Lean for small Make-to-Order Shops: Operationalizing Workload Control (WLC) using Spreadsheets

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Abstract
Lean has been one of the most important developments in OM. Yet, many make-to-order shops found lean's control techniques do not apply. Workload Control is a planning and control concept designed to address this need. A simple operationalization is presented underlining Workload Control's suitability for small shops with restricted financial resources.

Keywords: Workload Control, Lean, Decision Support System

Introduction
The emergence and subsequent popularization of lean has been one of the most significant developments in the history of operations management. Yet, many of lean's production planning and control techniques – such as the use of Kanban containers for inventory control – which emphasize simplified scheduling and synchronized flow cannot be directly applied to shops that produce high-variety products, such as small and medium sized make-to-order companies. Workload Control is a production planning and control concept designed to meet the needs of make-to-order companies (e.g. Stevenson *et al*. 2005). A key challenge these companies face is striking a balance between the input rate of orders and their capacity (i.e. the output rate) to ensure that the shop remains busy while simultaneously delivering confirmed orders in a timely fashion.

The key principle of Workload Control is input/output control; i.e. the actual output determines the input. This allows the work-in-process to be stabilized and reduced. So, Workload Control supports managers to effectively use the inventory, capacity and lead time buffer through the simultaneous control of inventory, capacity and lead time, integrating production and sales into a hierarchical system of workloads. The hierarchy of workloads consists of: the shop floor workload; the planned workload; and, the total workload. The shop floor workload, or work-in-process, is controlled through an order release mechanism, which decouples the shop floor from any higher level planning using a pre-shop pool of orders. Jobs are not release immediately once confirmed but flow into a pre-shop pool of orders from which they are released to meet due dates while maintaining work-in-process at a stable level. The planned workload consists of all accepted orders, and therefore includes both the shop floor workload and orders in the pre-shop pool. Finally, the total workload consists of all accepted orders plus a percentage of customer enquiries based on order winning history, known as the "strike rate". The planned and total workloads are controlled through customer enquiry management.

Order release and customer enquiry management act as workload filters; they are considered complementary tools for reducing variance in the system (e.g. Kingsman *et al*. 1989, Melnyk *et al*. 1991). Customer enquiry management defines the lead time buffer and controls the incoming workload in line with available capacity. This allows order release to balance the workload on the shop floor, reducing the inventory buffer required and ensuring capacity is used effectively.

Many simulation studies have demonstrated that Workload Control can lead to significant performance improvements in job shops (e.g., Land 2006, Oosterman *et al.* 2000, Thürer *et al*. 2012 and 2013); however, reports of successful implementation in practice are limited. Part of the reason for this is that practitioners are often unfamiliar with Workload Control, meaning resistance to change is encountered and significant training is required (Stevenson and Silva, 2008). Moreover, Workload Control adoption is often coupled with that of a computer system to support Workload Control-related decision making, which adds to the complexity of implementation; identifying an appropriate end-user for the system is often challenging (Hendry *et al.* 1993). In response, this study provides a first step towards future implementation outlining a simple operationalization of Workload Control using spreadsheets.

Workload Control

The Workload Control concept is summarized in Figure 1. Customer Enquiry Management will first be discussed before attention turns to Order Release. Note that we only give a short account of the concept here. For more and detailed information the reader is referred to Thürer *et al*. (2013) and www.workloadcontrol.com.

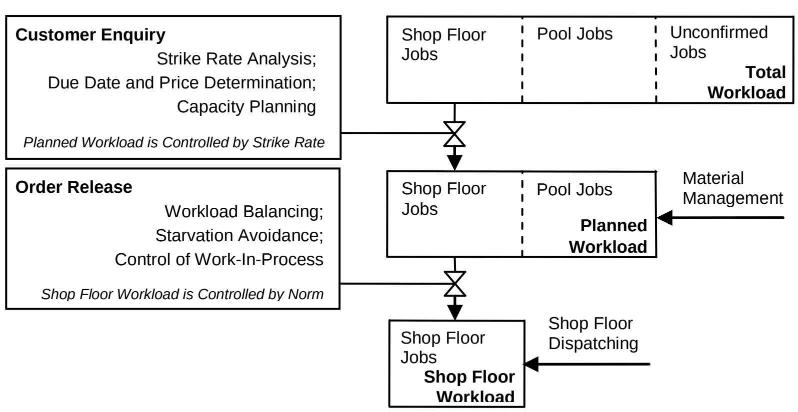

Figure 1: Summary of Workload Control Stages and Hierarchical Workload Management

Customer enquiry management acts as a first filter which undertakes some coarse smoothing of the planned workload. This workload smoothing or load balancing corresponds to one of the main principles of *heijunka* in lean operations and prevents surges in work which temporarily deplete the capacity buffer and increase the inventory buffer in the form of work-in-process. Customer enquiry management consists of three inter-dependent parts:

- *Forward Scheduling (due date setting):* a feasible due date is determined by the company planning and controlling capacity over time.
- *Backward Scheduling (due date feasibility):* the feasibility of a due date specified by the customer is assessed and capacity is planned and controlled over time.
- *Strike Rate Analysis:* the probability of winning a tender for a specific set of outcomes (e.g. due date and price) is assessed using historical data.

The three elements of customer enquiry management provide a company with the tools to bridge the commonly encountered production/sales divide caused by the conflicting objectives of these two functions. On the one hand, the sales department wants to maximize sales revenue (i.e. the strike rate) by quoting often unrealistically short due dates and prices. On the other hand, the production department pushes for a high backlog and longer lead times to create a continuous flow on the shop floor.

The forward/backward scheduling element can be used to set or assess the feasibility of due dates and incurred production costs to ensure quotes are competitive but with realistic due dates and prices which reflect the actual operational capabilities of the firm. A set of decision criteria – e.g. the expected profit - can then be developed based on the strike rate analysis to support the bidding process. This allows profitability to be maintained while controlling the planned workload (i.e. the workload on the shop floor and in the pool) through realistic due dates.

From an operational point of view, this provides a control loop that: (i) reduces variability – as the incoming workload is controlled – allowing the capacity buffer to be minimized; and, (ii) regulates the 'over-booking' strategy of a company necessary for ensuring the utilization of scarce capacity. For example: When the workload starts to increase, the lead times that can be realistically offered become longer – this reduces the strike rate of the company and, therefore, its workload. Then, as the workload decreases, the lead times that can be realistically offered start to shorten – this improves the strike rate and, therefore, increases the workload.

Order release controls the flow of work unto the shop floor. Jobs are not released immediately but flow into a pre-shop pool of order from which they are released in time to meet due dates while keeping the work-in-process within limits or norms.

Empirical research has reported that the use of order release control can lead to reductions of more than 25% in work in process, 15% in lead times and 20% in the percentage of tardy jobs (e.g. Wiendahl *et al*. 1992). Similar, Thürer *et al*. (2012) observed in their simulated job shop environment that at the appropriate workload norm level: throughput times - i.e. the time from job release to completion - and work-in-process, is cut in half; percentage tardy can be reduced by more than 25%; and lead time, i.e. the time from job arrival to completion, is reduced by 10%.

The Workload Control order release mechanism outlined here incorporates both a periodic and a continuous element as follows:

- *Periodic Element:* At periodic time intervals - e.g. once a day or once a week - jobs are considered for release comparing the job's workload and the workload of all uncompleted operations for a particular work center (either directly queuing in front of this work center or still upstream) against workload limits or norms.
- *Continuous Element (Starvation Avoidance):* In addition to the above periodic release procedure, if the load of any work center falls to zero, a job with that work center as the first in its routing is released from the pre-shop pool.

Both elements are important: the periodic release mechanism allows the workload to be balanced - creating an even flow of work - while the continuous release mechanism allows premature work center idleness or starvation to be avoided - creating a swift flow of work. In line with the principle of input/output control the release decision is dependent on the capacity gap created by the output.

How to Design a Decision Support System

Workload Control adoption is often coupled with that of a computer system to support Workload Control-related decision making: a Decision Support System. The design of a Workload Control based Decision Support System should follow a structure specific design. This design approach consists of three elements: goals, means and tasks (Johannsen 1995, Park and Lim 1999). In other words: the definition of the typical goals of a company implementing a Decision Support System; the means of meeting these goals (i.e., through the Workload Control concept); and, the tasks or roles of humans within the domain of the Decision Support System. The tasks then define how the Decision Support System should be designed; such a task-oriented approach is considered by many to be the key to successful Decision Support System design (see, e.g., Johannsen 1995, Johannsen 1997, McKay and Wiers 2003).

- Defining *goals* starts with the following questions: What are the strategic objectives of the company? And, why does the company need a Decision Support System?
- Defining the appropriate *means* to achieve the *goals* starts with the question: How can Workload Control contribute to achieve these objectives or goals?
- Defining the *tasks* to be accomplished to effectively use the *means* to achieve the *goals* starts with the question: How is Workload Control to be used to achieve the goals?

For example one important Workload Control task is to release the right job at the right time without violating a pre-established level of workload to balance the workload. In line with authors such as Barthelemy *et al*. (2002), Higgins (1996) and McKay and Buzacott (2000) - who argued against a strict computer-based approach to scheduling - it is argued that, in practice, the user should be the center of the decision as to which job to release. Instead of permitting a human user to alter or intervene in computer-generated schedules, the user should actively participate in the generation of the schedules. Nonetheless, production planning tasks not only consist of elements which need special attention but also routine elements (Fransoo and Wiers, 2006). Therefore, and in order to reduce the cognitive workload of the human user, the Decision Support System should also offer the option of making the decision for the human, e.g., by automatically releasing jobs for the remaining load after the human user has released the jobs that he or she considers most important.

It has been acknowledged that Information Systems often fail to meet pre-implementation expectations (Calisir and Calisir 2004, McKay and Buzacott 2000, Szajna and Scamell 1993), perhaps because most systems are designed and built without considering human factors; and, because most systems are generic tools which are not customized to company-specific needs (McKay and Buzacott 2000, McKay and Wiers 2003). Workload Control is a simple yet effective production planning and control solution which principles can be implemented on a sheet of paper or using a spread sheet as in the example outlined here. This makes it easy to create a customized Decision Support System which reflects the particular needs of a enterprise.

Arguably, an important factor is that the user feels that the Decision Support System has a strong 'usability'; in other words, that it is user-friendly, supports the accomplishment of the tasks and is efficient in achieving the goals. The most important criterion that should be considered for the design of the user interface can be summarized in three groups as follows:

- *Design and Functionality:* The Decision Support System design should support task perception and performance (Higgins 1996, Park and Lim 1999). The design and functionality of the system should be consistent throughout all layers of the human-machine interface (Marcus 1992, Park and Lim 1999). Short and diverse tasks should be avoided and the cognitive workload of the user should be kept low (Oborski 2004).
- *Presentation:* An appropriate level of aggregation for the information presented in the Decision Support System is required (Higgins 1996, Oborski 2004); for example, by using data charts or graphs. This means that the user does not have to remember data from other screens which would otherwise imply an unnecessary cognitive workload; at the same time, maintaining a clear design and avoiding small graphical objects (that prove difficult to read) is also important.
- *Human Factors:* Support and guidance to help the user understand the system (Lin *et al*. 1997, Park and Lim 1999) should be provided. Human errors should be prevented and corrected (Oborski 2004, Park and Lim 1999), e.g., by warning if system parameters are violated. Exits should be clearly marked and short cuts provided (Lin *et al*. 1997).

Recent studies have underlined the strong link between the perceived aesthetic appearance of a human-machine interface and the perceived and experienced usability (e.g., Szajna and Scamell 1993, Tractinsky 2000). There is also a strong link between user satisfaction and perceived and experienced aesthetics and usability (Tractinsky 2000). Therefore, a Decision Support System should not only follow the criteria outlined in the bullet points above but also primary rules for the design of aesthetically appealing human-machine interfaces. The main primary rules are: consistency, clarity, simplicity and familiarity (Marcus 1992). Considering the main criterion for the design outlined above, each is described in more detail below:

- *Consistency:* Each unit of the layout grid (i.e., the grid which subdivides the computer screen) should have visual, conceptual and functional integrity. Data, functions and tools should be organised and presented appropriately to meet the criterion outlined in groups one and two above (i.e., Design & Functionality and Presentation).
- *Clarity:* Where possible, lines of text should be kept short, legible and readable. Letters of serif type, e.g., Times New Roman, should be used where long text is necessary while short text should be presented in non-serif letter types, e.g., Arial. Colors should be used with discretion and extreme colors should be avoided. Whereas colors might be more 'enjoyable', they do not improve learning or comprehension more so than the use of black and white.

- *Simplicity:* Efficient and simple navigation possibilities should be provided. Data should be presented in a simple intuitive and easy-to-understand-format. In response to the criterion outlined in group three (Human Factors) error messages should be clear and simple.
- *Familiarity:* The user should feel familiar with the navigation possibilities and the design of the Decision Support System. Therefore it should follow standards as, e.g., Windows © or Linux ©.

Decision Support System for Workload Control

While Workload Control principles can be operationalized with a simple sheet of paper, it is often coupled with the use of a computer system to support Workload Control-related decision making: a Decision Support System. An example for the operationalization of Workload Control for a shop with six work centers and a set of randomly generated orders is described below. Note that this is a simple example to show how easy workload control principles can be implemented.

Workload Control is operationalized using five Excel © sheets: (i) Customer Enquiry, which creates the order in response to a customer enquiry determining processing times, routing characteristics, operation due dates and due dates; (ii) Unconfirmed Orders, which contains all unconfirmed orders; (iii) Pool Orders and Order Release, which controls the release of orders to the shop floor; (iv) Shop Floor, which contains all orders currently on the shop floor; and (v) Order Winning History, which contains all orders (whether won or not) which passed the customer acceptance/rejection decision. Orders (or Jobs) pass sequentially from one sheet to the next. Each sheet will be explained in what follows. Figures have been added which update automatically if input data is changed to support the decision process. To make workload control work, this is not required. The basis is the load calculation and the control of the workload. The Excel © file can be found at www.workloadcontrol.com.

Customer Enquiry: When a request for quotation is received, a job is scheduled considering available capacity and current workload (see Figure 2). The workload and capacity measures are given in cells E26:O31. The Figure above these measures summarizes the cumulative total workload (including the load of the new job) and available capacity. The cumulative total workloads are calculated from the respective sheets in cells B41:O65 and Q41:AD59. While the latter contains the individual shop floor, pool and unconfirmed workload does the former aggregate these loads into the workload measures typically applied within workload control: the total, planned and shop floor workload. The cumulative available capacity until a certain time (i.e. the total capacity times the Overall Equipment Effectiveness) is determined by the user in the grey marked cells in B41:O65.

The order itself is created in cells B36:W36. In this simple example a job's information consists of its identity number (ID), Planned Release Date (PRD), due date, strike rate estimate and the routing and processing time information. Each order follows the standard format thus it can easily be cut and paste from workload measure to workload measure (i.e. one sheet to the other). In order to schedule an order, first determine the strike rate. Then the work center is selected in cells E18:E23. Cells E26:O31 and the figure are automatically updated being the cells linked by an *If* logic. The operation processing time is then inserted in one of the cells E29:O29 which represent the time buckets for the operation due dates. The workloads and figure are automatically updated. Shifting the time bucket or changing the processing time allows the cumulative workload to be fitted into the cumulative available capacity. Once the operation is scheduled, the position of the operation in the routing, the processing time and the operation due dates are inserted in the cells corresponding to the work center in cells B36:W36. Once all operations have been scheduled, the order is cut and pasted into the Unconfirmed Order sheet until its confirmation.

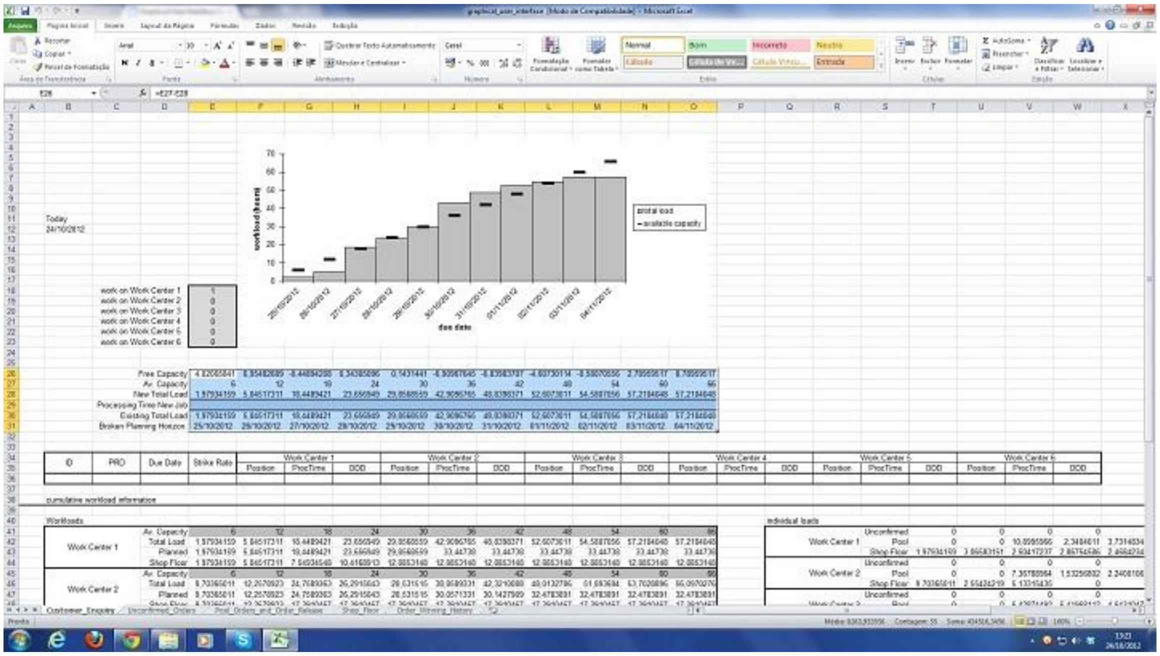

Figure 2: Workload Control based Decision Support System: Customer Enquiry Management

Unconfirmed Orders: This sheet contains all unconfirmed orders (see Figure 3). In addition columns AB-AG and AK-AP calculate and provide information required at Customer Enquiry. AB-AG gives the days until the operation due date for each operation and AK-AP gives the workload which contributes to the total workload, which is the original load multiplied by the strike rate. Additional measures for Customer Enquiry are calculated in column AB-AG and AK-AP. Once an order is confirmed it is cut and pasted into the Pool Orders and Order Release sheet. Both, orders which are confirmed and not confirmed are also copied into the Order Winning History sheet and marked accordingly.

Pool Orders and Order Release: In the Pool Orders and Order Release sheet (see Figure 4), the corrected aggregate load on the shop floor, the corrected load contribution of jobs currently selected for release and the resulting workload are given in cells H17:S19. The workload norm for each work center is determined in cells H16:H19. Jobs from the pool are selected for release through column C. The Figure and load contributions in H17:S19 update automatically being linked by *If* logic. In addition column B can be used to create a specific priority value for jobs in the pool. Jobs can easily be sorted using the sorting function of Excel ©. Additional measures for Customer Enquiry are calculated in column AM-AR and AV-BA; the corrected aggregate load for order release which would be contributed by each job in the pool is calculated in column AD-AI. Once order release is completed, the selected orders are cut and pasted to the Shop Floor sheet.

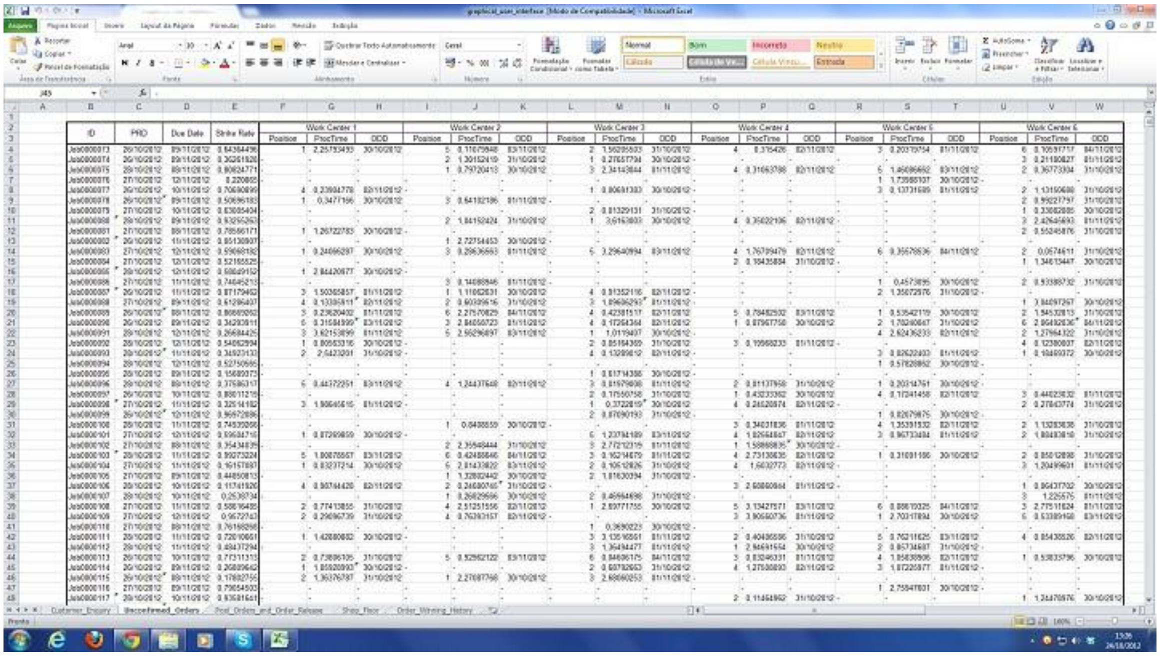

Figure 3: Workload Control based Decision Support System: Unconfirmed Orders

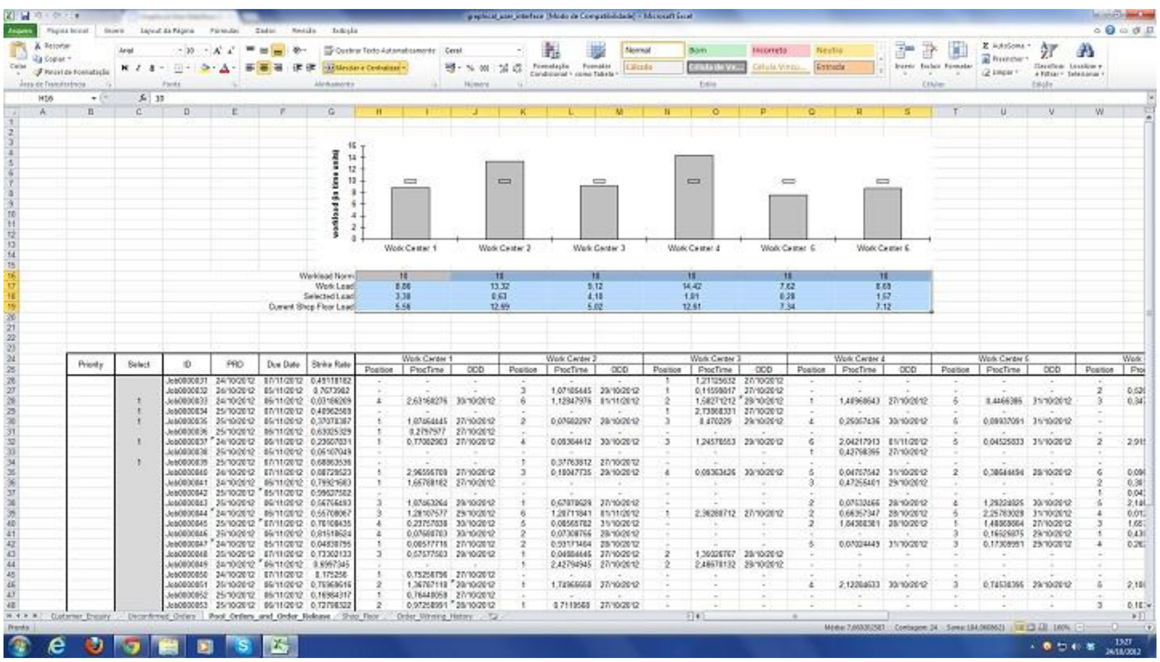

Figure 4: Workload Control based Decision Support System: Order Release Control

Shop Floor: Completed Operations are marked in cells AA-AF of the Shop Floor Sheet (see Figure 5). Operations marked as completed are not considered when the corrected aggregate load for order release and the load for Customer Enquiry are calculated in columns AK-AP and BC-BH, respectively. The columns AT-AY give the days until the operation due date for calculations at Customer Enquiry. Once an order is finished, it is deleted. Alternatively, additional data could be collected – e.g. on realized operation due dates – for further analysis e.g. on schedule deviations (see e.g. Soepenberg *et al*. 2008).

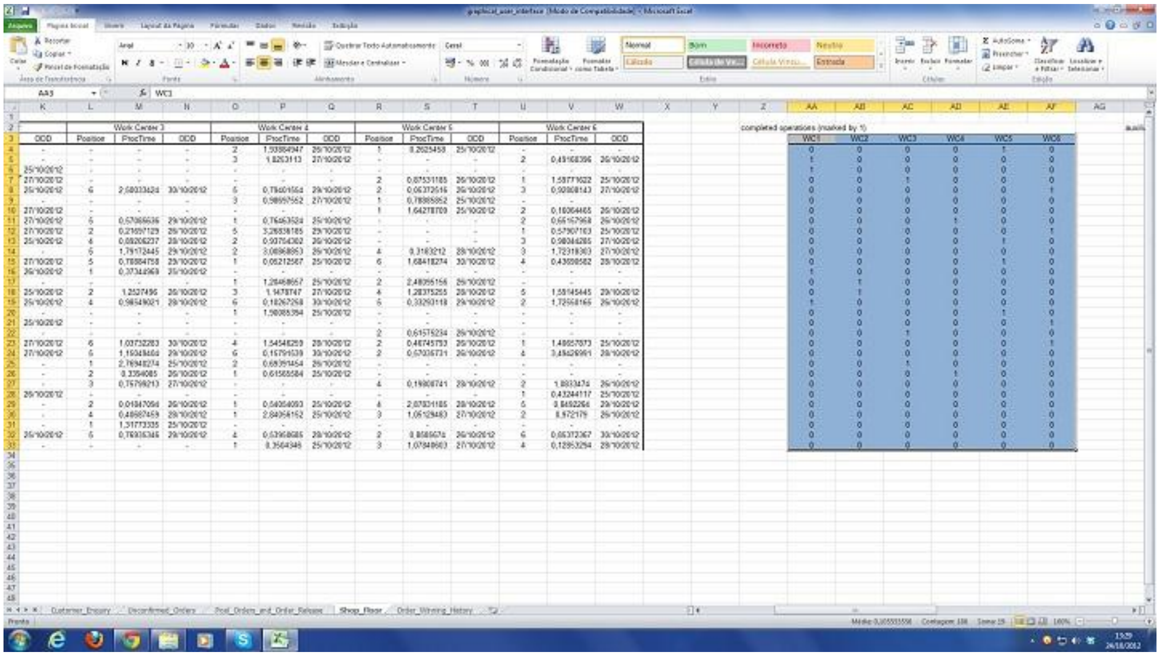

Figure 5: Workload Control based Decision Support System: Shop Floor

Order Winning History: Finally, the Order Winning History sheet summarizes the order winning history (i.e. whether a quote was accepted or rejected) and the outcomes quoted for the strike rate analysis.

Conclusions

Lean has been one of the most important developments in Operations Management. Yet, many make-to-order shops found lean's planning and control techniques do not apply. Workload Control is a planning and control concept designed to address this need. However, while many simulation studies have demonstrated that Workload Control can lead to significant performance improvements in job shops, reports of successful implementation in practice are limited. Part of the reason for this is that practitioners are often unfamiliar with Workload Control and Workload Control adoption is often coupled with that of a computer system to support Workload Control-related decision making, which adds to the complexity of implementation. In response, this study provides a first step towards future implementation outlining a simple operationalization of Workload Control using spreadsheets. Future research should now support managers of small shops during the implementation process.

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