Human factor: the bridge to a successful intervention in MTO (Make-To-Order) manufacturing environment

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Abstract

This paper aims to demonstrate how human factor played an essential role in the design and implementation of a production planning and control (PPC) system to improve a company's operating performance. Although various operations management (OM) concepts, tools and techniques have been introduced by academia, the disconnection between academia and actual practice is still apparent. The importance of 'contextual knowledge' in introducing an intervention refers not only to the 'technical', but also to the 'socio' aspect of the system. Balance is achieved by considering the 'fit' between OM concepts and technology, as well as the human/social and organisational aspect in introducing a practical PPC system.

Keywords: human factor, production planning and control, S-DBR

Introduction

In the field of Operations Management (OM), there is a shift in research focus to highlight the important role of 'contextual knowledge' in implementing OM 'best practices'. Various OM 'best practices' have been developed and now proliferate, such as TQM (Total Quality Management), Lean Management (Womack et al., 1990) and Theory of Constraints (Goldratt and Cox, 1984). The mixed results in the linkage between adoption of 'best practice' and operation performance improvement has prompted researchers to issue caution against blindly 'copying' best OM practice with the intention of achieving 'world-class performance' (Done et al., 2011; Schmenner and Swink, 1998; Stevenson et al., 2005). The importance to identify and understand the underpinning philosophies, theories, laws, and assumptions of OM 'best practices' has also been emphasised (Boer et al., 2015; Done et al., 2011; Hayes and Pisano, 1994; Hopp and Spearman, 2004). Acknowledging the heterogenic nature of businesses, the alignment between 'best practices' and 'contextual dependencies' has increasingly become the focus of research (Sousa and Voss, 2008; Voss, 1995; 2005). However, the 'contextual' element advocated has not explicitly stress the importance of human factor. As highlighted by McLean et al. (2017), continual improvement is key to all these developments and most of the continuous improvement efforts either failed or fall short of meeting targets. A common 'thread' among the factors highlighted in their review is 'human factor'. This paper, by reflecting on a recent successful implementation of a production planning and control (PPC) system in a small MTO manufacturing company, aims to demonstrate how 'human factor' is the corner stone to this success. This paper begins by providing a critical review of the role of 'human factors' in the implementation of PPC. This is followed by a discussion on the research methodology/design adopted. Based on the research data, the important role of 'human factors' is analysed and discussed. In the conclusion the contribution of this research and possible directions for future research will be highlighted.

Who Decides: PPC or People?

With the advancement in technology, PPC concepts can be realised by embedding scheduling heuristics and algorithms in computer-based devices. However, ignoring 'human factors' in the development of PPC is a critical omission (Crawford, 2001; McKay, 2001). While it is acknowledged that PPC fundamentally utilises mathematical models to substantiate rational decision-making and system optimization, it is argued that these generalised algorithms are not necessarily applicable in all ostensibly similar environments (Brocklesby, 2016; Mokotoff, 2001; Stochhecker et al., 2016). As described by MacCarthy and Wilson (2001), ultimately, it is the 'people' who run the shop floor, make things happen, and reap the fruit of their work. It is argued that problems encountered on the shop floor are not discrete nor static and cannot be solved by optimising algorithms on their own. Rather, the problems are seen as 'dynamic processes' which requires 'people' to manage them over time. Placing the question in another way: who bears the consequence of decision made: PPC or 'people'? It is obvious, given the context of today's world, it is 'people' who reap the fruit of the decision making. If 'people' are the ultimate recipient of the decision made, it is argued that PPC is perceived as successfully implemented if it provides positive benefits to 'people' and vice versa. On this basis, it is necessary to develop PPC into a 'tool' to assist 'people' in making decisions. This is supported by calls to develop PPC into a decision support tool with the synergy of both 'technology' and 'people' factors (Arica et al., 2016; Higgins, 2001; Jackson et al., 2004; McKay and Buzacott, 2000).

PPC as a Decision Support Tool

Although both PPC (theoretical) and 'people' (practitioner) make scheduling decisions, it is argued that PPC merely makes decision based on simple quantitative measures and algorithmic procedures (Higgins, 2001). In contrast, 'people' regards the decision making process as a social activity, an interaction of complex values and goals within the system of people which might affect themselves. From an empirical study, Jackson et al. (2004) found three common roles of human in PPC: (i) interpersonal role: '*developing interpersonal networks, informal bargaining, friendship and favour network and mediation*', (ii) informational role: '*as information hub, filtering information to the shop floor, and ensuring that information is accessible and visible*' and (iii) decision making role: '*problem prediction and problem solving, interruption handling, and resource allocation*'. Thus, in developing PPC as a decision support tool, it needs to be able to support these human roles within PPC. A guideline consists of four design aspects has been proposed: (i) level of support, (ii) transparency, (iii) autonomy, and (iv) information presentation (Wiers and van der Schaaf, 1997; Wiers, 2001). Other than achieving an improved operating performance on the shopfloor, the decision support tool has a wider implication in the business process, acting as the interface between sales/marketing (pre-sales) and production (post-sales) which is particularly important to MTO companies (Berglund et al., 2011; Schragenheim and Dettmer, 2000; 2009; Stevenson, 2006).

Level of Support

PPC developments need to support 'people' rather than the other way around (Higgins, 2001; McKay, 2001). Instead of seeing PPC as a potential threat of replacing 'people'

(Tarafdar and Gordon, 2007), Wiers (2001) suggested the sharing of responsibility between 'people' and the decision support tool. It is also suggested that a proper division of functions is able to improve worker empowerment, quality leadership and human coordination (Slomp, 2001; Wilson, 2003). This could be done by identifying the routine and non-routine elements on shop floor (Fransoo and Wiers, 2006; Mckay and Buzacott, 2000). With this, PPC is anticipated to process tasks which require manual skills and abilities. Humans would focus on tasks which requires tacit knowledge and mental interpretive skills and abilities (Slomp, 2001).

Transparency
As described by McKay (2001), the tool has to reflect the contextual problem on hand. In addition, the logic (or assumption) used by PPC to arrive at proposed decision has to be simple enough for 'people' to intuitively understand. The decision support tool should not create additional complexity for the users (Gasser et al., 2011). To avoid falling into this trap, Wiers (2001) has encouraged the active involvement of 'people' in co-developing the algorithm. This process is indeed a challenge, as highlighted by Crawford (2001), in capturing the 'tacit knowledge' hidden within the daily routine of 'people', filtering and analysing them, before converting the generic patterns into heuristic algorithms to support PPC decision making.

Autonomy
As a decision supporting tool, it needs to support the activities within the individual's area of autonomy, so enabling them to take control in making decisions (McKay, 2001). This may require higher management clarifying the boundaries associated with the management role at various (both vertical and horizontal) control points within the company's business process flow (Harvey, 2001).

Information Presentation
As described by Wiers (2001), this is a 'key factor' of an effective human-computer interaction consisting of 'what' and 'how' information is presented to 'people'. In addition, it includes the human-computer interface, leading to human-computer interaction. This guides, stimulates, and advances their decision making capabilities over time without interfering with their perception (Higgins, 2001).

PPC with a human-centred architecture

Seeing the importance of human factors within PPC as well as business in a whole, particularly as an intermediary between real world of manufacturing and abstract world of operations research (Higgins, 2001), this paper reflects upon how 'human factors' enabled the successful implementation of a PPC into a decision support tool in a small MTO company. The PPC is based on S-DBR (Simplified Drum-Buffer-Rope), a PPC application based on the Theory of Constraints philosophy (Schragenheim and Dettmer, 2000; 2009). Although some aspects such as '*Constraint Management*' (Gupta and Boyd, 2008) is widely discussed, other important aspects such as '*Buffer Management*' are not and this is a particular focus of this research. The simplified approach of using 'time' as a leverage point is also highlighted by McKay (2001): '*time and the meaning of time is the essence of scheduling in the real world*'. In addition, the simple representation of work priority with colour coding in '*Buffer Management*' will also be demonstrated.

Design/methodology/approach

This paper is in part the output of a DBA (Doctoral in Business Administration) study where the researcher is a practitioner in a make-to-order (MTO) manufacturing environment. As a practitioner, the researcher has been tasked by the management to introduce a PPC intervention to improve Company A's operating performance. In order to understand the contextual environment including the customs and habits of people where McKay, 2001 highlighted the need to be '*seen as one of them*'. He argued it is necessary '*to sit, observe, and work with the dispatchers and schedulers on a daily* base' to gain an '*intimate knowledge of the plant, products and processes*'. As an engaged scholar, the researcher should capture the knowledge generated throughout the intervention process. Action Research (AR) was chosen as the most appropriate research approach to carry out the emergent enquiry process which encompasses both the 'technical' and 'socio' aspects (Coughlan and Coghlan, 2016; Shani et al., 2008). This research is divided into three main phases, over-arched by the AR meta-cycle: pre-change (determine context and purpose, constructing and planning action), in-change (taking action), and post-change (evaluating action). Data was collected via formal and informal meetings/discussions, job shadowing, observation of actual practice, direct communication with people, and company archival data (Bendoly et al., 2010; Crawford, 2001; McKay, 2001). The generic S-DBR guide for practitioners is used to inform the 'technical' part of the PPC. The 'soft'/'socio' part of the PPC will be guided by the four design aspects of the decision support tool discussed in the literature review.

Findings

Manufacturing Environment

This company is a rotational-moulding plastic product manufacturer who has been in the industry for over forty years. There is no dedicated production line, resources are heavily shared and the production process is labour intensive. The simplified process diagram is as shown in *Figure 1* below. Although the company uses Sage with a bespoke manufacturing module, the function of the manufacturing module was restricted to generating paper job tickets to the shop floor. There were no digital means of communication between shop floor and the other departments except by physically visiting the premise. Production is only started upon receipt of firm orders and the plastic products produced are based on a standard range of product design offered, known as the 'base unit'. Based on the selected base unit, customers are offered a range of sixteen colours. In addition, customers are able to customise their moulds using mould-in graphics. The customised features and acceptance of small order quantities provides a unique service in the market. Some of the issues faced by the company are discussed in *Table 1* below. The remainder of this section will begin by analysing the role of the production manager, using the three roles discussed in literature review. This is followed by a demonstration of how PPC is developed according to the four design aspects identified in previous section.

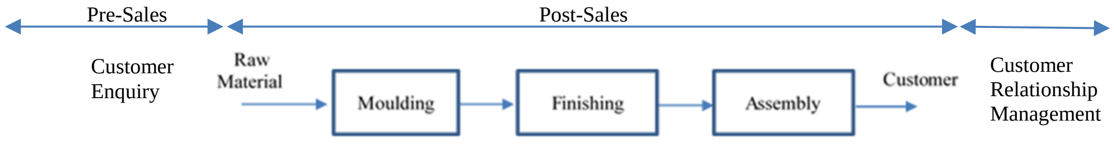

Figure 1: Simplified Production Process in Company A

Table 1: Summary of Issues identified in Company A

	Standard Practice	Description	Undesired Effects (UDEs)
Pre-Sales	Customer Enquiry Stage: • Standard industrial lead time is quoted • Exceptional cases such as large quantity or with particular customised features will be discussed between shop floor, sales/marketing, and purchasing before deciding on a most probable delivery date (often based on experience)	• As management's attention is only triggered on exceptional cases, this causes accumulation of small quantity orders on similar products by different customers to evade management's attention. For example, an order of hundred units will immediately catches the management's attention, but not twenty five orders of four units. • Some of the products, though being named differently, uses similar resources on the shop floor, for example the mould. Other than causing unrealistic due date to be quoted, it also causes the emergence of critical capacity resources (CCR).	• Unrealistic due date quoted • Causing critical capacity resources (CCR) to form unknowingly • Too late for management to response
Post-Sales	• Similar products are being accumulated and produced, reducing setup time • Office will only be notified upon work order completion • A practice where each work centre will work towards the 'shop floor accepted production time'.	• All production related matters are decided by production manager • The production manager has been managing well with his abundance of tacit knowledge. However, the process is manual, providing no visibility to others. • 'Shop floor accepted production time' adopted in each department has 'buffer time' allocated to them individually. Parkinson's Law exist where jobs tend to automatically 'spread' to consume the buffer time unnecessarily. This often cause job priority to be masked.	• Missed due date • Hidden capacity resources • Not able to deploy buffer capacity in time • Buffer time is wasted • Issue of succession and knowledge dissemination • Reactive and fire-fighting production management

Interpersonal Role

As the production process is labour intensive, the production manager, holding the responsibilities of production planning, scheduling, and control has to rely on his network to get things done. At the beginning of each day, shop floor personnel generally arrive slightly earlier to spend time socialising. Personnel might complain about health or personal issues, which might hinder work performance. Production manager will reallocate job tasks and resources accordingly. This informal network allows production manager to gather informal information to complement decision making. The show of empathy will earn favours in return, for example in negotiating to work overtime when the need arises. Other than within the shop floor, the production manager also maintains intra-department network. For example, information from sales about potential new work orders can be useful for decision making. In exchange, sales might get favour to informally expedite jobs if necessary.

Informational Role

As all production related information was held by production manager, he was the 'go to' person for all levels within the company. Both formal and informal information is filtered, processed, and reflected in the decisions made. For example, after a job ticket was received, the production manager used his knowledge to 'visualise' the number of 'parts' to be produced, the necessary resources required to produce the 'parts', and the 'time' available to produce them. An estimated completion date was worked out but the job ticket status could only be known by checking with the production manager as other shop floor personnel only had the information on what to be produced, and not which jobs they were fulfilling. Upon assigning a job to a machine, the progress of each machine was updated daily by communication to the production manager, where he would mark them on respective job ticket. Other production related issues, for example machine breakdown, product defect, machine configuration and setup, were all channelled to the production manager for directive on next course of action.

Decision Making Role

The above discussed roles, bothinterpersonal and informational, enabled the production manager to carry out his decision making role, which mainly centred on job release, job prioritisation and resource control. At the beginning of each day, decision making starts by allocating resources based on availability (particularly human resource). Being the most experienced personnel (with tacit knowledge) on the shop floor, together with the use of his network and gathered information, the Production Manager established his reputation and garnered trust from the shop floor to make the most appropriate decision. This included recommendation to activate capacity resources, such as additional machineries or additional shifts.

Development of PPC into a Decision Support Tool

The development of PPC into a decision support tool is illustrated in *Table 2 below*, bringing together the perspectives from both the 'Role' and 'Design aspects'. Agile software development was adopted throughout the process, involving daily one-to-one training and job shadowing in order to capture the flow of thought of the Production Manager, as well as to improve human-computer interfaces. The illustration on how priority of a work order is obtained is shown in *Figure 2* below. This priority is the common priority observed by the whole company. An example is shown in *Figure 3* below.

Table 2: Key Points Identified in the Development of a PPC Decision Support Tool for Company A

<table>
<tr><th></th><th>Level of Support</th><th>Transparency</th><th>Autonomy</th><th>Information Presentation</th></tr>
<tr><td>Interpersonal</td><td>• Should not be adding complexity and burden to existing workload
• Facilitate communication</td><td>• Support personnel performance evaluation</td><td>• Encourage team work
• Allow higher management to provide empowerment</td><td rowspan="3">• Dashboard
• Graphical/Visual
• Easy to understand
• Easy to navigate
• Job priorities are represented using five colours:
(i) blue: to be pooled
(ii) green: could choose to start if no other jobs which are more urgent
(iii) yellow: start job
(iv) red: expedite job
(v) black: late</td></tr>
<tr><td>Informational</td><td>• Information on all job tickets in hand (In-Progress and In-Queue)
• Auto-resource allocation (under normal condition)
• Resource Utilisation
• Workload per Standard Industrial Lead Time
• Job Ticket Priority
• Due date for confirmed orders to be based on current system loading
• Job ticket status and progress
• Allow proposed due date to be enquired based on current system loading
• Allowed centralised work order information to be captured and shared on single platform by all departments</td><td>• Easy to understand PPC principles: Time Buffer Management for job priority
• User defined Resource Loading algorithm
• User defined Performance Target
• User defined touch time (rough cut actual time worked on an item)
• Product related Information/knowledge can be easily updated and proliferated</td><td>• Allow manipulation of capacity options/variables to simulate outcome:
- Machines deployed
- Machine performance
- Additional mould deployment
- Batch size
• Information source traceability</td></tr>
<tr><td>Decision Making</td><td>• To Prioritise
• To Expedite
• To Escalate if need higher management's attention
• To Target areas requiring continuous improvement</td><td colspan="2">• Allow final resource assignment
• Allow rescheduling</td></tr>
</table>

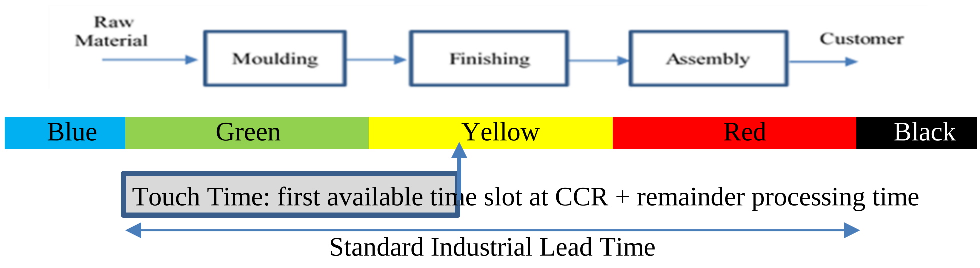

Figure 2: Illustration on Work Order having priority of 'Yellow'

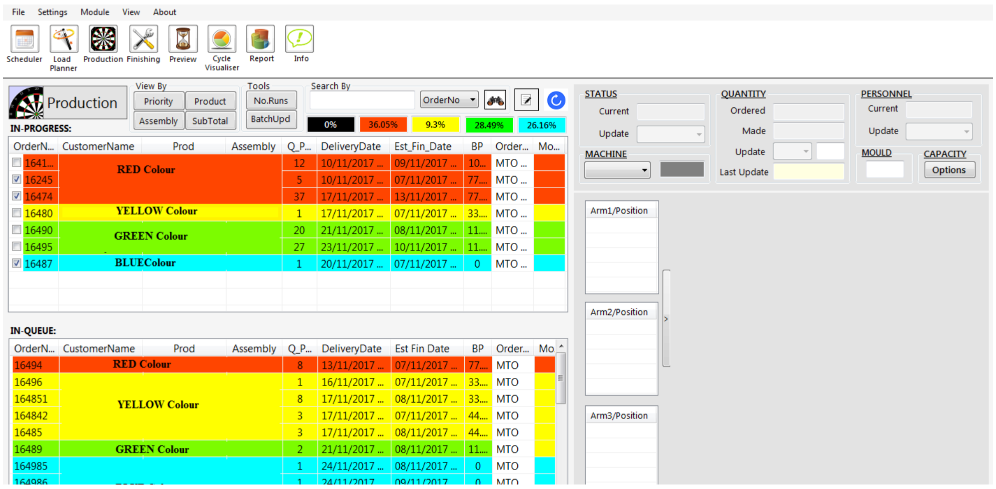

Figure 3: An example on how priority of jobs are displayed

A year after implementation of the system, in year 2017, in spite of experiencing the highest sales since year 2012, the company was able to achieve more than 90% of due date performance without deployment of additional shifts. Increased empowerment happened on the shop floor together with a 'new culture' involving stronger team work and lesser intervention from management. Shop floor personnel are encouraged to make informed decisions and as a personnel commented: 'You have given us a tool, not a toy. We are workers and we appreciate the use of tool as it helps us to work more efficiently'.

Conclusion

This research demonstrates the significance of 'human factors' in both the design and implementation stages of a PPC OM intervention. This research demonstrates the need for both fundamental OM concept which involve rationale mathematical modelling but also the practical understanding of how 'human factors' provide contextual knowledge that enables the introduction of a practical OM intervention unique to each organisation. By explicitly acknowledging the role of 'human factors', the PPC introduced and developed went beyond conventional PPC in providing a decision support tool well integrated into the daily work routine of the company. Although Crawford and Wiers (2001) consider human factors has been acknowledged as an essential element by both academia and practitioners, the contradicting implementation results by MacLean et al. (2017) warrants further research. In order for universities to increase relevancy in contributing towards both academia and practitioners, it is recommended that more OM research to be conducted using AR. By having '*resident*' rather than '*tourist*' company information, universities arguably stands a better position to provide a practical PPC solution.

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