ENABLING SMALL FIRM GROWTH THROUGH PROCESS INNOVATION – A REFLECTION

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ABSTRACT

The aim of this paper is to demonstrate the importance of tacit knowledge in non-product innovation. This is done by reflecting on a successful implementation of a Production Planning and Control (PPC) system in a small MTO (Make-To-Order) manufacturing company. Recent reviews on high failure rate in PPC implementation has prompted calls to implement PPC according to contextual requirement, and the need to assimilate tacit knowledge into the design and implementation process. Drawing from the literature on non-product innovation and knowledge conversion and generation process, PPC implementation is being analysed using the SECI ('socialisation', 'externalisation', 'combining' and 'internalisation') knowledge conversion process. Action Research (AR) approach was adopted to capture the knowledge generated throughout the implementation process. Through the lens of SECI, the role and importance of tacit knowledge is evident throughout the PPC implementation process. A year after the inception of PPC into the company's business process, a new culture has emerged on the shopfloor, which enabled the company to experience a significant year-on-year growth in 2017. This result has the following implication to small firm's management. Firstly, in order to gain the full benefit of non-product innovation, it is necessary to acknowledge the existence of tacit knowledge within the company. Secondly, is to realise the need for capital equipment (IT infrastructures and PPC software) to be assimilated and become part of the firm's new tacit knowledge in an incremental way in order to achieve sustainable competitive advantage. To the academia, other than contribution towards the body of knowledge of innovation and PPC, AR type of collaboration might be the way forward for universities to provide sustainable PPC solutions to the industry.

INTRODUCTION

Attention and effort has been given by both practitioners and academics to introduce process innovation in the form of 'best OM (Operations Management) practices' in manufacturing. The 'best OM practices' includes total quality management (TQM), Lean Manufacturing, Six Sigma, and Theory of Constraints (TOC). However, a recent review by MacLean et al. (2017) shows alarming failure rate in achieving the expected sustainable competitive advantage through these initiatives. The failure, according to the research, is largely due to the conscious or unconscious negligence of 'contextual requirements' and the act of merely 'jumping onto the bandwagon'. This phenomena is also observed by other researchers, and have stressed the critical need to identify underlying philosophies, laws, theories and assumptions of 'best practices' and identifying the 'fit' with the contextual requirements (Boer et al., 2015; Done et al., 2011; Hayes and Pisano, 1994; Hopp and

Spearman, 2004; Sousa and Voss, 2001; 2008; Voss, 1995; 2005). The failure in adopting the appropriate 'best OM practice' has significant negative impact on SMEs due to their relatively limited resources (Stevenson et al., 2005). In the context of the design and implementation of an effective production planning and control (PPC) system: a core mechanism in 'best OM practices' for manufacturing, researchers have red-flagged the attempts to over-simplify firms into structured mathematical problem definitions (Arica et al., 2016; Berglund and Karltun, 2007; Karltun and Berglund, 2010; Jackson et al., 2004). Instead, these researchers have called for the design of contextual knowledge based PPC, and to integrate human, the 'embodiment' of tacit knowledge, into the implementation of PPC. With the aim of contributing to the body of knowledge of both process innovation and OM practice, this paper attempts to reflect upon the practical knowledge generated through the successful introduction and implementation of PPC in a small manufacturing firm through action research (AR). This PPC is based on the TOC application for make-to-order (MTO) firms. Thus, the first research question focuses on the role of tacit knowledge in the implementation of non-product innovation through PPC. As the AR is conducted via Knowledge Transfer Partnership (KTP) between the UK government, the company (hereby known as Company A) and the university, it is also the aim to understand how knowledge can be effectively captured in such collaboration. The remainder of this paper is structured as follows: the literature review begins by providing an understanding on the importance of non-product innovation: technological process innovation and non-technological organizational innovation, in relation to PPC. Under similar context, a review is done on the importance of 'incremental' approach in innovation to allow the generation of new tacit knowledge through the implementation of PPC. This is further supported by a brief review on the process needed for tacit knowledge to become new tacit knowledge. The subsequent section summarises the research methodology used, followed by analysis and discussion in the findings section. This paper ends with a conclusion and potential future research direction.

LITERATURE REVIEW

Product versus Non-Product Innovation

Innovation has established its vital role in creating competitive advantage and enabling firm growth (Brown and Eisenhardt, 1997; Piening and Salge, 2015; Reichstein and Salter, 2006). However, traditionally, innovation is often 'conveniently' associated with product innovation (Hervas-Oliver, 2014; 2017; Oke et al., 2007). A review conducted by Keupp et al. (2012) on the current state of strategic management of innovation revealed the lack of attention from researchers on non-product innovation. The inadequacy of academic literatures for focusing merely on predicting process innovators but not the consequence of adopting process innovation is also well highlighted by Hervas-Oliver et al. (2014). In addition, they also lamented the lack of exploration on the impact of co-adoption of technological and organisational process innovation. This is echoed by Piening and Salge (2015) in demonstrating the critical gap in the understanding of antecedents, contingencies, and impact of process innovation. To a large extend, innovation is treated as research and development (R&D) activities. This is criticised by researchers for neglecting the non-R&D activities contributors to innovation (Arundel et al., 2008; Zheng et al., 2012; Oliver et al., 2011; 2015). The traditional view of equating innovation with R&D was challenged

by the conclusion from the 3rd European Community Innovation Survey (CIS-3) conducted, where almost half of the businesses achieved innovation via non-R&D activities. As highlighted by Heidenreich (2009), other than systematic R&D, innovation is also achievable via practical, experience-based tacit knowledge. This is characterised by phrases such as 'learning-by-doing', 'learning-by-using', 'learning-by-interacting', 'learning-by-producing', and 'learning-by-searching' (Cabral and Leiblein, 2001; Lundvall and Johnson, 1994).

OECD (Organisation for Economic Co-operation and Development) (2005) has categorised non-product innovation into 'process innovation', 'marketing innovation' and 'organisational innovation'. As the focus of this paper is on the OM practice in manufacturing environment, the discussion will be limited to process innovation and organisational innovation. Process innovation is defined by OECD (2005) as 'the implementation of a new or significant improved production or delivery method. This includes significant changes in techniques, equipment and/or software … intended to decrease unit costs of production or delivery, to increase quality … includes significantly improved techniques, equipment and software in ancillary support activities'. Organisational innovation is 'the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations'. Some researchers refer 'organisational innovation' as 'administrative innovation' (Damanpour, 1991; Teece, 1980). Although OECD (2005) has categorised 'OM best practice' under organisational innovation, it also recognises the existence of grey area in this. While process innovation could involve the introduction of capital equipment, for example, machineries and robots to improve productivity (Reichstein and Salter, 2006), the guideline given by OECD (2015) was to consider process innovation to include 'implementation of new equipment, software and specific techniques or procedures, while organisational innovations deal primarily with people and the organisation of work'. In this information era, PPC usually involves the use of both software and ICT equipment, acting as the communication platform to enable flow of information between shop floor and other departments. The underpinning management philosophy, together with its assumptions are translated into algorithms, which normally integrates with software which supports ancillary activities. For example, Material Requirement Planning (MRP), Manufacturing Resource Planning (MRP II), Enterprise Resource Planning (ERP), the TOC based Optimised Production Technology (OPT) and Work Load Control (WLC) based LUMS software (Stevenson et al., 2005). In this aspect, implementation of new PPC is arguably process innovation. However, together with the implementation of PPC, changes might be introduced in business practices and workplace organisation. This aspect involves organisational innovation. Organisational innovation is arguably necessary in order to achieve maximum benefit of technological process innovation (Freeman, 1995). This view is strongly supported by Edquist (1997:24) by highlighting 'organisational innovation' as a requirement for technological process innovation to be successful in the real world. The supplementary and complementary relationship between both technological process and non-technological organisational innovation is also highlighted by Pereira and Romero (2013) and Oliver et al. (2014).

'Radical' versus 'Incremental' innovation

Innovation has also been classified as 'radical' and 'incremental' by some researchers. 'Radical' innovation causes major disruptive changes, which includes new products, new

methods of production, new markets, new sources of supply for raw materials, and new industries (OECD, 2005; Schumpeter, 1934; Meyer et al., 1990; Tushman and Romanelli, 1985). This innovation, according to Utterback (1994:200), 'sweeps away much of a firm's existing investment in technical skills and knowledge, designs, production technique, plant, and equipment'. 'Incremental' innovation, on the contrary, refers to the process of continuous improvement (OECD, 2005). This improvement can be of 'procedural' (rules and procedures), 'personnel' (human resource management and development), 'process' (new methods of production) or 'structural' (new ways in which work functions are structured) (Herbig, 1994; Koberg et al., 2003). This taxonomy is criticised by some researchers as misleading, arguing that the seemingly 'incremental' innovation might cause 'disastrous' outcome and vice versa (Henderson and Clark, 1990). This has prompted Robertson et al. (2012) to view 'incremental' innovation with the following perspectives. Firstly, 'incremental' innovation refers to any innovation, which does not fall under 'radical' innovation discussed above. Secondly, this innovation starts by focusing on one or a few segments within a process, although the implication of change is systemic. Thirdly, whether or not an innovation is seen as 'incremental' has to be seen from the standpoint of the firm who undertakes the change. In other words, 'incremental' innovation is relative and subjective to each individual company. These perspective fits well in the context of implementing PPC, where it does not fall under the 'sweeping' change as described above. Rather, PPC such as Lean (Womack et al., 1990), TOC (Goldratt, 1984), or WLC (Hendry et al., 2013) has a focus in introducing change with a systemic view and implication. There are also researchers who interpret 'incremental' by linking innovation to the resource, knowledge and dynamic capability of a firm (Fores and Camison, 2016; Nonaka et al., 2000). While implementing PPC, it is necessary to acknowledge the heterogeneity of firm resources, particularly the existence of scarce and difficult-to-imitate intangible assets, such as the know-how (Barney, 1991; Grant, 1997; Wernerfelt, 1984). However, according to Teece (2007), merely possessing the 'know-how' is inadequate. In order to possess sustainable advantage, dynamic capabilities is necessary to 'enable business enterprises to create, deploy, and protect the intangible assets that support superior long-run business performance'. This includes the capacity to 'enhance', 'combine', 'protect' and 'reconfigure' both intangible and tangible assets. Incremental innovation is suitable in the implementation of PPC as it allows firms to accumulate new knowledge to be generated from both internal (tacit) and external knowledge (Lichtenthaler, 2009).

Tacit Knowledge

The concept of 'tacit knowledge' has been crystalized by Polanyi (1966:4) into one phrase: 'we can know more than we can tell'. As described by Nonaka et al. (2000), there are two types of knowledge: explicit and tacit. Explicit knowledge can be codified, processed, shared and stored. With the advancement in information technology, accessibility of explicit knowledge has been greatly increased. On the contrary, tacit knowledge is personal in nature and difficult to be formalised. It is normally found, for example, in values, commitment, action, procedures and emotion (Seidler-de Alwis and Hartmann, 2008). According to Kikoski and Kikoski (2004), this knowledge is acquired by sharing experiences, observation, and imitation. As highlighted by Nonaka et al. (2000), both explicit and tacit knowledge interacts between each other through 'knowledge conversion' process: Socialisation (from Tacit to Tacit), Externalisation (from Tacit to Explicit),

Combination (from explicit to explicit) and Internalisation (from explicit to tacit), also known as the SECI process, as shown in *Figure 1* below. Knowledge created through this spiral process will issue in innovation (Nonaka et al., 2002; Seidler-de Alvwis and Hartmann, 2008). In this research, SECI process is adopted as the lens to reflect the role of tacit knowledge in the implementation of PPC.

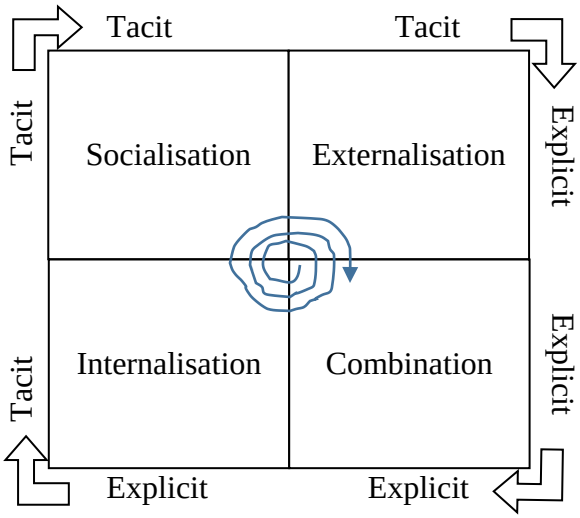

Figure 1: SECI Spiral Process
Source: Nonaka et al. (2000)

Measurement for non-product innovation

Traditionally, measurement for non-product innovation is predominantly related to sales turnover, which is arguably a product innovation centric measurement (Hervas-Oliver et al., 2014). Instead, other production related measurements such as production flexibility, cost reduction and increased capacity are more relevant. In this research, as implementation of PPC is posit to involve both process innovation and organizational innovation, a set of measurement has been adapted from previous successful PPC implementation for MTO (Hendry et al., 2013; Benavides and Van Landeghem, 2015) as summarised below:

1) Time Related : Mean Lead Time (MLT)
2) Dependability : Due Date Performance (DDP)
3) Shop Load Measures : Resource Utilisation, Productive Capacity
4) Financial Related : Operating Expenses, Profitability
5) Internal co-ordination : Coordination between production and other departments

RESEARCH METHODOLOGY

Research Questions

From the above discussions, the exploratory research questions (RQs) are formulated as below:

1. What are the PPC related tacit knowledge in company A?
2. How was tacit knowledge used in the implementation PPC: S-DBR?
3. What was the performance outcome?
4. How can this inform future PPC implementation?

Research Data

As part of the two years Knowledge Transfer Partnership (KTP) collaboration between a small firm (Company A), a university and the UK government, the researcher was employed to work as a Business System Designer/Programmer in Company A. The purpose of the collaboration is to introduce innovation in its production process. As the researcher is also a practitioner, who is actively involved in the change process, action research (AR) was adopted to capture the contextual knowledge generated throughout the change process (Coughlan and Coghlan, 2016; Raelin, 2015; Shani et al., 2012). This fits the aim of the researcher to provide a solution to a practical problem as well as to capture knowledge generated as a contribution to the innovation and PPC body of knowledge. AR is about cycles of 'Constructing', 'Planning Action', 'Taking Action', and 'Evaluating Action'. An overarching meta-cycle of 'pre-change', 'in-change' and 'post-change' was developed in parallel with the project. Within the meta-cycle, there are various smaller AR cycles. As engaged scholar, data was captured through work shadowing, field notes, informal interviews, formal meetings with minutes of meetings, observations and company data/documentation (Bendoly et al., 2010; Van de Ven, 2007). The execution of the KTP is summarized in *Table 1* below.

Phases	Pre-Change	In-Change	Post-Change
AR Cycle	Context & Purpose, Constructing, Planning Action	Taking Action	Evaluating Action
Time Scale	6 months	12 months	6 months

Table 1: Overview of macro AR cycle in relation to research phases

Research Approach

This paper illustrates the knowledge captured in the final AR cycle: to reflect upon the KTP implementation using the RQs described in previous section. The following table illustrates how the RQs relates to the four steps in AR cycle.

AR Cycle	Context & Purpose, Constructing	Planning Action, Taking Action	Evaluating Action
RQs	What are the PPC related tacit knowledge in Company A?	How was tacit knowledge used in the implementation of PPC: S-DBR?	What was the performance outcome? How can this inform future PPC implementation?

Table 2: AR cycle in relation to RQs in this paper

FINDINGS

The findings are structured according to SECI process with the aim to demonstrate the role of tacit knowledge and its conversion throughout the PPC implementation.

Socialisation

<u>black box manufacturing</u>

The company has been established for over forty years. It utilizes rotational moulding technic to produce own range of customizable plastic planters and bins products. The company adopts MTO strategy where production process only begins once a firm order is

received. Delivery due date is given by providing a standard industry accepted lead-time for all generic orders. Although the company has an existing ERP system, the function of the manufacturing module is limited to work order generation. As there are no formal feedback mechanisms deployed for the manufacturing process, it becomes a 'black box' to the senior management. The first aspect of 'Black Box' refers to the information related to work order production progress, resource planning, status, and utilization. This hinders early warning and forward planning, causes senior management to often resort to fire-fighting. Situation becomes worsen during 'peak season', which normally falls in spring and summer. In order to meet the increase in market demand within industry accepted lead-time, additional shifts will be introduced to increase production capacity. However, the lack of visibility on manufacturing resources often causes senior management not able to activate or end the utilization of additional capacity resources effectively, either activating or ending additional capacity too early or too late. The lack of manufacturing information also causes sub-optimization and unhealthy inter work centre competition. During peak season, direct intervention by senior management is often required to utilise 'executive rights' to manually obtain internal and external information and over-ride shop-floor decision. This has caused the due date delivery performance to drop to as low as around 70 percent during peak season.

The second aspect of 'Black Box' refers to the hidden tacit knowledge embedded in the day-to-day manufacturing operation. As the manufacturing process is not automated and requires substantial human labour, tacit knowledge becomes essential. Shop-floor personnel has over the years amassed various invaluable tacit knowledge through experiences or 'trial-and-error'. For example, theoretically, by size and weight, a mould is suitable to be placed on side position of a machine arm. However, due to the design of the mould which affects the 'flow' of the molten plastic during the rotation process, it would need particular steps to overcome the problem without compromising the quality. There are also 'situational' optimized coordination between work centres for example the sequence of unloading moulded goods from the machine as certain moulded goods are easier to be processed while it is still 'warm'. These 'implicit' arrangements depends on the 'mutual understanding' between operators working in between work centres. A 'bonding' has been formed, both human-human and human-machine. A domestically recognized 'best practice' based on tacit knowledge has been well established, which offers the company the competitive edge in the industry. This was evident with the return of customers after failed attempts to 'switch' to other competitors.

<u>black box management</u>

From the above discussion, to the senior management and the non-manufacturing departments, manufacturing is indeed a 'Black Box'. However, to the shop-floor personnel, looking outward from inside the 'Box', it is a 'Black Box' too. Firstly, as the company offers standard due date delivery to customers, this is translated as the common production lead-time to the shop floor. This becomes a problem when certain resource becomes a constraint on the shop-floor. The resource constraint might 'evade' early detection due to the relatively small order quantities placed by customers. To the non-manufacturing departments, the issue of shop-floor inefficiency in fulfilling small quantity orders on time are often raised. To the shop-floor, the company is often seen as over-promising customers without understanding the actual manufacturing process and resources required. As the

main and potential resource constraint is normally located at the upstream of the manufacturing process, it is often the downstream work centres taking the blame for not able to fulfil the delivery on time. In addition, It is often too late by the time issues are escalated to the higher management for decision making on activating additional resource capacity. If additional shift is to be introduced, other than it incurs higher operating cost, it also takes time, as new temporary workers have to be hired and it takes at least one to two weeks to be trained for basic operation. Once the additional shift is activated, shop-floor will attempt to keep the additional capacity for as long as possible. To achieve this, shop-floor will resort to 'Parkinson's Law' (Parkinson, 1955) where lead time will expand in order to fill up the available time. This turns into a vicious cycle where senior management are 'forced' to work towards 'micro-managing'. However, the result is often worsen as senior management do not have the 'tacit knowledge' shop-floor has.

Externalisation

The summary on the process to externalise tacit knowledge is as shown in *Table 3* below. The following steps are not unidirectional, but rather iterative and requires confirmation by testing the 'logic' formulated with the shopfloor.

No	Activity	Remarks
1	Record 'raw data' (gathered in socialisation stage)	- Machine loading logic - 'Load balancing' logic - Machine configuration and setup logic - Touch time (actual time a part is worked on) collection - Product dependent 'special setups/arrangement' - etc - 'Champions' from each department were identified to facilitate the process
2	Data Interpretation and Analysis	- Identify common thread or pattern - Determine assumptions (common or special course) - Determine the 'relationship' with PPC
3	Data Utilisation	- Codify threads which has implication to PPC - Part of this knowledge is used to update company's record or operating manual - The 'thinking logic' for decision making under common course is embedded into PPC design

Table 3: Externalisation in Company A

Combining

In this stage, the knowledge generated through the externalisation stage is combined with other explicit source of data. The external sources of knowledge are: non-manufacturing departments within the company (this includes the knowledge gain through upstream and downstream of the supply chain), the university (both researcher and lead academic), and TOC practitioners (Theory of Constraints International Certification Organisation (TOCICO) and Theory of Constraints Practitioner Alliance (TOCPA)). Further illustration is shown in *Table 4* below. Each of the 'other sources' of knowledge also gone through 'Socialisation', 'Externalisation' and 'Combining' process, before able to be used in PPC design to generate new knowledge. Various formal and informal events, meetings and opportunities are used to allow knowledge combination process. The researcher plays the

central role as the researcher is the only person who is engaged with all other sources of knowledge as depicted in *Figure 2*. The output of the stage of 'Combining' is the development of the PPC software.

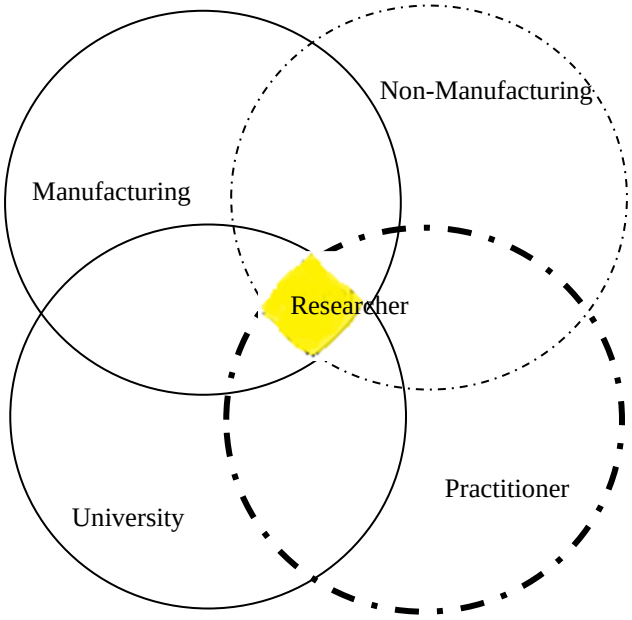

Figure 2: Position of researcher within Sources of Knowledge

No	Other Sources	Description	Remarks
1	Non-manufacturing departments within company	- To understand the overall business process, including the wider supply chain - To understand senior management's perspective	Presented PPC related information in company annual year end event (2015, 2016, 2017), as part of executive presentation by senior management
2	University		Presented in Euroma 2017, Edinburgh
2.1	Researcher	- Management experience gained prior to this project - Prior experiences in working with all levels within a company - Software development and ICT (Information Communication and Technology) knowledge, skills and experience	Enrolled in Doctoral in Business Administration (DBA) program

		- PPC theoretical and conceptual knowledge gained through management studies	
2.2	Lead academic	- PPC and operations management knowledge - Past PPC implementation supervision knowledge and experience - Strong network with other PPC sources, both academia and practitioner	As supervisor for researcher in DBA studies as well as mentor in TOC practice Weekly company/ shopfloor visitation
3	TOCICO and TOCPA	- Generic S-DBR implementation guide - Obtain feedback from practitioners for proposed S-DBR design	Presented in TOCICO 2017 (Berlin) and TOCPA 2016 (Northampton) International Conferences

Table 4: Combining in Company A

Internalisation

As agile software development was adopted, the development of PPC started with the manufacturing department, subsequently integrated with existing ERP system, and gradually extended its usage to 'non-manufacturing' departments. Currently, it is being adopted as the 'communication platform' within the company. In order for the designed PPC to function effectively, interfaces are designed to enable work order processing and resources utilisation information to be feedback to the PPC within reasonable time (Huang, 2017; Schragenheim et al., 2009). In this stage, the PPC is made to become an integral part of the overall business process through 'learning by doing' and was actualised through action and practise (Nonaka et al., 2000). The purpose is to create new tacit knowledge by the use of PPC. The internalisation process is as shown in *Table 5* below.

Item	Description	Remarks	Innovation Type
PPC	- The generic S-DBR guide was modified to suit contextual requirement of company A, characterised by significant touch time and highly shared parallel machine resources, sequence dependent setup and fix lead-time.	- A new S-DBR implementation guide is generated specifically for company A. This serves as a means for documented continuous improvement	<u>Process</u>: - Generic S-DBR software falls under process innovation. Knowledge embedded within the software is acquired together with the acquisition of S-DBR software. Tacit knowledge was 'combined' with the acquired knowledge to generate new knowledge which is unique to the company

Decision Making	- Common course machine loading logic is embedded into the PPC as heuristic algorithm. - A second heuristic algorithm is build to determine and suggest the recommended production 'path' to be taken (parallel machine resources). - PPC displays and populate current loading using the common course logic above. - All work orders waiting to be released into the production line are subjected to 're-planning' according to new confirmed work orders, work order progress update, and configured resource capacity - Potential capacity constraint resources are displayed and monitored with warning given if loading exceeds a pre-set threshold - Based on the information suggested by PPC, together with the situational tacit knowledge, the shopfloor makes the final decision in work order release and machine loading assignment - All decisions made are logged and live data is viewable by all authorised personnel	- A new culture has been introduced where shopfloor personnel has been empowered with decision making. - Shopfloor personnel are open to raise new ideas or steps for improvement. - Involvement of senior management is only needed if 'intervention' is required. - There were very limited intervention done by senior management since the inception of PPC (January 2017). - Senior management was able to devote their time into growing the market.	<u>Process:</u> Software has been custom designed according to the 'decision making' process on shop floor. Rather than being a generic dashboard, the software becomes a tool to assist decision making by providing the necessary 'trigger', 'prompt', 'sign post'. Tacit knowledge has been embedded and combined with other knowledge to generate new tacit knowledge. <u>Organisational:</u> With the process innovation described above, new daily practice and routine has been developed. As commented by a shopfloor personnel, 'you have provided us a 'tool', not a 'toy'. We are workers, we like and appreciate tools, as it helps us to work more efficiently'. 'Old' tacit knowledge is embedded, generating 'new' tacit knowledge.
Feedback Mechanism	- User interface was developed to enable work progress to be reported - This will affect the PPC proposed decisions as described in item 1 and 2 above.	- As the performance of shopfloor can now be reflected in the PPC, shopfloor is motivated to have their performance logged by PPC.	Same as above.

Integration	- PPC is integrated with existing ERP system - This has allowed information to be automatically populated in the PPC system - This exposes and avoids accidental errors made which can be rectified in early stage - Work order status can be easily accessible by other departments, avoiding unnecessary panic	Smoothen work coordination. Limited panic during peak season was recorded as compared to the year before implementation	<u>Process:</u> IT interface was developed to enable existing ERP system to work with PPC system. <u>Organisational:</u> New business practice is introduced as it gradually replaces the 'paper' system. Rather than visiting the shopfloor in person to obtain work order status, customer enquiries can be easily and speedily responded by referring to the PPC system.
Extending the use of PPC to other departments	- Various extended functionalities and features have been included to avoid PPC becoming an isolated and neglected software - <u>Sales Department</u>: A check can be done to determine if standard due date delivery can be reliably met. System will identify the resource constraint which will allow management to determine if special intervention is necessary to accept certain 'urgent' work orders - <u>Admin Department</u>: a customised interface to allow admin users to record, follow-up and communicate work order related information within company. - <u>Simulation</u>: users are allowed to make 'simulated' changes to 'preview' effect of changes made in resource capacity has on the overall system delivery performance	- This allows reliable delivery due date to be given. - This allows senior management to allocate resources strategically	<u>Process and Organisational:</u> Customised modules were developed for each department. Combining tacit knowledge with external knowledge, user interface and information displayed is custom designed according to make existing work practices more efficient. This was done in an 'incremental' way to increase acquiescence and develop new 'bond' between human and machine.

Performance	Time Related : Mean Lead Time (MLT) Dependability : Due Date Performance (DDP) Shop Load Measures : Resource Utilisation, Productive Capacity Financial Related : Operating Expenses, Profitability Internal co-ordination : Coordination between production and other departments	Throughout year 2017, although sales turnover has increased by 30%, it was the first time where no additional shifts were deployed. This implies lowered operating cost, higher profit, and exposure of hidden capacity. The average DDP was maintained at over 90%. It was also reported as a year with the least panic experienced.	
Continuous Improvement	- Monitoring dashboard and Report module were developed to facilitate operation performance review. - In middle of March 2018, shopfloor has requested additional feature, where the company is prepared to extend the current PPC to have Make-To-Availability (MTA) feature, a new business strategy in the making.	PPC has enabled visibility in the company. The platform provided, together with the cultural change, and the support of senior management, shopfloor personnel are more actively engaged in the process of continuous improvement.	<u>Organisational:</u> As manufacturing performance is made visible, ideas raised and action taken becomes 'tangible'. Shop floor performance review becomes more specific and focus. With the encouragement from senior management, the positive attitude towards continuous improvement/innovation becomes a new tacit knowledge formed

Table 5: Internalisation in Company A

CONCLUSION

This research successfully demonstrated the role of tacit knowledge and its importance in the implementation of PPC in a small company. In addition, it also demonstrated the adoption of 'incremental' approach in allowing SECI process to take place. In this process, the existence of tacit knowledge is acknowledged and appreciated through 'socialisation'. Incremental innovation provides time for tacit knowledge to be converted into explicit knowledge in the 'externalisation' process. This conversion stage is essential to enable 'internal knowledge' to synthesise with 'external knowledge' through the 'combining' process. The spiral SECI process together with the agile software development method enables incremental process and organisational innovation to take place in a 'learning-by-doing' and 'learning-by-using' approach. In addition, AR approach in this project forms a fit where it stresses incremental, continuous, and iterative approach, enabling new

knowledge to be generated. In contribution towards the body of knowledge of innovation, this research successfully shown the importance and dynamic of tacit knowledge in the implementation of PPC to achieve non-product innovation. The successful collaboration between university and industry in the implementation through AR shows an alternative collaboration method. Although this type of collaboration is relatively more resource consuming as it requires the researcher to take up a role as a practitioner in the company, this might provide the competitive edge over consultancy based collaboration. More of such collaboration method, together with the longitudinal element will enable further empirical evidence to confirm the effectiveness of university as one of the preferred source of innovation. This research is particularly important to small firms and family owned businesses where resources are limited and has a vision of achieving sustained competitive advantage. Other than avoiding 'quick fixes' or jumping onto the bandwagon, non-product innovation is achievable in an incremental way without sacrificing the internal scarce resource such as tacit knowledge. As highlighted by Hervas-Oliver et al. (2017), it is inadequate to be solely dependent on the capital equipment and its embedded knowledge. Rather, the capital equipment in technological process innovation, which in this research refers to both the ICT software, hardware and the associated PPC practice, must become an integral part of the organisation to capture the maximum benefit of innovation (Damanpour, 2014).

REFERENCES

Arica, Emrah, Haskins, Cecilia and Strandhagen, Jan O. (2016). A framework for production rescheduling in sociotechnical manufacturing environments. Production Planning & Control, 27(14), 1191 – 1205.

Arundel, Anthony, Bordoy, Catalina and Kanerva, Minna (2008). Neglected innovators: How do innovative firms that do not perform R&D innovate? Results of an analysis of the Innobarometer 2007 survey No. 2015. INNO-Metrics Thematic Paper.

Barney, Jay (1991). Firm Resources and Sustained Competitive Advantage. Journal of Management, 17(1), 99 – 120.

Benavides, Buestan, Marcos and Van Landeghem, Hendrik (2015). Implementation of S-DBR in four manufacturing SMEs: a research case study. Production Planning & Control, 26(13), 1110 – 1127.

Bendoly, E., Croson, R., Goncalves, P. and Schultz, K. (2010). Bodies of Knowledge for Research in Behavioural Operations. Production and Operations Management. 19(4), 434 – 452.

Berglund, Martina and Karltun, Johan (2007). Human, technological and organizational aspects influencing the production scheduling process. International Journal of Production Economics, 110, 160 – 174.

Boer, Harry, Holweg, Matthias, Kilduff, Martin, Schmenner, Roger, Voss, Chris (2015). Making a meaningful contribution to theory. International Journal of Operations & Production Management. 35(9), 1231 – 1252.

Brown, Shona L. and Eisenhardt, Kathleen M. (1997). The Art of Continuous Change: Linking Complexity Theory and Time-Paced Evolution in Relentlessly Shifting Organizations. Administrative Science Quarterly, 42(1), 1 – 34.

Cabral, Ricardo and Leiblein, Michael, J. (2001). Adoption of a process innovation with learning-by-doing: evidence from the semiconductor industry. The Journal of Industrial Economics, 49(3), 269 – 280.

Coughlan, P. and Coghlan, D. (2016). Action Research. *In:* Karlsson, C (Eds)., Research Methods for Operations Management. 2nd Edition. New York: Routledge, 2016, 233 – 267.

Damanpour, Fariborz (1991). Organizational innovation: a meta-analysis of effects of determinants and moderators. Academy of Management Journal, 34(3), 555 – 590.

Damanpour, Fariborz (2014). Footnotes to Research on Management Innovation. Organization. Organization Studies. 35(9), 1265 – 1285.

Done, Adrian, Voss, Chris, Rytter, Niels G. (2011). Best practice interventions: Short-term impact and long-term outcomes. Journal of Operations Managmeent. 29, 500 – 513.

Edquist, Charles (1997). Systems of Innovation Approaches – Their Emergence and Characteristics. *In:* Edquist, Charles (Eds). Systems of Innovation: Technologies, Institutions and Organizations, Routledge.

Freeman, Chris (1995). The 'National System of Innovation' in historical perspective. Cambridge Journal of Economics, 19, 5 – 24.

Fores, Beatriz and Camison, Cesar (2016). Does incremental and radical innovation performance depend on different types of knowledge accumulation capabilities and organizational size?. Journal of Business Research, 69, 831 – 848.

Grant, Robert, M. (1997). The Knowledge-based View of the Firm: Implications for Management Practice. Long Range Planning, 30(3), 450 – 454.

Goldratt, E.M. and Cox, J. (1984). The Goal. Croton-on-Hudson, The North River Press, New York.

Hayes, Robert, H. and Pisano, Gary, P. (1994). Beyond World-Class: The New Manufacturing Strategy. Harvard Business Review. January – February, 77 – 86.

Heidenreich, Martin (2009). Innovation patterns and location of European low- and medium-technology industry. Research Policy, 38, 483 – 494.

Henderson, Rebecca M. and Clark, Kim B. (1990). Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. Administrative Science Quarterly, 35(1), 9 – 30.

Hendry, L., Huang, Y., and Stevenson, M. (2013). Workload control: Successful implementation taking a contingency-based view of production planning and control. International Journal of Operations & Production Management, 33(1), 69 – 103.
Herbig, P. A. (1994). The innovation matrix: culture and structure prerequisites to innovation. Westport, CT: Quorum Books.

Hervas-Oliver, Jose-Luis, Sempere-Ripoll, Francisca, Alvarado, Ronald Rojas and Estelles-Miguel, Sofia (2017). Beyond product innovation: deciphering process-oriented innovators, complementarities and performance effects. Technology Analysis & Strategic Management.

Hervas-Oliver, Jose-Luis, Sempere-Ripoll, Francisca, Boronat-Moll, Carles and Rojas, Ronald (2015). Technological innovation without R&D: unfolding the extra gains of management innovations on technological performance. Technology Analysis & Strategic Management, 27(1), 19 – 38.

Hervas-Oliver, Jose-Luis, Sempere-Ripoll, Francisca, and Boronat-Moll, Carles (2014). Process innovation strategy in SMEs, organizational innovation and performance: a misleading debate?. Small Business Economics, 43, 873 – 886.

Hervas-Oliver, Jose-Luis, Garrigos, Jose, Albors, Gil-Pechuan, Ignacio (2011). Making sense of innovation by R&D and non-R&D innovators in low technology contexts: A forgotten lesson for policymakers. Technovation, 31, 427 – 446.

Hopp, Wallaco, J. and Spearman, Mark L. (2004). To Pull or Not to Pull: What is the Question?. Manufacturing & Service Operations Management. 6(2), 133 – 148.

Huang, Yuan (2017). Information architecture for effective Workload Control: an insight from a successful implementation. Production Planning & Control, 28(5), 351 – 366.

Jackson, Sarah, Wilson, John, R. and MacCarthy, Bart, L. (2004). A New Model of Scheduling in Manufacturing: Tasks, Roles, and Monitoring. Human Factors, 46(3), 533 – 550.

Karltun, Johan and Berglund, Martina (2007). Contextual conditions influencing the scheduler's work at a sawmill. Production Planning & Control, 21(4), 359 – 374.

Keupp, Marcus Matthias, Palmie, Maximilian, and Gassmann, Oliver (2012). The Strategic Management of Innovation: A Systematic Review and Paths for Future Research. International Journal of Management Reviews, 14, 367 – 390.

Kikoski, C. K. and Kikoski, J. F. (2004). The Inquiring organization: Tacit Knowledge, Conversation, and Knowledge Creation Skills for 21st-Century Organizations. Praeger, Westport, CT and London.

Koberg, Christine, S., Detienne, Dawn, R. and Heppard, Kurt, A. (2003). An empirical test of environmental, organizational, and process factors affecting incremental and radical innovation. Journal of High Technology Management Research 14, 21 – 45.

Lichtenthaler, U. (2009). Absorptive capacity, environmental turbulence, and the complementarity of organizational learning process. Academy of Management Journal, 52(4), 822 – 846.

Lundvall, Bengt-ake and Johnson, Bjorn (1994). The Learning Economy. Journal of Industry Studies, 1(2), 23 – 42.

Meyer, Alan D., Brroks, Geoffrey R. and Goes, James B. (1990). Environmental Jolts and Industry Revolutions: Organizational Reponses to Discontinuous Change. Strategic Management Journal, 11, 93 – 110.

Nonaka, Ikujiro, Toyama, Ryoko and Konno, Noboru (2000). SECI, *Ba* and Leadership: a Unified Model of Dynamic Knowledge Creation. Long Range Planning, 33, 5 – 34.

Oke, Adegoke, Burke, Gerard, and Myers Andrew (2007). Innovation types and performance in growing UK SMEs. International Journal of Operations & Production Management, 27(7), 735 – 753.

Parkinson, C. N. (1955). Parkinson's law. The Economist, 177(5856), 635 – 637.

Piening, Erk P. and Salge, Torsten Oliver (2015). Understanding the Antecedents, Contingencies, and Performance Implications of Process Implication: A Dynamic Capabilities Perspective, 32(1), 80 – 97.

Polanyi, M. (1966). The Tacit Dimension. Routledge & Keagan Paul, London.

Raelin, J. (2015). Action Modes of Research. *In:* Anderson, L., Steward, Gold J. and Thorpe, R. (Eds). A Guide to Professional Doctorates in Business & Management. Sage, 2015, 57 – 76.

Reichstein, Toke and Salter, Ammon (2006). Investigating the source of process innovation among UK manufacturing firms. Industrial and Corporate Change, 1 – 30.

Schragenheim, Eli, Dettmer, William, H., Patterson, Wayne, J. (2009). Supply Chain Management at Warp Speed: Integrating the System from End to End. CRC Press: Boca Raton.

Schumpeter, J. A. (1934). The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle. London: Transaction Publishers.

Seidler-de alvis, R. and Hartmann, E. (2008). The Use of Tacit Knowledge Within Innovative Companies: Knowledge Management in Innovative Enterprises. Journal of Knowledge Management. 12, 133 – 147.

Shani, A. B., Coghlan, D. and Cirella, S. (2012). Action Research and Collaborative Management Research: More than Meets the Eye?. International Journal of Action Research, 8(1), 45 – 67.

Sousa, Rui and Voss, Christopher, A. (2008). Contingency research in operations management practices. Journal of Operations Management, 26, 697 – 713.

Sousa, Rui and Voss, Christopher, A. (2001). Quality management: Universal or context dependent?. Production and Operations Management, 10(4), 383 – 404.

Stevenson, M., Hendry, L. C. and Kingsman, B. G. (2005). A review of production planning and control: the applicability of key concepts to the make-to-order industry. International Journal of Production Research, 43(5), 869 – 898.

Teece, D. J. (1980). The Diffusion of an Administrative Innovation. Management Science, 26(5), 464 – 470.

Teece, D. J. (2007). Explicating Dynamic Capabilities: The Nature and Microfoundations of (Sustainable) Enterprise Performance. Strategic Management Journal, 28, 1319 – 1350.

Tushman, M. L. and Romanelli, E. (1985). Organizational evolution: a metamorphosis model of convergence and reorientation. *In:* Cummings, L. L. and Staw, B. M. (Eds.), Research in Organizational Behavior, 7, 171 – 222. Greenwich, CT: JAI Press.

Utterback, James M. (1994). Mastering the Dynamics of Innovation: How Companies Can Seize Opportunities in the Face of Technological Change. Harvard Business School Press, Boston.

Van de Ven, A. H. (2007). Engaged scholarship: a guide for organizational and social research. Oxford: Oxford University Press.

Voss, Chris (2005). Alternative paradigms for manufacturing strategy. International Journal of Operations & Production Management, 25(12), 1211 – 1222.

Voss, Chris (1995). Operations management – from Taylor to Toyota – and Beyond?. British Journal of Management, 6, Special Issue, 17 – 29.

Wernerfelt, Birger (1984). A Resource-Based View of the Firm. Strategic Management Journal, 5(2), 171 – 180.

Womack, J. P., Jones, D. T. and Roos, D. (1990). The Machine that Changed the World. The United States of America: Rawson Associates Scribber.

Zheng, Gang, Liu, Fang, and Xu Feng (2012). Non-R&D Innovation: A Neglected Innovation Approach for Chinese SMEs, Proceedings of the 2012 IEEE ISMOT.