The Appropriation of Trust for a Successful PPC Implementation

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Abstract

Production planning and control (PPC) systems are deployed to enable the effective management of variation and uncertainty. In spite of the advancement in technology such as big data and artificial intelligence, the complimentary roles of human and system is becoming more apparent. This paper explores the human-PPC relationship from the perspective of *trust*. This is done by investigating a recent successful PPC implementation in an SME. In relation to this case the concept of *trust* is explored as a psychological state and it is suggested that *trust appropriation* is a continuous process achievable through the leveraging of the basis of trust: *purpose*, *process* and *performance*.

Keywords: Trust Appropriation, Production Planning and Control, Action Research

Introduction

For decades, researchers have called for better alignment between the underpinning concepts and the contextual environment in which the PPC (Production Planning and Control) system is to be implemented. The critical role of the 'socio' aspect in developing and implementing a practical PPC solution is well highlighted (Brocklesby, 2016; Burglund and Karltun, 2007; Davis et al., 2014; MacCarthy et al., 2001). Some researchers have gone further, highlighting the importance of developing positive human-system relationship in a successful PPC implementation (Fransoo and Wiers, 2008; Higgins, 2001; Jackson et al., 2004). However, the main focus has been on the complementary roles (tasks) of human and system in the decision making process. For a successful human-system relationship design, development and implementation, some researchers have suggested the pivotal role of *trust* between the human-system relationship (Fransoo and Wiers, 2008; Muir and Moray, 1996). As *trust* is 'fluid' (Hoffman et al., 2013), appropriation is necessary to avoid 'mistrust' and 'distrust' (Hoff and Bashir, 2015; Lee and See, 2004).

The remainder of this paper begins by reviewing the need for PPC to be developed into a human centred Decision Support System (DSS). This is followed by a review on the construct of 'trust' in the human-automation context. Based on the above reviews, the role and importance of *trust* in the successful implementation of PPC as a DSS will be explored through theoretical argument. The conceptual framework developed will be used as a lens to explore *trust* and its appropriation in a successful human-system

implementation. This human-automation implementation is in the context of a PPC-DSS system in a rotary moulding environment. Details of the research methodology used is discussed followed by a discussion of the findings before ending with research contribution and potential future research.

PPC, a human centred DSS system

The advancement in technology such as Internet of Things (IoT), Big Data and Robotics is reshaping manufacturing industries (Brauner et al., 2019; Brettel et al., 2014). Although automation has enabled data collection, interpretation, decision making and process control (Lee and See, 2004), the role of the human remains critical. A taxonomy has been proposed by Parasuraman et al. (2000) to describe the types and levels of automation. The four primary types of automated system includes information acquisition, information analysis, decision selection and action implementation. An automated system can be designed to fall within single or multiple types (Hoff and Bashir, 2015). Human involvement in an automated system is depicted across a continuum of autonomy levels. This is represented by a scale of 1 to 10 where level 1 refers to system which offers no assistance and level 10 where the system ignores human acting autonomously.

PPC is concerned with managing variabilities and uncertainties in a manufacturing environment as well as the wider implication on the entire supply chain. As the manufacturing strategy moves from standardisation towards customisation, the associated variabilities and uncertainties increases (Cardin et al., 2017; Olhager, 2003). With the increase in complexity of manufacturing environments there are increases the necessity for human intervention (McKay and Wiers, 2001; Nakamura and Salvendy, 1994). This is mainly due to the perception that humans are able to provide a better response in dynamic environments due to their superior flexibility, adaptability and creativity (Parasuraman, 1997). Ultimately, it is the humans who are accountable for and recipients of the decisions made (MacCarthy and Wilson, 2001). This includes accountability for ethical and legal related issues (Brauner et al., 2019; Philipsen et al., 2019). Thus, it is expected that through the development of PPC into a DSS system, the reaction time of humans will be reduced while at the same time improving decision making quality (McGuirl et al., 2006). This places PPC in the mid region of the autonomy scale, requiring partnership between human and system.

The importance of the human-system complementary role has prompted calls to develop PPC into a human centred DSS system (Arica et al., 2016; Fransoo and Wiers, 2008; Higgins, 2001; Jackson et al., 2004; McKay and Buzacott, 2000). Building upon the human roles (HR) in PPC identified by Jackson et al. (2004) and the design and development criteria proposed by Wiers and van der Schaaf (1997) for a DSS in PPC. Yeong and Stratton (2018) proposed a HR-DSS matrix to support the development process. As shown in *Table 1*, this matrix crosses DSS development criteria with the human roles in PPC. The DSS criteria are (i) Level of Support, (ii) Transparency, (iii) Autonomy, and (iv) Information Presentation. The human roles in PPC are (i) Interpersonal, (ii) Information, and (iii) Decision Making. This taxonomy explicitly requires the boundary between the roles of human and system to be defined. This is useful in both the development of new PPC-DSS and the evaluation of existing PPC-DSS. With reference to *Table 1*, the quadrants involving 'Information Presentation' mainly concern feedback given by system to human These feedback becomes part of the input to the remaining quadrants to facilitate contextual interaction between human and system.

According to Lee and Moray (1992; 1994), this interaction is determined by the *trust* and *self-confidence* of humans. The success of a human-system development and implementation requires the system to reflect the trust of humans in the capabilities of the

system (the automation part). It is also necessary for human self-confidence to be reflected in their ability to use the system manually under 'uncommon' situation which requires intervention. The critical role of *trust* has prompted researchers to call for *appropriation of trust* in order to reduce misuse, disuse and abuse of a system (Hoff and Bashir, 2015; Lee and See, 2004; Lyons et al., 2017; Parasuraman and Riley, 1997).

Trust in Human-PPC relationship

Trust has been explored from various perspectives: psychological, neurological, sociological, organizational, and interpersonal. Based on the above inter-human trust perspectives, a detailed review was conducted by Lee and See (2004) and summarised them into four broad categories: beliefs, attitudes, intentions, and behaviour. By adopting the framework developed by Ajzen and Fishbein (1980), they argued that beliefs, attitudes, intentions and behaviour are distinct. Beliefs offers the information base in which determines attitude. Attitude guides the adoption of intention. Intentions, the willingness to act, are exhibited in behaviour according to the environmental and cognitive constraints faced. Based on the above arguments, Lee and See (2004) proposes to view *trust* as *attitude* which connects the four distinct categories in the following way. *Trust* is the *attitude* based on the underlying 'beliefs'. This is manifested in various intentions and behaviours according to the levels of trust.

The definition of *trust* from their research is "*the attitude that an agent* [trustee] *will help achieve an individual's* [trustor's] *goals in a situation characterized by uncertainty and vulnerability*". By applying this definition of *trust* to human-system relationship, the authors suggest that *trust* bridges the *beliefs* on system characteristics and the *intention* to rely and use the system. *Trust* is arguably not a *behaviour* due to it being one of the many factors which influences behaviour. Other factors could be both external and internal of a person. Internals could be the workload, situation awareness and self-confidence, whereas externals could be company policy or performance measurements (Lee and Moray, 1994; Riley, 1994). According to this definition, *trust* only comes into play if trustor is dependent on the trustee to complete certain functions of relevance to trustor's goals.

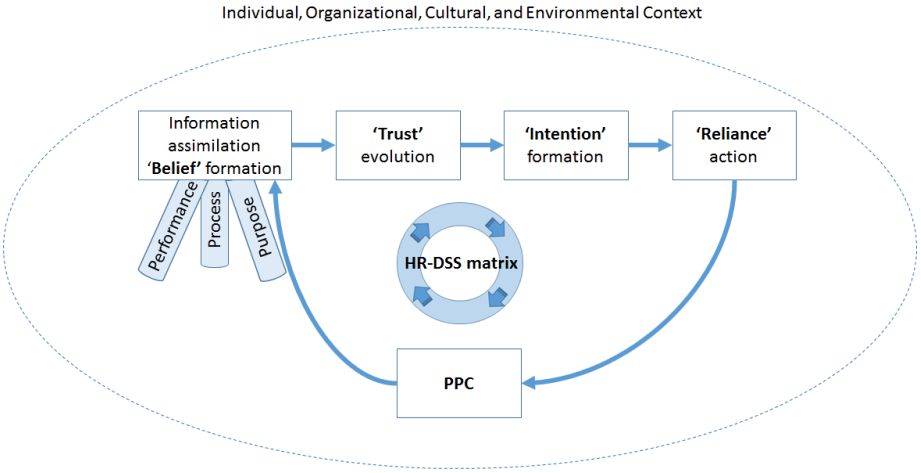

Figure 1: Appropriation of Trust and HR-DSS (Adapted from Lee and See (2004))

Due to *trust* is between *beliefs* and *intention*, any mistrust and distrust will result in negative or unwanted intension, i.e. unwillingness. 'Mistrust', also known as 'over-trust', occurs at instances where level of *trust* exceeds actual system capabilities. 'Distrust'

refers to the phenomena where *trust* is below the system capabilities. As shown in *Figure 2*, the 'level of trust' and 'system capabilities' are represented by Lee and See (2004) in a two axes chart. A diagonal line is drawn in between to depict the *appropriated trust*, where 'level of trust' matches 'system capabilities'. The region above and below the diagonal line represents 'mistrust' and 'distrust' respectively. 'Mistrust' results in 'misuse', whereas 'distrust' results in 'disuse' of a system (Lee and See, 2004; Parasuraman, 1997).

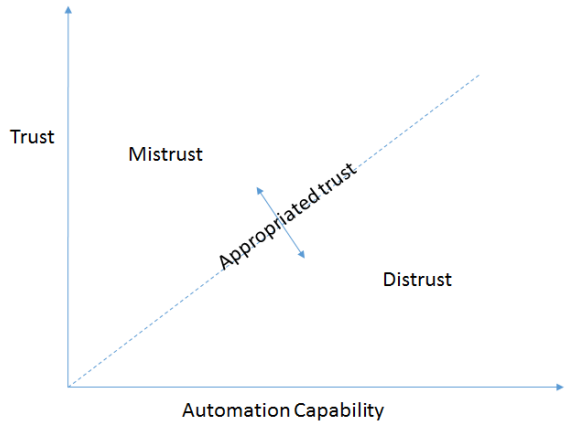

Figure 2: Trust Appropriation (Adapted from Lee and See (2004))

With the perspective that *trust* is dynamic (Hoffman et al., 2013; Lee and See, 2004; Lewandowsky et al., 2000), *trust* needs to be appropriated. This is also known as *trust calibration* (e.g. McGuirl and Sarter, 2006), *trust repair* (e.g. Quinn et al., 2017; de Visser et al., 2018) or *trust restoration* (Philipsen et al., 2019). In the appropriation of trust concept proposed by Lee and See (2004) apparently assumes automation (system) to be static in its capabilities, represented by the appropriation of trust occurring outside of automation (system). In the development and implementation of PPC into a DSS system using HR-DSS matrix, as shown in *Figure 1*, it is proposed that automation (system) to be included as part of the trust appropriation process (McGuirl and Sarter, 2006).

In the context of implementing PPC-DSS system as an intervention in a company, it is not the purpose of this paper to debate the taxonomy of trust. However, the above discussion highlights the critical role of trust and the need to appropriate trust in a human-PPC relationship. With reference to *Figure 1*, to effectively appropriate trust, it is necessary to address the 'belief' stage of this cycle. This is also known as the basis of trust. Based on a review by Mayer et al. (1995), the general basis of trust in inter-human relationship has been described as *Ability*, *Integrity*, and *Benevolence*. In human-automation relationship, Lee and Moray (1992) describes the general basis as *Performance*, *Process* and *Purpose*. The resemblance in both have been highlighted by Lee and See (2004): *Ability-Performance*, *Integrity-Process*, and *Benevolence-Purpose*. To strengthen the three general basis of trust proposed in human-automation, they reviewed thirteen other research conducted on basis of trust and discovered each of them falls into one of the three categories.

In the context of PPC-DSS, *performance* refers to both present and historical information relevant to the competency of PPC-DSS in achieving human's goals. It captures the information related to *what* the automation does. This information encompass the subjective human-PPC-DSS interaction and experience. *Process*, in the context of PPC-DSS refers mainly to the *algorithms* and *management philosophy*, which underpins the behaviour of PPC-DSS. This centres on the issue of *how* PPC-DSS works.

The third basis: *purpose* refers to information related to *why* PPC-DSS is developed. This is related to the designer or originator's intent.

The approach of appropriating trust by targeting 'belief' stage is also adopted by de Visser et al. (2014). Based on this, they proposed a trust cue taxonomy to conduct trust assessment on trust agents. In the context of PPC-DSS development and implementation, it is posit that HR-DSS matrix is able to be used to facilitate trust appropriation. As shown in *Table 1,* the *purpose* of the PPC-DSS is represented by considering the Level of Support (S) offered to accomplish the human roles in PPC. The concern on *process* is addressed by looking into the *transparency* and *autonomy* of the system in fulfilling each human role. Through *information presentation* and *level of support* exhibited, *performance* of the system can be evaluated.

Table 1 – HR-DSS Matrix and Basis of Trust (Adapted from Yeong and Stratton, 2018)

<table>
<tr><th></th><th>Level of Support (S)</th><th>Transparency (T)</th><th>Autonomy (A)</th><th>Information Presentation (I)</th></tr>
<tr><td>Interpersonal (IPR)</td><td rowspan="3">Purpose / Performance</td><td colspan="2" rowspan="3">Process</td><td rowspan="3">Performance</td></tr>
<tr><td>Information (IMR)</td></tr>
<tr><td>Decision Making (DMR)</td></tr>
</table>

The above conceptual discussion provides an insight on the potential role of *trust* and its appropriation for a successful PPC-DSS implementation. It is also the purpose of this paper to explore the relevance of *trust* and its appropriation in real life PPC-DSS implementation.

Design/methodology/approach

This research is based on a recent successful PPC implementation in an SME rotary moulding company, Company A. Simplified-Drum-Buffer-Rope (S-DBR), the latest Theory of Constraints (TOC) application for Make-To-Order (MTO) manufacturing environment (Schragenheim and Dettmer, 2000) was adopted. The PPC implementer, who worked as a business system architecture designer, was also a researcher pursuing professional doctoral degree. The dual purpose of this project has prompted the use of action research (AR) to capture practical knowledge in both 'technical' and 'socio' aspects (Coughlan and Coghlan, 2016; Shani et al., 2008). This two years project was divided into pre-change (determine context and purpose, constructing and planning action), in-change (taking action), and post-change (evaluating action) stages. Data was collected via formal and informal meetings/discussions, job shadowing, observation of actual practice, direct communication with people, and company archival data. As trust is defined as a psychological state in this research, trust level is interpreted by analysing verbal expression and the actual usage of system.

Findings

A contextually redesigned S-DBR based PPC has been successfully developed and implemented (Yeong, 2019). Of the various AR cycles in each project stage (pre-change, in-change and post-change), a few AR cycles from in-change is used to explore trust appropriation.

AR Cycle 1

To explore and exploit potential CCR (Capacity Constraint Resource), there were attempts to arrive at a detailed scheduling of potential CCR. To achieve this, it is desirable

to capture every possible machine-mould configuration. Senior management has expressed the intention to develop PPC into a strict directive tool to monitor performance of personnel. However, the researcher finds that it is impractical and impossible to code every possible scenario in this dynamic and complex environment where tacit knowledge and human intervention is necessary. From the perspective of *purpose*, shop floor personnel felt threatened by the presence of the system. It is seen as a monitoring tool which will cause them their job. In addition, p*rocess* of the proposed system is deemed impractical which cast doubt in the *performance* expected. Coupled with the bad experience with old manufacturing software which produces job tickets and pushes jobs onto the shop floor with unrealistic delivery date, comments such as '*the computer* [PPC-DSS] *system will never work'* is often heard.

AR Cycle 2

Informed by the management philosophy of S-DBR, which proposes light planning and heavy execution, it adopts the concept of buffer management (BM) to provide visual and easily understood signals to user (refer to *Figure 3a*). Each work order is represented by BM colour. Through these colours, work orders are *prioritised*, *expedited* and *escalated*. For continuous improvement purposes, it has the function of *targeting* (Stratton and Knight, 2009). Efforts are done to develop heuristic algorithm based on tacit knowledge and modus operandi under normal situation. The concept of planned load (PL) is used to represent outcome of tacit knowledge in a visual way (refer to *Figure 3b*). Multiple improvement cycles were done to obtain confirmation from shop floor personnel on the practicality of the heuristic algorithm and information presentation (*process and performance*). The use of BM and PL and its representation suggest the PPC-DSS system as only giving feedback and suggestion, without dictating the final decision (*purpose*). In the process, it increases the trust level of shop floor personnel, evident from their participation to share tacit knowledge and validate the outcome.

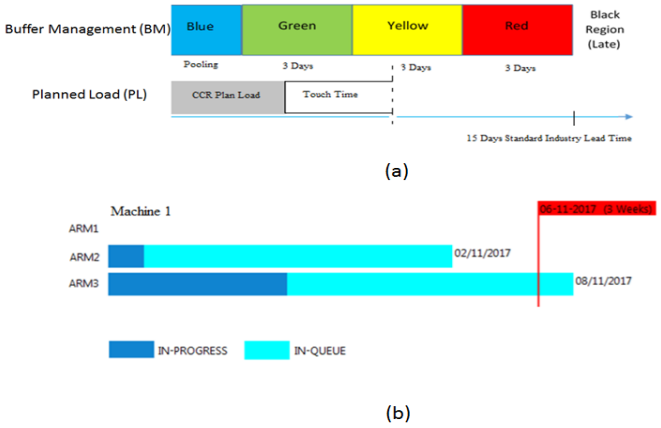

Figure 3: Illustration of: (a) Buffer Management and (b) Planned Load

AR Cycle 3

Although the outcome of AR cycle 2 has gained trust, it is still a supplement to existing manufacturing process. The machines do not have any data input/output (I/O) interface, an interface is necessary to capture the final decisions made in resource allocation and work order progress updating. Feedback information is critical for the PPC-DSS system to suggest solutions, such as promised due date in customer enquiry stage. The human role (HR) is evaluated in the context of company business process flow. As demonstrated in *Figure 4*, PPC-DSS and its associated interfaces are developed and integrated into the

business flow of company, from pre-sales to post-sales. This further enhance the *purpose*, *process* and *performance* of the system to increase human trust level towards the system.

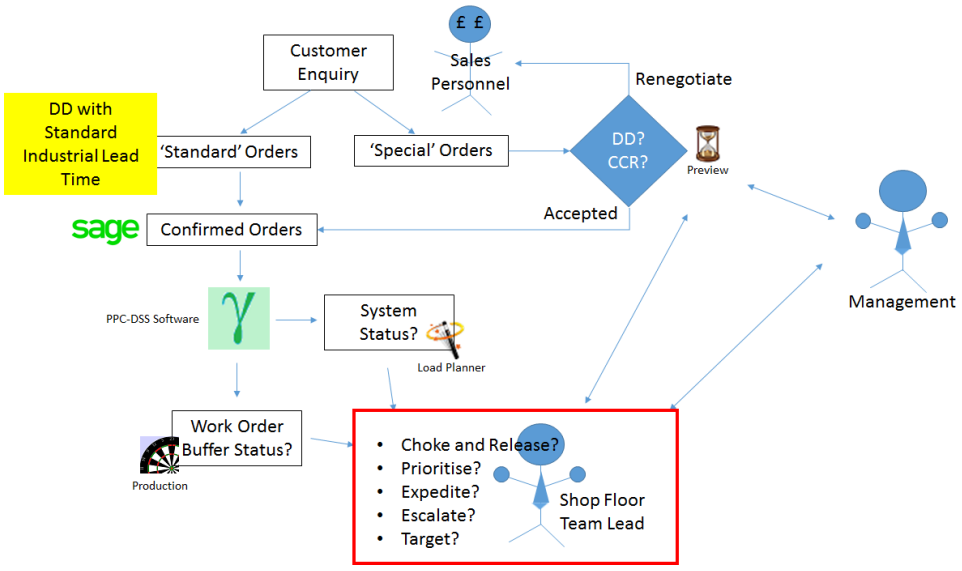

Figure 4: Integration of PPC-DSS into business flow of Company A (Yeong, 2019)

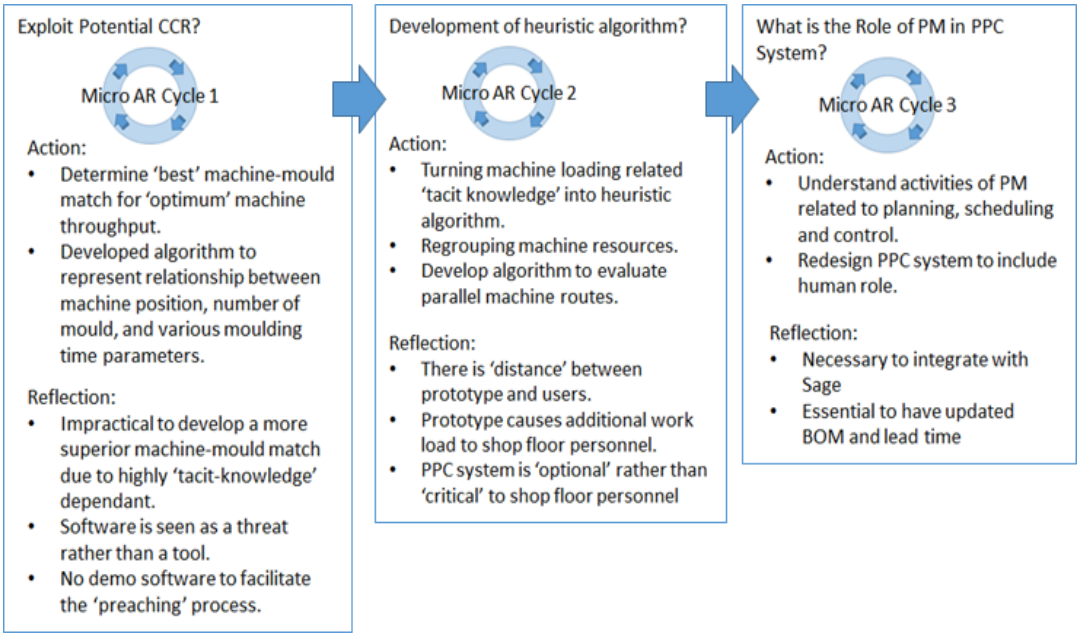

Figure 5: Selected In-Change AR cycles to demonstrate trust appropriation (Yeong, 2019)

From the above findings, trust appropriation is shown to be a continuous process. In this case, it began in the *distrust* region. Firstly, PPC-DSS with flexibility to customise according to contextual requirement places automation system into the trust appropriation process, as shown in *Figure 2*. This offers opportunities to improve trust level. Secondly, it demonstrates how enhancement in the capability of PPC-DSS is able to increase trust level. In this research, the PPC-DSS enhancement is done in accordance

to human requirements and tacit knowledge, acquired through AR cycles. Thirdly, not necessarily proportional amount of PPC-DSS capability increase will be translated to equal amount of increase in trust level. Based on the trust appropriation concept proposed by Lee and See (2004), *Figure 6* attempts to illustrate the trust appropriation process through the AR cycles discussed. The increase in automation capability, Δc_a is lesser than from AR cycle 2 to 3, Δc_b. However, the trust gained from the later, Δt_b is higher than earlier AR cycle, Δt_a. Finally, the PPC-DSS system in company A is being made known to be 'improvable'. Rather than being treated as a 'sacred cow', or requires immense cost or resources to amend, it is able to be improved according to contextual requirements.

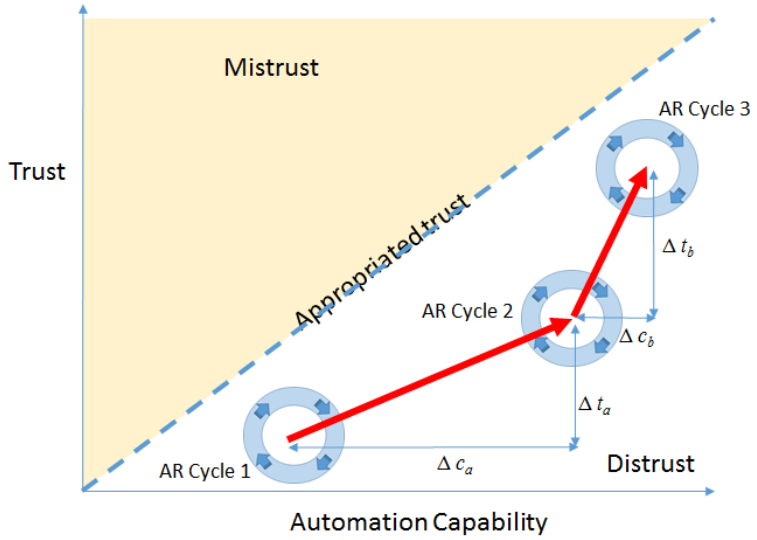

Figure 6 – Trust Appropriation illustration for AR cycle 1, 2 and 3

Conclusion

This research attempts to explore the role of *trust* and its *appropriation* in the design and implementation stages of PPC. By borrowing the literature from *trust in automation*, it is used as lens to reflect on a recently completed development and implementation of a human centred PPC-DSS system in an MTO company. In the context of PPC-DSS, the existence of such a system is to assist humans to better manage variability and uncertainties. By adopting the perspective that *trust* is a psychological state, it is suggested that *trust* can be appropriated by influencing the three aspects of *trust*: *purpose*, *process*, and *performance*. Through reflection on the selected AR cycles, it is suggested that *trust appropriation* is a continuous improvement process. This is made possible with the inclusion of PPC-DSS customisation as part of the *trust appropriation* process. In other words, the possibility of adjusting PPC-DSS capabilities contributes positively towards *trust appropriation*. *Trust* has captured the attention of researchers in the area of automation (for example: driverless vehicles, nuclear plants and flight system). Further research could be conducted to explore the significance of *trust appropriation* in PPC-DSS adoption and implementation. This may potentially narrow the gap between PPC theory and practice. In real life PPC-DSS implementation, it is not isolated from organisational related context. This implies that *trust* and its appropriation process might be influenced by other factors which requires further research.

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