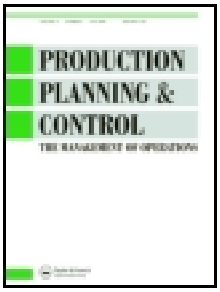

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The development and application of an interactive end-user training tool: part of an implementation strategy for workload control

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The development and application of an interactive end-user training tool: part of an implementation strategy for workload control

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Workload control (WLC) is a production planning and control (PPC) concept designed for complex manufacturing environments, with particular relevance to make-to-order (MTO) companies and small and medium sized enterprises (SMEs). Despite receiving much attention in the literature, few successful implementations have been reported. Moreover, a lack of awareness regarding WLC in industry affects the support it receives from employees within a company and, if implemented, it is sometimes misused or neglected. This article presents a new interactive WLC training and implementation tool developed within a WLC decision support system (DSS) which uses simulation to generate the incoming order stream at the customer enquiry and job entry stages and to mirror the throughput time variability on the shop floor of real-life manufacturing environments. This provides an action-learning package for end-users in order to improve understanding of the concept and generate support prior to implementation. In particular, the tool provides training and decision-making experience in: parameter setting; due date setting; the acceptance/rejection of jobs; scheduling intervention; order release decisions; and capacity management. This article reports on the application of the tool as part of a strategy to implement WLC in a small subcontract MTO company. Among other results, use of the tool: improved understanding of WLC; highlighted gaps between current business processes and those supported by WLC; and led to rethinking the choice of end-user for the DSS.

Keywords: implementation strategy; decision support system; production planning and control; small and medium sized enterprises; training

1. Introduction

Workload control (WLC) is a production planning and control (PPC) concept which, when commenced from the customer enquiry stage, is considered a leading solution for manufacturers of bespoke products, such as make-to-order (MTO) companies (Stevenson *et al.* 2005). Despite receiving much attention from researchers since the early 1980s, only a handful of empirical 'success stories' have been reported (e.g. Bechte 1988 and 1994). Researchers conducting empirical research often note a lack of awareness and understanding regarding the concept in practice (Silva *et al.* 2006, Stevenson 2006a). Previous research suggests that practitioners are not as familiar with WLC as they are with other PPC systems such as material requirements planning (MRP), theory of constraints (TOC), Kanban or quick response manufacturing (QRM) which have been popularised through influential texts by authors such as Orlicky (1975), Goldratt and Cox (1984), Shingo (1995) and Suri (1999), respectively.

This lack of familiarity can lead to resistance to change and a lack of support during the implementation process. WLC is typically implemented in the form of a software package; the sophistication of both the software and the concept underpinning the package mean that implementation can be a challenging process. A number of implementations presented in the literature reflect this (e.g. Hendry 1989, Hendry *et al.* 1993), where key problems have often related to the users of software packages that support WLC – if implemented, the WLC systems are sometimes misused or neglected.

To facilitate more widespread use, Hendry *et al.* (2008) investigated issues arising from implementing WLC through comparative case study analysis. The authors examined two implementation projects, one at a capital goods manufacturer in The Netherlands and one at a subcontract engineering firm in the UK. The authors investigated how implementation issues that arise in the context of WLC should be addressed

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to enable improved implementation in practice. The study identified seventeen implementation issues under five headings: market/customer, primary manufacturing process, WLC system requirements, information flow and organisational embedding related issues. The authors contribute by raising a series of research questions, including: 'how can planners and other personnel be trained such that decisions will be taken in correspondence with the integrated WLC approach?' And, 'how can a good balance be realised between showing (e.g. graphically) only results of WLC calculations, while maintaining sufficient understanding of the underlying logic for planners to take the right measures?' The authors suggested that a WLC training tool could be developed as a means of facilitating understanding, leading to appropriate use of the WLC system in both capital goods manufacturers and subcontract engineering companies.

The work of Hendry *et al.* (2008) provides the backdrop for this article in which we seek to address the above research questions by developing such a training tool and applying it to a small subcontract engineering company in the north-west of England (hereafter referred to as Company Y) as part of an implementation strategy for WLC. Other stages of the implementation strategy include: diagnosing current problems within the company; grouping machines; determining capacities; raising awareness both within the company and with customers and suppliers; determining the availability of information; populating the WLC system with job data, pre- (and later, post-) implementation data collection, and so on. The interactive training tool for WLC is built within a decision support system (DSS) based on the concept of WLC written in C# which builds on the system previously presented by Stevenson (2006a, b). The training described is being conducted prior to a proposed full implementation of WLC in Company Y.

The remainder of this article is organised as follows. Section 2 provides a brief overview of the concept of WLC before Section 3 explores the importance of training and the specific training needs of WLC. In Section 4, the interactive training tool is presented. Results from the application of the tool in Company Y (together with how the results were obtained) are discussed in Section 5; concluding remarks follow in Section 6.

2. Overview of the WLC concept

In its simplest form, WLC combines the use of an order release mechanism with a pre-shop pool of orders to reduce shop floor congestion, making the shop floor more manageable, consisting of a series of short queues. Thus the approach stabilises the performance of the shop and makes it independent of variations in the incoming order stream (Bertrand and Van Ooijen 2002). For most WLC concepts, jobs are only released onto the shop floor if released workload levels will not exceed preset maximum limits, whilst ensuring jobs do not stay in the pool too long in order to reduce (or stabilise) overall lead times and meet due date (DD) objectives. While jobs remain in the pool, unexpected changes to quantity and design specifications can be accommodated at less inconvenience. With an effective release method in place, only a simple shop floor dispatching rule, such as first-in-system-first-served (FSFS) or first-at-work-centre-first-served (FWFS), is needed (Kingsman 2000). Releasing mechanisms have a significant effect on the performance of the production system, reducing WIP and lead times (Hendry and Wong 1994). Despite the benefits of the order release stage, when a company is producing bespoke products, it is also acknowledged as important to control the customer enquiry and job entry stages.

There are a wide variety of WLC methodologies; these methodologies vary in sophistication in order to cater for a range of shop configurations from the general flow shop towards the pure job shop. In a broad sense these are typically classified into three types, based on their approach to workload accounting over time: the Probabilistic approach (such as Bechte 1988, 1994, Wiendahl 1995), the Aggregate or Atemporal approach (such as Hendry and Kingsman 1989, 1991, Stevenson and Hendry 2006) and the Time Bucketing approach (such as Bobrowski 1989). At the order release stage, methods also vary in their approach to workload bounding (i.e. the use of upper and/or lower workload restrictions), with some others adopting a (less rigid) workload balancing philosophy (Cigolini and Portioli 2002). For a more complete description of WLC, see also Land and Gaalman (1996), Bergamaschi *et al.* (1997) and Kingsman (2000).

The WLC methodology incorporated in the DSS as described by Stevenson (2006a and b), and thus also incorporated in the training tool described herein, is commonly referred to as the 'LUMS approach' and can be described as an aggregate load-oriented approach using upper bounding of the workload lengths. The LUMS approach is built around the control of a hierarchy of workloads beginning when a prospective customer first enquires, thus accommodating the customisation offered by MTO companies in the design of the PPC concept. Hence, the methodology includes the customer enquiry, job entry,

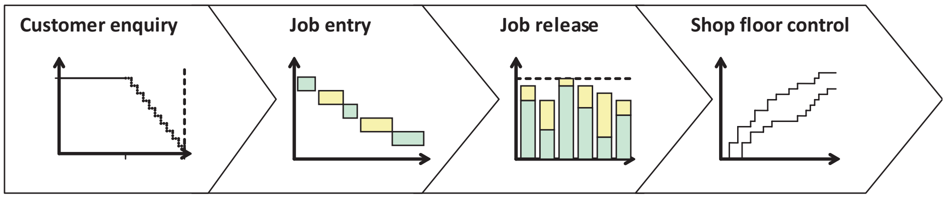

Figure 1. Workload control planning and control stages.

job release and shop floor control stages. In the case of the shop as a whole, the hierarchy of workloads incorporated in the LUMS approach is as follows, where each is a subset of the workload below.

(1) Released Workload: The total work content of jobs on the shop floor.
(2) Planned Workload: The total work content of accepted jobs awaiting materials, in the pre-shop pool and on the shop floor.
(3) Total Workload: A proportion of the total work content of unconfirmed jobs (the strike rate), in addition to the total work content of all accepted jobs.

Figure 1 illustrates the planning and control stages involved in the LUMS approach together with typical control charts that aid the user of WLC systems; for example, the time-phased total workload distribution is controlled at the customer enquiry stage, Gantt charts can be used at the job entry stage in relation to backward scheduling, released workload charts are controlled at the job (or order) release stage and shop floor throughput oriented diagrams (e.g. Wiendahl 1995, Soepenberg *et al*. 2008) can be consulted for shop floor control.

A screen shot from the job entry stage of the DSS, with a job Gantt chart produced using the backward scheduling method described above, is shown in Figure 2. For a more complete description of the LUMS approach, see Hendry and Kingsman (1989 and 1991), Hendry *et al*. (1993), Kingsman (2000), Stevenson and Hendry (2006) and Stevenson and Silva (2008).

3. Training and implementation issues

Although the fit between an organisation and a PPC system is important, it is not usually the functionality of an information system (IS) that leads to implementation failure (Petroni 2002) but less tangible aspects such as internal political factors and the level of management support. It is argued here that providing an interactive software tool prior to implementation is a useful means of gaining support for the project and of improving the effective utilisation of the system once implemented.

If employees anticipate a negative impact on their working environment as a result of a new IS, they may decide to sabotage this in some way; the anticipated negative impact may result from a lack of understanding of the system and its benefits. Laudon and Laudon (2001) refer to Keen (1981) in stating that an implementation strategy must address the issue of counter-implementation. The authors explain that counter-implementation relates to a deliberate strategy to thwart the implementation of an IS or innovation in an organisation. Cooper (1994) finds that when information technology conflicts with the culture of an organisation it can be resisted in one of two ways. Firstly, employees may undermine the analysis and design process: if the system is developed the potential of it will be under-utilised or the implemented system sabotaged. Secondly, users may adapt the system (to suit their needs) once implemented or use it in a way that reduces conflict. To understand the motives of the end-users it is important to look at the project from their viewpoint. Joshi and Lauer (1998) summarise some of the perceived potential *impacts* on the working environment of employees when facing the implementation of an IS system and explain that implementation may also affect *inputs* from the user in a positive or negative way. For example, a new IS may mean more data input for the employee, require the user to learn new skills and increase anxiety for the user. On the other hand, it may reduce the need to search for an effective solution to a problem, reduce manual effort required and result in less rework previously caused by errors.

Addressing intangible aspects prior to implementation is clearly an important step. The following discussion focuses on pre-implementation training of end-users for two reasons. Firstly, to create enthusiasm for the future implementation of WLC (thus addressing the issue of counter-implementation) and secondly to improve understanding of the concept, thus avoiding misuse or neglect of the system in practice.

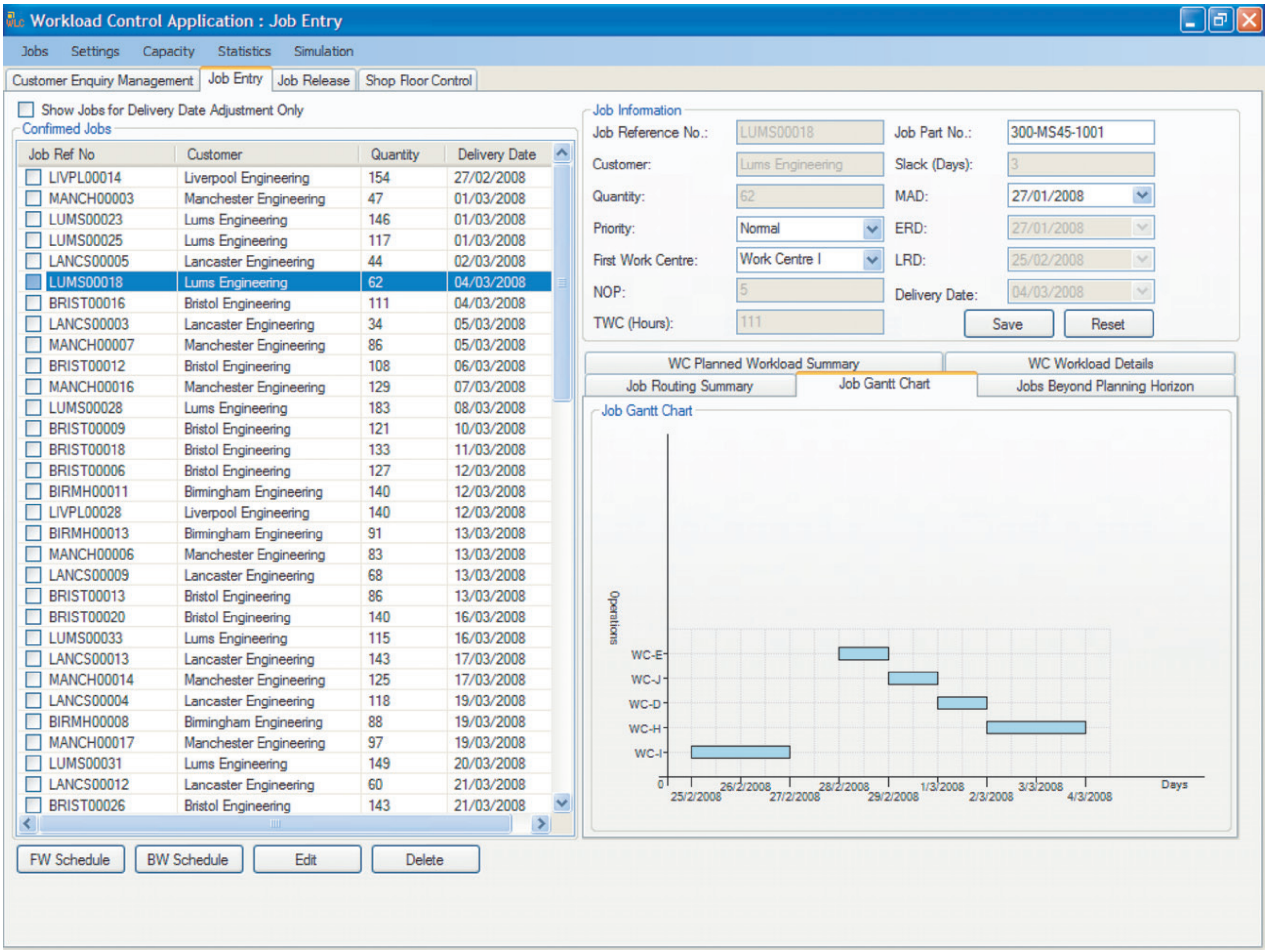

Figure 2. Job entry stage of the DSS.

3.1. *The importance of end-user training*

In general terms, the importance of end-user training to the acceptance and effective use of software solutions is well documented (Nelson and Cheney 1987, Davis and Bostrom 1993, Compeau *et al*. 1995, Lee *et al*. 1995, Shayo *et al*. 1999). But while training users of planning systems like enterprise resource planning (ERP) systems has begun to receive attention (Choi *et al*. 2006, Bradley and Lee 2007), this issue has been neglected in the context of WLC. Training and learning in an organisation can provide many advantages to the (pre)implementation process, such as greater awareness, reduced resistance to (and 'fear' of) procedural change, greater system utilisation, and improved motivation. Training can take many forms, including courses, manuals, lectures, demonstrations and seminars, but can be particularly effective when presented in a hands-on manner, i.e. 'action-learning' or 'learning-by-doing'. Computer-based simulation and gaming in particular provide useful hands-on learning approaches (Towne *et al*. 1993, de Jong and Sarti 1994, Riis 1995, Shtub 2001, Rauch-Geelhaar *et al*. 2003, Olhager and Persson 2006) stemming from the notion of programmed learning and teaching machines (e.g. Thomas *et al*. 1963). Such computer-based simulated learning tools can provide an interactive platform through which end-users can gain rapid exposure to the types of problems they will experience in a 'live' environment, increasing their understanding of the system and improving their diagnostic skills.

3.2. *Addressing WLC end-user training needs*

Empirical research has noted a number of problems when using WLC systems in practice (Hendry 1989, Silva *et al*. 2006, Stevenson (2006a, b) but few authors have focused on resolving the implementation problems of WLC or on providing guidance for practitioners. Six reasons why it is argued that training in the use of WLC systems and techniques is required are summarised below:

(1) WLC researchers have thus far failed to provide adequate guidance for setting the various parameters that underpin WLC. Multi-dimensional interactions between the various parameters make setting these values a difficult and time consuming process often performed over time through an iterative trial and error approach. Hence, at present the process relies heavily on the experience and judgement of management and end-users but managers and end-users are unfamiliar with some of the parameters that need to be set. For example: how is a manager with no experience of WLC expected to set anticipated pre-shop pool delays or released workload length restrictions accurately?
(2) Previous empirical studies have observed that end-users have a cultural tendency to quote short and unrealistic DDs in order to 'win' tenders. Without understanding the importance of quoting reliable DDs, this process is likely to be repeated and can undermine the control of the lower levels of the hierarchy of workloads (e.g. job release).
(3) Users and managers have a reluctance to reject jobs with fixed DDs even if they know there is insufficient capacity and that late delivery will harm the reputation of the company. In some cases, rejecting a small percentage of jobs could dramatically improve the overall DD performance of the shop.
(4) Managers often want detailed schedules from which to work; without understanding the nervousness of discrete scheduling in highly variable manufacturing environments, users may consider the shop floor control support offered by WLC to be inferior (rather than more appropriate and robust).
(5) Users have a tendency to release jobs from the pool almost immediately (i.e. on their earliest release dates when materials are first available) without considering workload lengths or latest release dates. Users also attempt to batch repeat orders with staggered DDs and release them collectively (perhaps resulting in some late deliveries and some jobs being in finished goods inventory for a long time). This is because the idea that delaying the release of a job can improve throughput times and DD adherence can be a relatively 'alien concept'. This issue is also touched upon by Wiendahl (1995) who explains that companies must give up 'traditional manufacturing concepts'.
(6) Finally, users must be able to make effective capacity management decisions, such as by reallocating operators from under-loaded to overloaded work centres. This relies on experience of diagnosing problems highlighted by the WLC system (e.g. by interpreting graphs), which can only be gained through repeat use. It is also important that users understand the impact of making capacity adjustments throughout the hierarchy of workloads.

Wiendahl *et al.* (1995) are the only known authors to have developed an interactive training tool that can be utilised by end-users of WLC concepts. The authors developed a simulation-based training system for job shop control known as TRAIN-F to be used in small group situations. In the system, users can set rules and parameters for lot sizing, capacity planning, scheduling, and order release before simulating the shop's processes for 'n' time periods. The user can then view reports on shop performance and make changes before running the simulation again. This gives the user a unique insight into a WLC system before they encounter it in a 'live' environment; however, the package focuses on parameter setting, does not include control at the customer enquiry stage, and gives the user only limited exposure to the WLC decision-making process (there appears to be no user interaction with the training tool between the start of the run, time period '1', and the end of the run, time period 'n'). It is argued here that there are many other important issues beyond the scope of TRAIN-F in which users of WLC systems require training.

The remainder of this article describes a new interactive software tool and its application in Company Y. The tool incorporates simulated order arrivals and production uncertainties; in contrast to Wiendahl *et al.* (1995), the tool begins at the customer enquiry stage and addresses all six of the problem areas described above. The training tool is developed within the DSS that will be used in the 'live' environment, providing a more hands-on learning tool for end-users than that presented by Wiendahl *et al.* (1995).

4. The interactive training and implementation tool

Despite the value of simulation for end-user training, simulations in a WLC context can commonly be criticised for two reasons (Stevenson 2006b): (1) for failing to capture the characteristics of real-life manufacturing environments and job shops; and

(2) for not adequately reflecting the ad hoc decisions made by managers and planners in practice, i.e. assuming that users will employ WLC exactly as planned, releasing jobs according to shortest slack, maintaining workloads below restrictions, and so on. This tool overcomes both of these criticisms by striking a balance between simulated theory and real-world practice. For example: (1) by using data collected from a case study, the tool mirrors the characteristics of a real-life company (thus ensuring the practical applicability of the tool); and (2) by combining simple but realistic simulation techniques with interactive user decision-making, the tool incorporates both process variability and the types of ad hoc decisions made in practice.

4.1. *Job shop characteristics*

One of the key advantages of this tool is that it provides a dynamic environment that mirrors the instability of a real-life job shop in which the user can directly, and gradually, influence performance. A purely simulation-oriented training tool would provide limited interaction for the user while the DSS on its own without 'live' data provides only a static environment. The shop characteristics of the tool are based on data collected through interviews during the early stages of the current research project with Company Y. Company Y is a small precision engineering company producing a wide range of subcontract components to the bespoke needs of its customers in the aerospace, commercial, textile and food industries. The company is involved in producing one-off jobs as well as the repeat production of bespoke products that a customer repeatedly orders over the length of a contract.

The following company characteristics have been incorporated into the tool (these can be changed to reflect other shop and job characteristics):

- 23 shop floor machines organised into 12 work centres (including work centres for inspection and subcontracting).
- Work centre capacities based on 20 operators and three shift patterns.
- The strike rate of the company, initially set to 20%, i.e. 20% of quotations lead to firm orders.

4.2. *Simulated order arrivals and shop variability*

Simulation provides: (1) the incoming order stream at the customer enquiry and job entry stages and (2) shop floor variability. This creates an unpredictable environment in which the user must make decisions. The simulated elements of the tool have the features described below, based on data collected in Company Y to provide familiarity but simplified in parts to improve understanding during initial training.

- The number of customer enquiries (per period) follows a Poisson distribution with a mean of 5.
- Each job has characteristics that are statistically independent of other jobs.
- The number of operations per job follows a discrete uniform distribution from one to seven (mean of four operations).
- The routing sequence is generated randomly across the 12 work centres.
- Order quantities follow a (non-negative) Normal distribution with a mean of 250; hence focusing largely on the repeat products of the company. Detailing quantities allows users to apply lot splitting if they wish.
- Estimated processing and set-up times at the customer enquiry stage follow a (non-negative) Normal distribution with means of 20 minutes per unit and 1 hour, respectively. Giving set-up and processing times separately allows for batching and lot splitting decisions.
- 10% of jobs are given 'high priority' in the pool and on the shop floor (as an additional decision-making consideration for the user).
- The acceptance of tenders by customers is modelled based on the strike rate of the company (initially set to 20%) and the expected customer confirmation time (an average of 2 weeks).
- Order progress on the shop floor is updated automatically; orders are initially given a probability of 70% of being completed on time.
- The time delay of operations not completed on time, and hence the subsequent operation completion date of late orders, follows an exponential distribution.

4.3. *User decision-making*

The user is encouraged to gain experience in making decisions throughout the order progress cycle from DD setting at the customer enquiry stage to expediting jobs on the shop floor. In particular, the user gains understanding of the WLC system by making the decisions outlined below, while the roles of the user, simulation module and existing DSS are also summarised in Table 1.

Table 1. Summary of the roles of the DSS, simulation module and end-user.

	Action taken by	Roles/Responsibilities
System setup	End-user	Initial parameter setting (e.g. pool delays, workload length restrictions and expected shop floor queuing times); Over time the user can revisit parameters and change them in order to more effectively control the workload of the shop.
Customer enquiry	WLC simulation	Customer enquiries (and job specifications) generated on a periodic basis. Each customer enquiry is given a unique (sequential) reference number on arrival.
	WLC DSS	Due dates are proposed by the WLC system.
	End-user	The user is able to assess (and alter) due dates, considering job characteristics; The user can also change capacities in order to improve the competitiveness of due dates calculated by the system.
Order acceptance	WLC simulation	A proportion of tenders are offered to the company.
	End-user	The user must decide whether to accept/reject jobs based on the due dates, shop load, etc; The user can also change capacities before making the final decision.
Schedule entry	WLC DSS	Accepted jobs are backward scheduled from their due date to a latest release date (creating a series of operation completion dates).
	End-user	The user can assess job schedules and decide whether to manually alter these or change capacity before re-scheduling using the functionality of the DSS; Alternatively, the user can forward schedule jobs to new due dates.
Order release	WLC DSS	Jobs are listed in the pre-shop pool in accordance with latest release dates.
	End-user	The user can simply release jobs in accordance with latest release dates or experiment with different job mixes, lot splitting, capacity changes and so on, before making the final release decision.
Shop floor control	WLC simulation	The progress of jobs on the shop floor is updated automatically, incorporating throughput time variability.
	End-user	The user can view work-in-progress and manage capacity/expedite jobs to meet the required operation completion dates and due dates.

- *Parameter Setting*: Parameters for WLC are set at the start of the 'run' and can be adjusted over time as the user develops a greater appreciation of the interactions between parameters and the relationship with shop performance; for example, the link between total workload restrictions and delivery lead times and between pool delays and latest release dates. Parameters include: material lead times, pool delays, expected shop floor queuing times per work centre and the workload length restrictions.
- *Due Date Setting*: The advised DDs of new customer enquiries are proposed by the training tool based on a standard calculation, as detailed in Stevenson (2006a and b). The user can assess proposed DDs and change them if necessary. The user can also reallocate operators and assign overtime to improve the competitiveness of the DDs proposed.
- *Acceptance/Rejection of Jobs*: A subset of tenders, based on the strike rate, are 'won' by the company. The user must decide whether to accept or reject each tender won by considering the DD, current load of the shop and job characteristics. The user may also decide to use further output control measures to avoid rejecting jobs.
- *Job Scheduling*: Accepted jobs are backward scheduled from the DD to a latest release date (generating a set of operation completion dates). For jobs that the system has been unable to schedule, the user can choose to forward schedule to new and more realistic DDs or change capacity to improve the feasibility of backward scheduling. The user can also choose to manually change operation completion dates, latest release dates and the priority of jobs.
- *Order Release*: The user is introduced to the order release process and the use of released workload restrictions. The user can view jobs in the pool and experiment with different job mixes before making the final release decision. Users can change capacity to improve release options, choose to release jobs in accordance with latest release dates, change the chosen mix of jobs, override workload restrictions, split large quantity items, etc.

4.4. *Typical training and parameter setting cycle*

Training can be performed individually or in cross-functional teams to expose employees to the problems faced by other members of a company. The user(s) of the training tool begin with an empty shop and the load of the shop is gradually built up over time; this is also considered a sensible approach to implementing WLC in a 'live' environment. Given the need for short and competitive lead times, the periodic interval at which the system is utilised is likely to be set to 1 day. This is true of Company Y; when the system is implemented, customer enquiries will have to be managed on a daily basis and the system will support job release decisions made each morning at the company's planning meeting.

In the first period (Day1), the user must set up the initial parameters. The user can then view the simulated customer enquiries, job offers, job schedules, jobs awaiting release and those on the shop floor, as described above. If the user is happy with the proposed DDs, schedules, and release sequence, all that they are required to do is confirm the decisions; hence, the tool can be quick and simple to use. Decision-making is supported by a user-friendly graphical interface; the user can also consult performance indicators to assess the current state of the shop (e.g. DD adherence of jobs, planned versus actual operation completion dates, and the current workload of the shop). When the user has made all their decisions, they can click to accelerate the internal clock to the next time period (Day 2), where the next stream of enquiries, orders and shop floor problems will be generated. At the start of the next period the user may decide to make parameter changes; this experience will be invaluable when the system is implemented in practice, especially if the training tool reflects the real-life shop characteristics.

Figure 3 shows the customer enquiry management module of the DSS. Unconfirmed jobs in the list are sorted according to the earliest required DD based on the type of rule of thumb observed in practice (determining the DD by adding a lead time of 6 weeks to the enquiry date). The advised DD proposed by the DSS is shown in the job information part of the module. The form shows the expected delivery lead time for each job, the advised earliest possible DD (see top right of Figure 3), and displays all jobs for which quotations are being produced or that are currently under consideration by prospective customers (see left-hand table in Figure 3). Together with the delivery lead time and advised earliest DD, the time-phased Total Workload chart provides the user with a visual aid for DD determinations and negotiations with customers by indicating the distribution of workloads through time. The summary table (see bottom right of Figure 3) indicates the instantaneous workload details of the shop and resources. The user can experiment with changing the quantity, and hence the total work content of a job, and assessing the resulting impact on advised DDs and capacity requirements. The user can also assess the impact of changing material lead times on advised DDs. The user can then formally set the DDs of new enquiries to quote to the customer.

Figure 4 shows the job release module. Jobs awaiting release (in the left-hand table) can be selected and the impact on released workload lengths evaluated. The user can assess released workload length charts and tables, taking into consideration the maximum/minimum released workload lengths to avoid excess congestion or unnecessary machine idleness. The user is advised to consider e.g. job priority, slack, and the workload limits in choosing jobs for release. Providing an opportunity to assess the impact of multiple jobs on shop floor resources allows the user to see the cumulative effect that jobs have before making any decisions or releasing any jobs. Although the whole workload of a job is added to resources at the moment of release, inevitably the user is likely to pay particular attention to the immediate impact of the job on shop floor queues, especially if processing times, queuing times or routings are long. As a result, the DSS indicates the first resource that a job will visit. Once the user has made a final decision, the user can choose to release the selected jobs onto the shop floor and the DSS updates the released workloads. The full training and parameter setting cycle is illustrated in Figure 5; the following section presents results from the application of the tool in Company Y.

5. Results from the application of the tool

The tool was initially used by the production and procurement administrator (PPA) and the operations director (OD) of Company Y during a workshop held by two members of the research team as part of an implementation strategy for WLC. PPA and OD each spent several hours interacting with the system, discussing its functionality and asking questions, whilst working through the planning and control stages. The users were able to track a single job from enquiry through to completion to aid discussion and develop conceptual understanding. The researchers asked PPA and OD a series of questions both during and after the workshop (e.g. to gauge changes in their level of understanding) before comparing and validating their responses during a follow-up interview at a

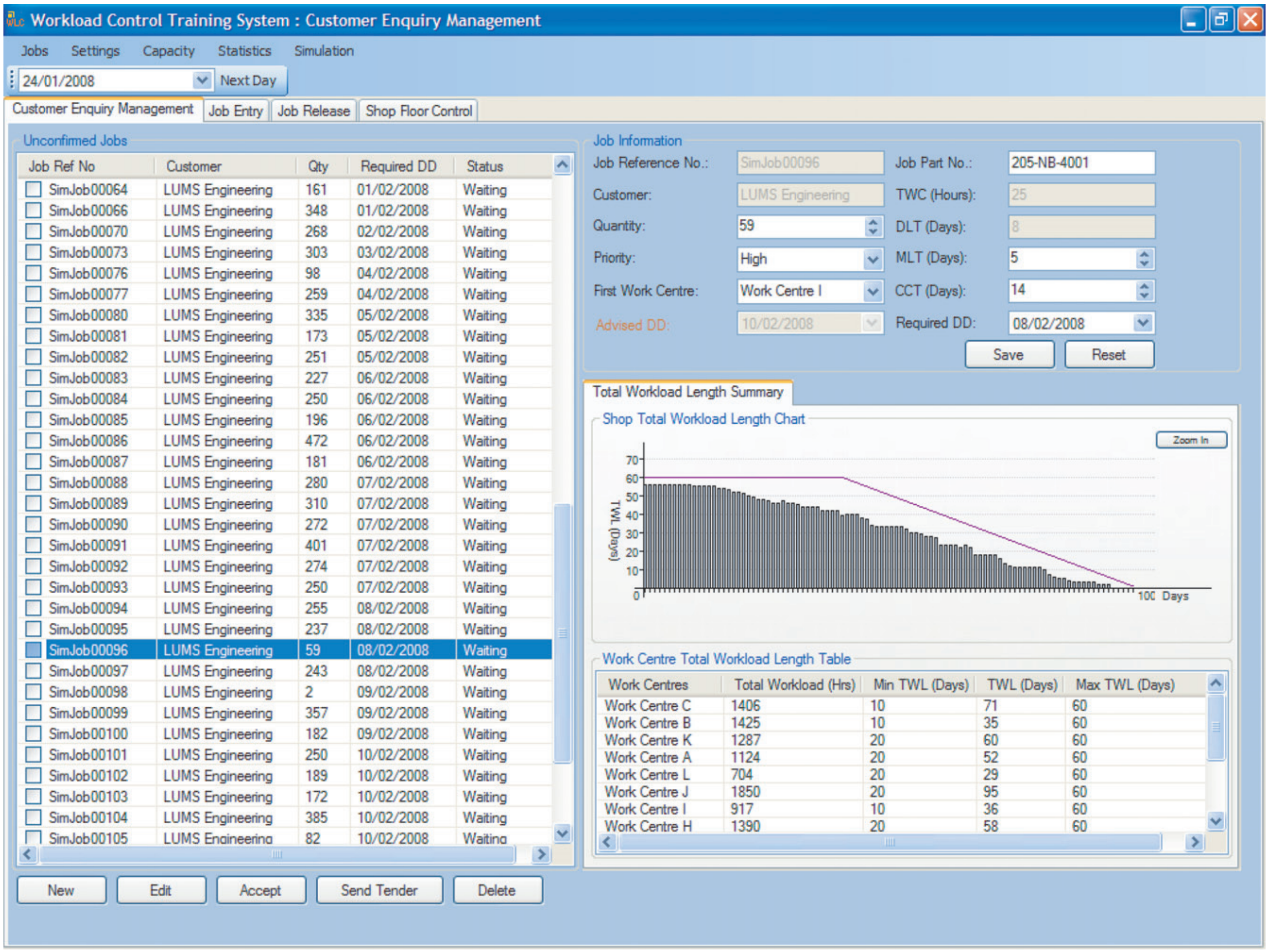

Figure 3. The simulated incoming order stream at the customer enquiry stage.

later date. A formal presentation on WLC was also given to PPA and OD and, after the workshop, PPA and OD were provided with a copy of the software so that training and awareness could filter through to other key actors (supported by members of the research team where appropriate). Since then, PPA, OD and others have used the training tool independently and the research team has been involved in additional training workshops for other members of staff.

5.1. *Results from the application of the tool*

Results support the suggestion by Hendry *et al.* (2008) that a training tool could facilitate understanding and appropriate use of WLC in practice. The tool has formed an important part of the overall implementation strategy, playing the following roles:

- *Confirming an appropriate system/company selection*: Training has provided an extra layer of assurance that WLC is an appropriate solution for the PPC problems of Company Y. Both PPA and OD confirmed that after the training they were more confident that WLC was the right solution for their problems and that other methods, such as highly discrete scheduling methods, would not be effective.
- *Reducing 'fear' of the system*: Prior to the training, PPA and OD were unaccustomed to terminology such as 'released workload length' and were unable to navigate their way round the DSS. Training improved their familiarity with WLC terminology and with the interface of the system.
- *Improving understanding of the WLC concept*: Training gave PPA and OD the opportunity to interact with the system, ask questions and gain experience making key WLC-related decisions, thereby improving their understanding. By experimenting with the capacity

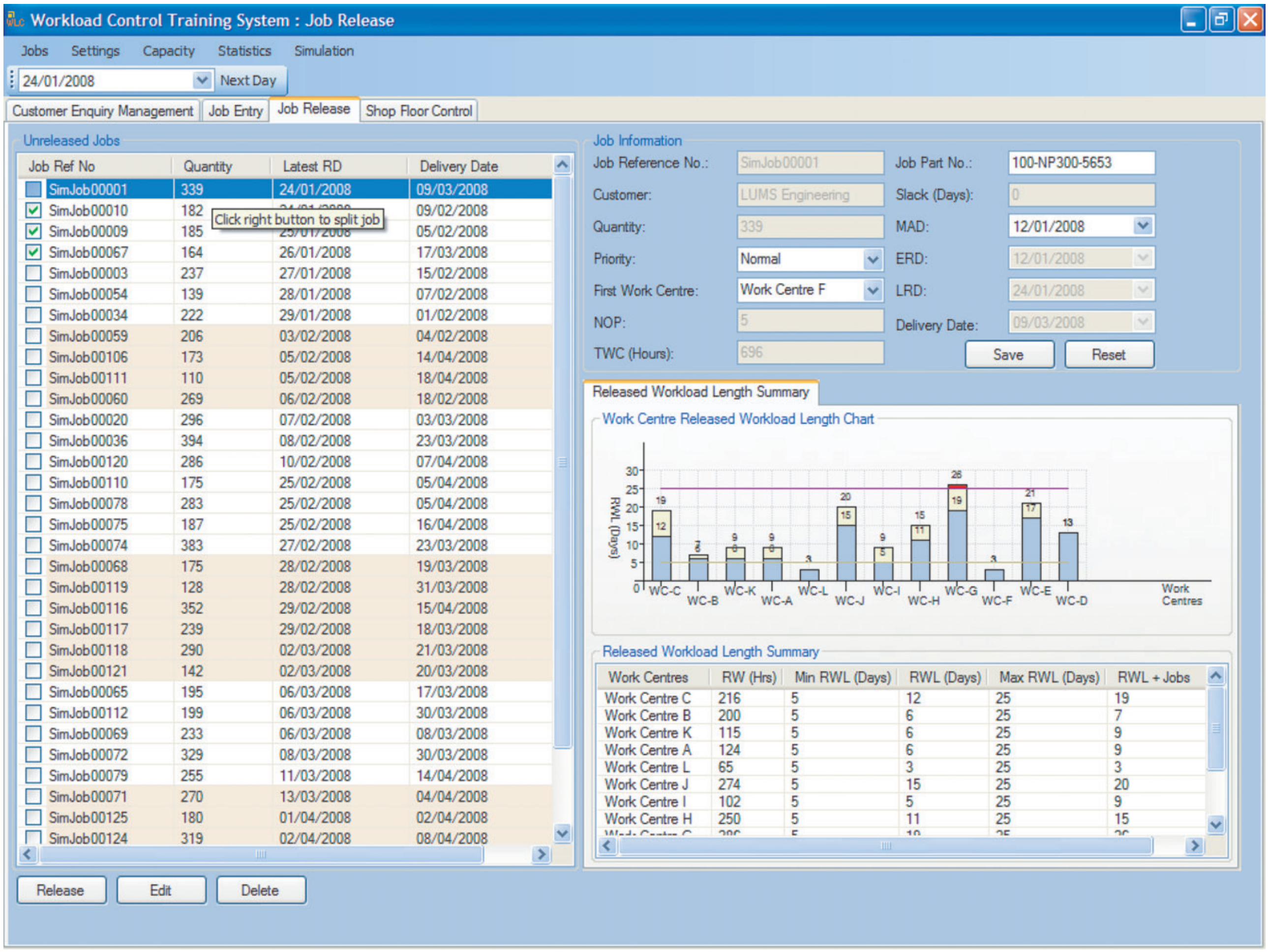

Figure 4. Job release user training and decision-making interface.

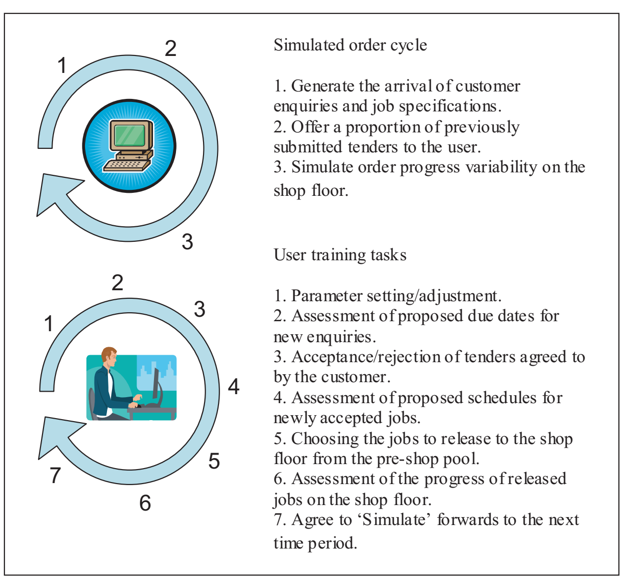

Figure 5. Interactive training and parameter setting cycle.

management module of the system, users can also learn how to effectively bring the shop 'under control' and respond to change. Both PPA and OD commented that they felt they had a better understanding of the WLC concept after the workshop.

- *Determining gaps between theory and practice*: Training provided the opportunity to compare Company Y's current business processes with those supported by the WLC system and the data that these processes require. This led to the conclusion that, in practice, Company Y is unlikely to be able to provide detailed information at the customer enquiry stage and so the system would have to propose DDs based on standard work centre throughput times rather than by more sophisticated means. Discovering this prior to implementation was important and allowed the proposed solution to be adapted.

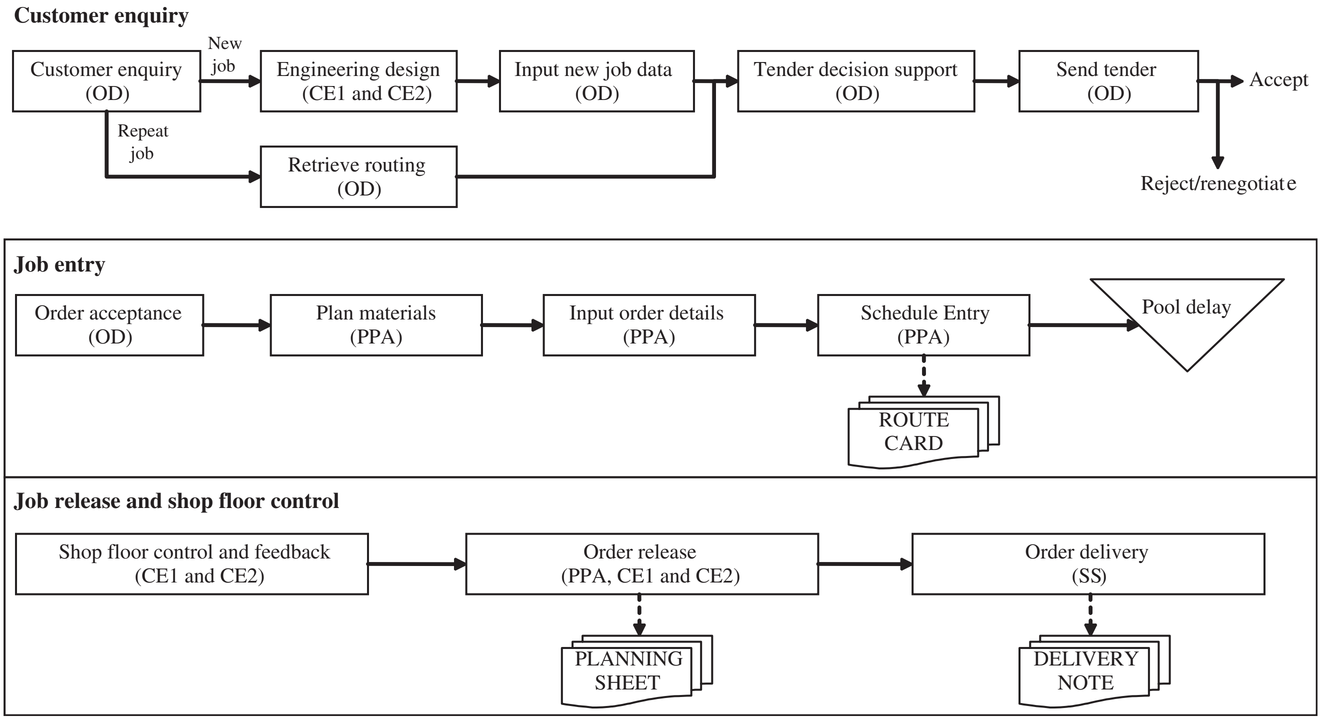

Figure 6. Workload control system roles and responsibilities in Company Y.

- *Facilitating system analysis and design*: For users to take 'ownership' of the system, it is important to meet individual functionality requests, providing that they do not create conflict with the WLC concept. The training tool provided a platform for determining individual requirements prior to 'going live'. PPA asked for the option to 'park' a quotation, i.e. to be able to save a draft tender prior to submitting it formally to the customer without it contributing to the total workload length of the shop. PPA also requested that the system be adapted to cope with scrap/material losses (e.g. the released quantity may be 100 but by the time the job has reached the fourth operation, the quantity may be 95 and this should be reflected in the workload) and inspections (e.g. incorporating a time delay to account for a specified percentage of the quantity being checked prior to delivery). OD requested that the system produce the route card and delivery note for each job. This was encouraged as it tied important business processes into the WLC system and means that, in the future, the company will have to use the system routinely and provide regular feedback information if route cards and delivery notes are to be produced. OD also requested that the system performs 'impact analysis' for rush orders, i.e. if a tight DD is requested by the customer, the system should inform the user whether meeting it is realistic and if the DD adherence of other jobs will be affected.
- *Prompting a rethink of roles and responsibilities*: Prior to training, it was decided that PPA would be the main end-user of the system; however, training provided an opportunity to determine who is responsible for each PPC stage in practice and to reconsider who should use the system. It became clear that OD and two chief engineers (CE1 and CE2: responsible for turning and milling) will also need to use the system. CE1 and CE2 are needed, for example, in order to determine the production and material requirements for non-repeat jobs at the customer enquiry and job entry stages. The system will also be used by multiple users to support job release decision-making and to feed information back into the system at daily planning meetings. In addition, secretarial staff (SS) will perform some administrative tasks. Figure 6 summarises the key roles and responsibilities agreed with employees of Company Y following the training exercise.

- *Highlighting outstanding implementation issues*: Training prompted a detailed discussion of issues that needed to be addressed before the system can be used in practice. For example, it became clear to PPA and OD that, if there were too many work centres, controlling all the individual workload lengths would become unmanageable; this convinced them to group machines into 12 work centres. It also became clear that machine groupings would be influenced not only by interchangeability but by machine location, operator responsibilities, and ownership (some machines are for the exclusive use of particular customers). Discussion also raised the question of how the system would be initially populated. It was decided that basic information (e.g. customer details, machine details, employee shift patterns, etc.) would first be input before data on repeat jobs is built up. Once the majority of repeat jobs have been entered, new enquiries will be entered as and when they are made and the current order book will be used to build up a picture of the current shop load. Given that most jobs are delivered to the customer within 6 weeks of order confirmation, this time horizon will be used as a system start-up period.
- *Supporting WLC parameter setting*: Relatively little research has been conducted to support parameter setting; it arguably remains a trial and error process. While iterative changes are inevitable post implementation, it is important that parameters are not altered continuously. Regular changes may also lead to extreme system nervousness; the user must give the system long enough to reflect the changes made to the parameters in the control of the hierarchy of workloads. Training provided an opportunity for PPA and OD to understand what parameters need to be set for WLC and played a role in determining what starting values would be appropriate.
- *A glimpse into end-user behaviour*: Training gave the research team the opportunity to observe how users interact with the system, albeit it in a test environment, and make decisions. Changes to the interface of the WLC system have been made in response. It also became clear that the behaviour of users is influenced by elements not captured by the theory currently underpinning the WLC system; for example, release decisions are strongly influenced by many factors, such as the strategic importance of the customer at a particular moment in time and order profitability (not just the latest release date).
- *Proposing what-if scenario testing*: Having benefited from the training, PPA and OD have been keen to find new uses for the tool. PPA and OD suggested that principles from the training tool should be incorporated in the full system. For example, users could be permitted to access the database underpinning the company's 'live' system in an off-line environment so that decisions can be simulated before being made in practice. For example, the company could accept certain DDs, change capacities, or release certain jobs in the test environment and accelerate forwards over several time periods to gauge possible effects before making the decision in practice.

6. Conclusion

Despite receiving much attention in the literature, successful implementations of WLC are few and far between. A lack of understanding in practice regarding WLC is considered to have been a major barrier to implementation. Hence, it is necessary to provide pre-implementation training and support to end-users of WLC systems. This article has contributed by describing a training and implementation tool which provides an interactive learning environment for end-users that goes beyond the tool proposed by Wiendahl *et al.* (1995) and addresses research questions raised by Hendry *et al.* (2008).

By applying simulation techniques to populate the shop and model typical job shop uncertainties and variability, users are exposed to the end-system in a test environment. The tool provides training and decision-making experience in six key areas: parameter setting; DD setting; acceptance/rejection of jobs; scheduling intervention; order release decisions; and, capacity management. Section 5 reflected on the application of this tool as part of a strategy to implement WLC in Company Y. Among other results, use of the tool: improved understanding of the WLC concept; highlighted gaps between current business processes and those supported by WLC; and led to rethinking the choice of end-user for the WLC DSS.

Current research focuses on implementing the DSS in Company Y and assessing the impact of

WLC in practice. Future research will explore other case study settings and seek to present a complete framework for implementing WLC. Future research may also use the tool described to ask: how does training affect the number of iterations required to set appropriate parameters for WLC? How does the sophistication of the WLC methodology (e.g. probabilistic versus aggregate load-oriented release method) affect the 'success' of training? And, how does training affect the decision-making processes employed within an organisation in the long term? The tool may also be further developed to train users in additional skills; for example, feeding back information from the shop floor to the system. Artificial intelligence could also be incorporated so that the competitiveness of individual DDs quoted by the user are reflected in the tenders 'won' by the company. The research has implications for the design of field studies: an appropriate level of training should be provided before attempting to implement WLC in practice.

Notes on contributors

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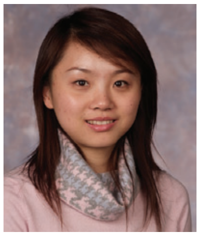

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