ORGANISATIONAL EMBEDDING OF A WORKLOAD CONTROL CONCEPT: AN ACTION RESEARCH PROJECT

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ABSTRACT
Workload Control (WLC) is a leading production planning and control solution for make-to-order companies; however, few successful case studies have been reported. To facilitate more widespread use, Hendry *et al.* (2008) identified seventeen WLC implementation issues through comparative case study analysis and described how many of these issues could be overcome in practice; however, it was concluded that WLC implementation requirements should be explored in additional settings. This paper uses these implementation issues as a checklist for embedding WLC in a small engineering company. Progress has confirmed the particular significance of twelve of the issues to an additional setting and identified a further six, including uncertainty after order release. The paper expands on how implementation issues can be overcome, e.g., by applying customer-specific strike rate values, and describes the refinement of WLC theory, e.g., to cope with rush orders. Future research will explore the impact of WLC on performance.

Keywords: Workload control (WLC); implementation strategy; make-to-order (MTO) sector.

INTRODUCTION
Workload Control (WLC) is a method of Production Planning and Control (PPC) which, when commenced at the customer enquiry stage, has particular relevance to producers of highly customised products. Research to date has concluded that WLC has the potential to significantly improve the operating performance of the Make-To-Order (MTO) sector (Stevenson *et al.*, 2005); however, few successful cases have been reported to support this. Although there have been many simulation studies highlighting the positive impact of WLC on performance, relatively little is known about the effectiveness of WLC in practice. Recent research by Hendry *et al.* (2008) and Stevenson & Silva (2008) compared several WLC implementation attempts (including those presented by Silva *et al.*, 2006 and Stevenson, 2006a) and highlighted the importance of gaining an in-depth insight into the process of implementing WLC in order to facilitate more widespread use of the concept in practice. Perhaps the most notable of these recent contributions was made by Hendry *et al.* (2008). By identifying and addressing a series of implementation issues, the authors provide the starting point for a detailed WLC implementation strategy but conclude that a number of research questions remain outstanding and that the implementation requirements of WLC should be explored in additional case study settings.

Building on Hendry *et al.* (2008), an action research project is being undertaken to implement WLC, incorporating use of a Decision Support System (DSS), in a small UK-based precision engineering company (hereafter referred to as Company Y) which supplies bespoke products to customers in the aerospace, commercial and food industries. The research seeks to apply and extend the implementation ideas presented by Hendry *et al.* (2008) and contribute towards addressing research questions the authors raised. The paper: provides an insight into the implementation

process for WLC; and, contributes both towards the development of a more comprehensive implementation strategy and to refining the WLC concept for use in practice.

The remainder of this paper is organised as follows. The following section reviews recent literature on implementing WLC before the paper outlines the action research method applied in this study and the reasons why this has been chosen over the case study research method (as typically adopted in previous attempts to implement WLC). Implementation issues encountered in Company Y to date, with a particular focus on new issues not previously indentified in the WLC literature, are presented in the fourth section of the paper. The fifth section outlines how challenges relating to these issues have been addressed during the study before the paper concludes, briefly identifying outstanding areas to explore through future research.

LITERATURE REVIEW

Cases of successful WLC implementation are few and far between in the literature. Moreover, the majority of empirical WLC papers written in the 1980s and 1990s (e.g., by Bechte, 1988 and 1994) give a very limited insight into the approach taken to embed WLC in practice and the obstacles that had to be overcome in order to do so, meaning that in most cases the implementation process itself remains a 'black box'. Some papers, particularly those which involve successful implementations, have tended to 'jump' from describing the method or tool developed to the results of implementation. Where implementation issues are discussed, these have largely focused on technical problems with the hard/software infrastructure rather than softer ideas related to managing change within organisations. In many ways, it is arguably the process of implementing the concept in practice, however successful, that provides the most beneficial insight for fellow researchers, rather than the often situational results that are presented. With this in mind, although the cases described by Hendry (1989) and Hendry *et al*. (1993) represent only partial implementations of WLC, the studies contribute by highlighting practical problems and barriers to the implementation of WLC in practice. For example, full implementation of WLC was obstructed by: the selection of an inappropriate end-user for the DSS which supports the concept, leading to misuse of the system; a lack of awareness in practice regarding WLC and the parameters that need to be set in order to use the concept; and, a reluctance or inability to meet the information requirements of the DSS, leading to neglect of the system. Among other insights, this work highlighted the need for the end-user to be trained in an attempt to ensure that the planning system is used appropriately.

The studies by Fry & Smith (1987) and Wiendahl (1995) are rare in that they present empirical studies which propose and apply strategies for implementing WLC in practice. The former present a six-stage implementation procedure which applies to the job release stage of the WLC concept; it does not encompass the customer enquiry stage (important in customised production contexts). The work of Wiendahl (1995) considers the implementation of a more complex WLC approach. It covers six stages, including an analysis of the current manufacturing performance, explores how to change company attitudes and concludes with a full implementation of the proposed WLC system. While valuable, this still does not generate a comprehensive list of the implementation issues that can arise and how they should be overcome. Furthermore, the six-stage strategy has been developed in the context of a particularly complex variant of the WLC approach: the probabilistic load oriented manufacturing control method.

More recently, comparative case study analysis has been conducted to provide a deeper insight into the factors that influence the implementation of WLC in practice (Hendry *et al.*, 2008; Stevenson & Silva, 2008). Stevenson & Silva (2008) focus primarily on theoretical refinements made to the WLC concept during two independent longitudinal WLC case study research projects undertaken in parallel in Portugal and the United Kingdom. Reasons for conceptual refinement are split into two groups: (1) refinements due to the time that has elapsed since the development of the original methodology; and (2) refinements due to company-specific characteristics. Refinements include: (1) changes to the impact that a new job has on the workload length; (2) changes to the

workload control infrastructure (at the total, planned and released levels of the hierarchy of workloads); and, (3) changes to the parameter setting requirements of the concept. The authors also highlight a number of implementation challenges, including: (1) meeting the data requirements of the WLC concept in practice; (2) the need to develop further strategies for implementing WLC in practice; and, (3) the need to increase awareness of the WLC concept in practice. Hendry *et al.* (2008) investigated issues arising from implementing WLC through comparative case study analysis involving a capital goods manufacturer in The Netherlands and a precision engineering subcontractor in the United Kingdom. The authors asked: how should implementation issues that arise in the context of WLC be addressed to enable improved implementation in practice? The study identified seventeen implementation issues under five headings (market-related; primary manufacturing process; WLC system requirements; information flow; and, organisational embedding). Each issue was discussed based on evidence from the two cases. For some issues, appropriate responses are identified (e.g., refinements to the WLC theory or strategies to overcome the implementation issue are developed), for other issues, outstanding research questions are posed. Other notable contributions to furthering the use of WLC in practice are made by Soepenberg *et al.* (2006 and 2008). For example, through the use of order progress diagrams and WLC principles, the authors seek to diagnose and resolve logistic performance problems in SMEs.

The low number of cases involving the implementation of WLC in practice, as described above, makes it difficult to generalise about how to implement WLC or about the effect of WLC on performance. This is further complicated by the fact that the companies described in the papers differ in their characteristics and that the particular WLC-based methods applied vary from case to case. Hence, there is a need to build up a greater body of evidence on the implementation of WLC in practice. In response, this paper takes the recent work of Hendry *et al.* (2008) and Stevenson & Silva (2008) as a starting point and uses the set of implementation issues detailed in Hendry *et al.* (2008) as a checklist for implementing WLC in Company Y. Experience gained with Company Y thus far has contributed to: developing the set of implementation issues further; enhancing the emerging implementation strategy, towards facilitating more wide spread use of WLC in practice; and, refining aspects of WLC theory to reflect the needs of real-life companies.

METHODOLOGY

This project is motivated by the following two research questions:

(1) *How can existing WLC implementation strategies and frameworks be enhanced in order to successfully embed the WLC concept within an organization?*

(2) *Can a WLC system be efficiently implemented in practice and achieve performance improvements such as those observed in previous simulation studies?*

As this paper describes an ongoing project, what follows focuses on the first of the above research questions. The second research question will be explored during future research.

Previous attempts to implement WLC, such as in Company X (as described by Stevenson, 2006a/b), have typically been labelled as “case study research”. This label was consistent with the initial role of the research team in the aforementioned project - that of observation. However, as time passed and project momentum reduced, the research team took on an increasingly participatory role in an attempt to fully implement the concept. For example, one member of the research team became the user of the system for a short period of time, entering data to get the system ‘up-to-speed’. This could not be a long-term solution but it was hoped that demonstrating the value of the system would renew enthusiasm for the project within the organisation. Hence, as time went by, the project shifted from case study observation more towards action research participation.

Many problems can obstruct the successful implementation of WLC in practice. As the above example suggests, overcoming these issues can require members of the research team to engage with practitioners and participate in the implementation process. It is argued that WLC implementation requires interaction between the organization and the research team to make step-

by-step progress through loops of research and action. In light of this, the ongoing implementation project in Company Y is described as "action research"; however, it is acknowledged that organisational embedding and long-term benefits from the use of WLC in Company Y will only be possible if key actors within the company also participate in the change efforts and take ownership of the concept.

Arguably, it is not important whether the research is labelled as a "case study" or as "action research" but whether the right skills are being utilised at the right time to: protect the rigor and validity of the research; and, pursue the objectives of the study. Therefore, a range of techniques for conducting high quality research, drawing on both the case study and action research literature, are being employed. Influential papers on case research include those by: Eisenhardt (1989 and 1991), Flynn *et al.* (1990), Pettigrew (1990), McCutcheon & Meredith (1993), Handfield & Melnyk (1998), Meredith (1998), Stuart *et al.* (2002), Voss *et al.* (2002), and Eisenhardt & Graebner (2007). Influential papers on action research include those by: Lewin (1946 and 1947), Westbrook (1995), Baskerville & Wood-Harper (1996), Eden & Huxham (1996), and Coughlan & Coghlan (2002). Westbrook (1995), for example, suggests: documenting the evidence to form a consistent approach that can be used by other researchers; and, employing the research approach that explores the commonalities and differences of outcomes. Such approaches have been undertaken in this project. For example, semi-structured interviews have been conducted with different members of staff within Company Y and with their key customer, providing triangulation. Tables have also been used extensively to document the whole WLC implementation process so that fellow researchers can replicate the approach, including: the key implementation issues encountered; the responses to the issues; and, the WLC parameter setting process.

NEW IMPLEMENTATION ISSUES ENCOUNTERED IN COMPANY Y

Hendry *et al.* (2008) presented 17 implementation issues and responses to these issues under five categories: (A) market/customer related issues (A1-5); (B) primary process related issues (B1-4); (C) WLC system related issues (C1-3); (D) organisational embedding related issues (D1-3); and (E) information flow related issues (E1-2). These categories and issues have been used as a framework for structuring the process of implementing WLC in Company Y. Many of the issues previously identified have again been significant in this project. In addition, new issues, not previously identified, have been encountered. Table 1 provides a summary of the 17 implementation issues described in Hendry *et al.* (2008) and six new issues from implementing WLC in Company Y. Particularly significant issues encountered in this WLC implementation project are marked with a '✓'. Newly identified issues, also considered to be of particular relevance to the implementation of WLC, are marked with an asterisk (*) and appended to the appropriate category (A-E). The following discussion explains why these new issues are important before the next section outlines how some of the challenges encountered in this study have been addressed, with a particular focus on new implementation issues and/or new responses.

Uncertainty after the order release stage (B5):* Change and uncertainty on the shop floor, after a job has been released, impacts the released workload of shop floor resources. According to the aggregate (or atemporal) load oriented WLC methodology, the workload contribution of a job is added to the Released Workload Length (RWL) of corresponding work centres at the moment of order release and deducted from the RWL of a work centre when the operation has been completed. Any changes during the primary production process in Company Y (e.g., scrap/quantity reductions) are not considered in the loading calculations of downstream work centres. Similarly, if a job is stopped indefinitely (e.g., at the request of the customer), the job continues to contribute to the RWL of downstream work centres. This raises the question: *how can the WLC concept be made flexible enough to cope with uncertainties after jobs have been released to the shop floor?*

Table 1: Summary of Key Issues Related to WLC Implementation

Category		Key Implementation Issues
A. Market/Customer	✓	Characteristics of order quotations (A1)
	✓	Uncertainty at the customer enquiry stage (A2)
	✓	Rush orders (A3)
		Seasonality and volume growth (A4)
		Hybrid production (A5)
B. Primary Process	✓	Assembly requirements (B1)
		Sequence dependent set-up times (B2)
	✓	Alternative shop floor routings (B3)
	✓	Industry-specific process (B4)
	✓	Uncertainty after the order release stage (B5*)
C. WLC System	✓	WLC-related start-up issues (C1)
	✓	Incomplete routing data at customer enquiry (C2)
		Time-span-dependent critical resources (C3)
	✓	Output control management (C4*)
D. Organizational Embedding	✓	Awareness of the concept of WLC (D1)
	✓	User visibility (D2)
	✓	Support of task structures (D3)
	✓	End-user choice and involvement (D4*)
	✓	Accommodating functionality requests (D5*)
	✓	Timely implementation procedure (D6*)
	✓	Performance measurement and review (D7*)
E. Information Flow	✓	System-related start-up issues (E1)
		Integration with other systems (E2)

A1-A5, B1-B4, C1-C3, D1-D3 & E1-E2 taken from Hendry *et al.* (2008);
"✓" refers to issues encountered in this research (other issues not considered significant in this case);
"*" refers to new issues identified in this research (not identified as significant in Hendry *et al.*, 2008).

Output control management (C4):* WLC is based on the concept of input-output control. For workload length calculations to be accurate, good estimates of work centre capacities are required. Furthermore, to use input-output control effectively, sufficient output control measures (e.g., subcontracting, overtime and the reallocation of operators) are required in order to create flexibility. In Company Y, overtime is limited, subcontracting is restricted by the need for aerospace approvals and reallocation is limited by the skill-sets of the operators. Company Y are more likely to use batching as a means of making more effective use of capacity. Hence, there is a difference between the output control management supported by WLC and the options typically available in reality. This raises the question: *how can the output control activities used in reality be reflected in the structure of the WLC concept?*

End-user choice and involvement (D4):* Previous attempts to implement WLC have suffered due to the choice of an ill-informed end-user. The user must be involved throughout the project to encourage ownership of the system and gain a sufficient understanding of the WLC concept to use the system effectively. In Company Y, the main end-user will be the Planning & Procurement Administrator who is in charge of planning, scheduling and order progress control. However, other members of staff are responsible for new enquiries, engineering and low-level production control. The end-user's lack of understanding of the quotation process and technical aspects of production means populating the WLC system with data is a slow process while many of the decisions that the WLC system supports will require interaction with other members of staff. This raises the questions: *how can the most appropriate end-user(s) for the WLC concept be identified? And, how can multiple users interact with the WLC system?*

Accommodating functionality requests (D5):* In order to embed WLC within an organization, it can be important to accommodate functionality requests made by the end-user if they do not

conflict with the theory underpinning WLC. Company Y, for example, requested that the WLC system produce route cards used on the shop floor and dispatch notes for delivering orders to customers. However, over-emphasis on the additional functions might distract from the core WLC system and lead to neglect or misuse. This raises the question: *how can functionality requests made by users of WLC systems be accommodated in order to embed the system within the company whilst simultaneously protecting the core WLC system?*

Timely implementation procedure (D6):* Previous attempts to implement WLC suggest a gradual implementation strategy (e.g., with a partial implementation/trial followed by the full system implementation) may be appropriate. However, it is important to adopt the most suitable WLC implementation procedure for the particular company. While parameter setting and populating the system with job data is time-consuming and has to be performed gradually, a partial implementation (e.g., in a subset of work centres or for a subset of jobs) is not being applied in Company Y as it is difficult to isolate a suitable area for a trial implementation. Instead, a full 'big bang' implementation is being undertaken. This raises the question: *how can the most appropriate approach to introducing WLC into the shop be identified?*

Performance measurement and review (D7):* It is important to record shop floor performance (pre- and post- implementation) in order to gauge the impact of WLC and to monitor performance (and parameters) over time. However, insufficient data is available in Company Y to support pre-implementation performance analysis and parameter setting decisions. Hence, measures must first be put in place; doing so could help to understand the current situation so that WLC can contribute to overcoming the company's biggest problems. Moreover, this follows the action research cycle of loops of diagnosis, planning, action taking, and evaluation during the whole implementation process. This raises the question: *how do regularly monitored and reviewed performance measures contribute to the successful implementation of WLC?*

ADDRESSING IMPLEMENTATION ISSUES

As demonstrated by Table 1, working towards the implementation of WLC in Company Y has confirmed the relevance of many of the issues identified in Hendry *et al.* (2008); new issues have also emerged. Table 2 summarises responses to these issues made during the current project, indicating whether the response is consistent with prior research or whether a new contribution is made (to the implementation strategy and/or the theory of the WLC concept). Due to space limitations, a full discussion of all the issues and responses is not possible. The following discussion focuses on responses which lead to refinements to the WLC implementation strategy and/or concept. Some issues, notably C4* and D4*, are not discussed and remain outstanding for future research to address.

Issue A2: There is a great deal of uncertainty surrounding the outcome of quotations in Company Y. The Customer Confirmation Time (CCT) varies and may depend on tendering decisions at other points in the supply chain. The length and accuracy of the anticipated CCT impacts the effectiveness of due date calculations in the WLC system. Given high CCT variability, a CCT estimate for each customer (also changeable for each individual order) is used rather than an average value for the whole business. In addition, to avoid an unconfirmed job contributing to the Total Workload Length (TWL) for too long, the DSS prompts the user to contact the customer when the anticipated CCT has passed; chasing-up quotations may also increase the probability of order acceptance. Company Y's strike rate also varies between customers (e.g., in different industry sectors). An average strike rate percentage can be incorporated in the TWL calculations at the customer enquiry stage; however, in Company Y, the strike rate is approximately 20% for aerospace work, 50% for commercial work and for some particular orders, almost 100%. Hence, using an average value is considered unsuitable. Therefore, different values are applied for different customers. In doing so, jobs with an anticipated strike rate of 100% will make a full contribution to

the TWL calculation when the quotation is made. The system also monitors and adjusts the strike rate over time according to company performance.

Table 2: Summary of WLC Implementation Issues and Responses in Company Y

Key Issues	Responses: Addressing Implementation Issues	Comments
A1: Characteristics of order quotations	• Gradual change towards realistic quotations. • Increase communication with customers.	*Same strategy as previously.*
A2: Uncertainty at the customer enquiry stage	• Determine individual CCTs for repeat customers. • Liaise with customers between enquiry and order acceptance decision. • Apply different strike rate values for different customers and update the strike rate over time.	*Implementation strategy refinement.*
A3: Rush orders	• Conduct rush order 'impact analysis' at the job entry stage.	*WLC theory refinement.*
B1: Assembly requirements	• Jobs with sub-assembly structures are planned based on a critical path method.	*Same strategy as previously.*
B3: Alternative shop floor routings	• Group machines into work centres.	*Same strategy as previously.*
B4: Industry-specific processes	• A 'participation percentage' can be defined for partial operations (e.g., a 10% inspection quantity). • Jobs with long (external) lead-time operations are de-coupled and treated as separate jobs when they return.	*WLC theory/ implementation strategy refinement.*
B5*: Uncertainty after the order release stage	• The released workload lengths of downstream shop floor resources are reduced in the event of scrap or if a job is suspended indefinitely.	*WLC theory refinement.*
C1: WLC-related start-up issues	• Gradual reduction of workload limits to gain control of lead times.	*Same strategy as previously.*
C2: Incomplete routing data at customer enquiry	• Use throughput norms at the customer enquiry stage when detailed data is not available.	*Same strategy as previously.*
C4*: Output control management	• A link must be established between output control management and the options available.	*Requires further research.*
D1: Awareness of the concept of WLC	• Training and support provided using an interactive WLC training Tool.	*Same strategy as previously.*
D2: User visibility	• Decision support provided without showing the user detailed calculations.	*Same strategy as previously.*
D3: Support of task structures	• Encourage cooperation between sales, planning and production departments. • Use WLC system at planning meetings (where all relevant departments are present).	*Implementation strategy refinement.*
D4*: End-user choice and involvement	• Interactive use of the system (e.g., at planning meetings) encouraged. • System access via the Intranet, allowing multiple users, is to be explored.	*Requires further research.*
D5*: Accommodating functionality requests	• Functionality requests that do not conflict with the WLC concept are accommodated.	*Implementation strategy refinement.*
D6*: Timely implementation procedure	• Initial period after implementation to be considered as a trial; WLC parameter changes expected during this period.	*Implementation strategy refinement.*
D7*: Performance measurement and review	• Performance monitoring and review functions have been created within the system.	*Implementation strategy refinement.*
E1: System-related start-up issues	• Populate the system manually with initial orders and shop floor workloads.	*Same strategy as previously.*

Issue A3: Company Y receives some rush orders from important customers, sometimes with a due date that has already passed, causing scheduling problems. Rework also has to be scheduled when quality problems occur. Reserving capacity for rush orders and rework, as described in Hendry *et al.* (2008), is impractical in this case since both rush orders and rework are highly unpredictable. To solve the problem of scheduling unexpected jobs with tight due dates, 'impact analysis' functionality has been developed. Under this method, if the unexpected job cannot be scheduled, the user has the option of changing the due date (e.g., by forwards scheduling) or determining the impact that expediting this job will have on other orders (e.g., potential length of delay). It is anticipated that this will be very useful information when negotiating with customers.

Issue B4: Some 'special' operations which require particular attention when applying WLC have been identified in Company Y. For example, there are several different inspection operations, some of which are only applied to part of the job (i.e., not to the full quantity). The WLC method was designed without considering such 'part operations'. To reflect part-processes in workload contribution calculations, the 'participation percentage' is defined as an operation characteristic and incorporated in the WLC system. In addition, there are some jobs which include operations performed externally by the customer themselves. Such operations could be treated as sub-contracting but often have long and unpredictable lead times, making it difficult to plan the job. It is impractical under the aggregate load oriented WLC methodology to account for the workload of operations that only commence after the job is returned to Company Y from the customer in the workloads of shop floor resources when the job is released. Therefore, the job is de-coupled into two. The workload of operations undertaken prior to the operation performed by the customer is accounted for when the job is released and the workload of operations after that performed by the customer is accounted for when the job returns to Company Y.

Issue B5:* Scrap, which leads to a reduction in the size of a job at subsequent operations (and, perhaps to the release of a 'replenishment order'), is common in manufacturing. In addition, sometimes jobs have to be suspended on the shop floor or return to the pool part-finished (defined as freezing or suspending a job), such as when a customer requests that a more urgent order takes precedence. The WLC concept should be flexible enough to cope with uncertainties, such as the above, after jobs have been released to the shop floor. The WLC system has therefore been refined so that Released Workload Lengths of downstream shop floor resources are decreased when scrap occurs or jobs are 'frozen'. This requirement is based on the primary manufacturing process of Company Y but is considered a relatively generic issue.

Issue D3: Integration and good communication within the organisation is critical for WLC implementation. In Company Y, sales, planning and production are the responsibility of different people that do not interact sufficiently during the customer enquiry management process. As a result, due date quotations are often unrealistic. In order to apply WLC, more involvement, for example, from engineers, is required to provide an adequate level of information for quotations at the customer enquiry stage. The company hold daily planning meetings, which key members of staff attend and this is a good opportunity for them to share information. Therefore, the WLC system can be initially used in this daily planning meeting for interactive decision making.

Issue D5:* The WLC system has been developed to incorporate several company-specific functions. To avoid these 'bells and whistles' distracting attention away from the core WLC concept, new functions are tied to encouraging appropriate use of the system. For example, the Operations Manager requested that the system produce dispatch notes, which must accompany each order when it is delivered to the customer. This has been accommodated but each note can only be produced if information on the progress is fed-back into the WLC system – information which is required by WLC for shop floor control and in order to release other jobs from the pool. Hence, unlike previous functionality requests (e.g., for discrete scheduling functionality as requested by Company X: see Stevenson, 2006b), these requests can help, rather than hinder, the core WLC

system. Hence, these particular functions not only generate a sense of ownership of the system within the company but also attempt to ensure the WLC system is used effectively.

Issue D6:* The strategy chosen for Company Y is to begin with the full implementation of WLC. This is arguably the most feasible solution in many cases since it can be difficult to identify and isolate an appropriate section of a real job shop where a trial implementation of the WLC system can be conducted. However, given that it will take time to get key actors used to the system, to set appropriate parameters, gain control of the shop, and stabilise lead times, the initial period after full implementation will be considered as a trial. In addition, prior to implementation, presentations on the concept of WLC have been undertaken and an interactive training tool has been developed. This has played a role in: increasing awareness of WLC within Company Y; ensuring members of staff have a good understanding of the concept; and, avoiding misuse of the system once implemented.

Issue D7:* Insufficient data is available to support pre-implementation performance analysis and parameter setting decisions. In order to keep a record of the data which is particularly important for WLC and to facilitate regular progress review during the implementation process, a performance review module has been incorporated within the system. For example, the strike rate is defined as the percentage of quotations that are converted into firm orders; any changes over time or across customers will be monitored and reviewed. Machine utilisation is a function of actual loading and available capacity; regular review of these values could help with long term capacity adjustments. In addition, reviewing order progress could help to diagnose problems on the shop floor.

CONCLUSION

This paper uses the set of implementation issues presented by Hendry *et al.* (2008) as a checklist for embedding WLC in Company Y. Progress to date has confirmed the relevance of twelve of the seventeen issues identified in Hendry *et al.* (2008) to an additional case setting; in many cases the response to the issues is the same as in the previous study. Where the response differs, this is often an improvement on the response previously presented (see Table 2). The five issues which have not been significant influences on the implementation of WLC in Company Y to date may emerge at a later stage or be important to the implementation of WLC in other contexts. In addition, a further six issues, considered likely to be important issues affecting the implementation of WLC in other contexts, have been identified. For four of the six issues, appropriate responses are described. For the other two (C4* and D4*), further research is required. In addressing the implementation issues encountered in Company Y to date, theoretical aspects of the WLC concept have also been refined. Hence, the paper: validates many of the issues previously presented; contributes to developing a deeper understanding of issues surrounding the implementation of WLC; contributes towards a more detailed implementation strategy for successfully embedding WLC within an organisation; and, refines theoretical aspects of the WLC concept.

The research remains ongoing. The full system is currently being introduced into Company Y. To contribute to the second research question, the impact of WLC on performance will then be explored using both quantitative data (such as: due date adherence, delivery lead times, and shop floor throughput times) and qualitative data (such as: the opinions of the production and procurement administrator, the operations director and the most important customer of the company).

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