn't want to work outside of perceived role or do overtime and were anti-management. Now screens on the shopfloor give transparency to processes and targets…Together with the* [team based] *bonus system,* [there is] *a huge turnaround in employee engagement. Staff can see how their input makes a difference and have brought into overall company objectives*".

Conclusion

Implementation of I4 technologies is generally perceived as capital intensive (Tortorella and Fetterman, 2018) and requires intensive digital and IT skilled and knowledge personnel. However, through theoretical arguments and a small business case example, this paper arrived at a proposed framework to explain the relevance of I4 to small business. Underpinned by fundamental concepts in operations management, this framework draws together operations management methodology, I4 technology, managerial capabilities, and operations performance objectives. This framework could potentially be used by small business to guide I4 initiative.

To achieve improved operations performance through I4, this paper advocates to have such initiatives underpinned by the four Concepts of Flow (CF). It is suggested that this foundation will help to align both the 'best practice' and I4 technology with the operation performance objectives. The primary objective is to improve the flow of value within the delivery system (CF1). There is no plug-and-play solution towards flow improvement. Instead, a practical mechanism must be developed to manage the flow (CF2). 'Practical' implies contextualising both methodology and technology. In addition, the associated performance measurement and reward related policies should abolish local efficiency

(CF3). Instead of satisfying with an optimised outcome, the culture of continuous improvement is advocated (CF4).

Characterised by limited resources, small business is warned against jumping onto the I4 bandwagon blindly. Instead, using the proposed framework as a guide, small business could explore using the 'outside-in' approach in implementing I4. The external resources available include both the industry and academia.

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