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# Modelling input–output workload control for dynamic capacity planning in production planning systems

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## Abstract

Workload control has been described as one of the new production planning and control concepts available for practical operations. The main principle has been defined by as to control the lengths of the queues in front of work stations on the shop floor. If these queues are to be kept short, then waiting times and hence overall manufacturing lead times will be controlled. There are four levels at which this control of queues can be attempted; priority dispatching level, job release level, job acceptance and job entry level. The first of these is a relatively weak mechanism for the control of queues if used alone. A stronger instrument, controlled job release, entails maintaining a ‘pool’ of unreleased jobs in the production planner’s office, which are only released onto the shop floor if doing so would not cause the planned queues to exceed some predetermined norms. The main aim of workload control, for those who advocate its use as a job release method, has been defined as to control the lengths of the queues in front of work stations on the shop floor. However, the true objective is to process the jobs so as to meet the promised delivery dates with the machine and workforce capacities and capabilities available. The job release stage can itself only be fully effective if the queue of jobs in the pool is also controlled. Otherwise, jobs may remain in the pool for too long so missing their promised *delivery dates*. Thus a comprehensive *workload control system* must include the customer enquiry stage, (the job entry stage), to control the input of work to the pool as well and plan the capacity to provide in future periods so the shop floor queues are also controlled. A methodology and systems to do this at both the job release and the customer enquiry stage have been presented in previous papers. The purpose of this paper is to provide a theory for *workload control* in a mathematical form to assist in providing procedures for implementing input and output control. It enables dynamic capacity planning to be carried out at the customer enquiry and order entry stages for versatile manufacturing make-to-order companies. The theory shows that attention should be concentrated on controlling the differences between the cumulative inputs and outputs over time, and not the period individual inputs and outputs. Although aimed at make-to-order companies, the theory and procedures give a general capacity planning method for other production planning methods; for example determining the master production schedule in MRP systems. © 2000 Elsevier Science B.V. All rights reserved.

*Keywords:* Make-to-order manufacturing; Production planning; Lead time management; Workload control; Input/output control; Order release

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## 1. The input–output transformation model for production systems and workload control

The input–output model is a very useful and commonly accepted way of looking at production

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and operations. Production is regarded as a transformation process that takes inputs and transforms them to outputs that are of a higher value than the inputs. This can be viewed at the macro system level, the whole of the organisation or the whole of the production function, or at the micro level of the individual transformation operations or activities. These latter are the work centres at which the successive different transformations of the item being processed are made. The production function consists of a network of work centres, each with a capability to do a particular transformation task. The inputs to the system from a directly physical viewpoint are raw materials, components and sub-assemblies, and the outputs are the finished final goods. Another viewpoint is that the processing is transformation of information. The inputs are orders from customers for specified final products. The order is the information that specifies the particular amounts of transformation work to be carried out to produce the finished products. The output is then the transformation work completed at that work centre.

A crucial aspect for any production input–output model is that the time that the transformation process takes is a very important factor. This is because the finished product is being delivered to a customer who requires receiving that product by a particular promised delivery date. Failure to meet this promised delivery date could, and does, affect the amount of future business likely to arise from that customer and the prices that can be secured. The ability to be able to carry out the necessary transformation processes is an essential qualifier to be in that particular market, but it is the price and delivery lead time quoted are crucial order winning factors. This is particularly so in most of the produce-to-order sector of manufacturing and service companies.

Viewed from both a marketing and a production perspective, the produce-to-order sector of industry can be divided into Repeat Business Customisers (RBCs) and Versatile Manufacturing Companies (VMCs). The former produce customised products for each of its customers on a continuing basis, where the regularity of the demands from the customer may enable some production to stock to be profitable at times. RBCs tend to have a relatively

small customer base and compete for the initial order of a continuing supply contract. Having won the initial order, the RBC automatically gets the repeat business on a regular basis for a certain period of time, say two or three years. The component suppliers to motor manufacturers are classic examples of RBCs.

The typical Versatile Manufacturing Company (VMC), in contrast, has to supply a variety of products, usually in small quantities, ranging from a range of standard products to all orders requiring a customised product. The arrival of customer enquiries is a stochastic process over time. Each potential order from the enquiry tends to be for a differing number of units and requires varying routings and processing times through the production facilities. VMCs include the classical job shop production environment. However, the supplier of expensive items to satisfy an intermittent customer demand also falls into this category, since the customer will often seek a quotation from other suppliers even if the previous orders had been bought from just one supplier. The manufacturing process here may be a batch or even a line production process. Many service operations, for example specialised banking services or training packages, also have the same problems. Generally, VMCs must compete for each and every order they receive, quoting either a price or a delivery lead time or both, although they may have an edge with repeat business. Furthermore, they have to make bids for many more orders than they will receive. Tobin et al. [1] found that the strike rate, the proportion of quotes that become firm orders, varied from 3% to virtually 100%.

Each order, or potential order in the form of a customer enquiry, requires transformation work on a series of work centres. It is well known that in the produce-to-order sector an order spends up to 90% of the total time in production waiting in front of or between work centres and only 10% in actual transformation work on the machines. This is due to the variability in order sizes and the number of transformation processes needed per order and the stochastic inter-arrival times between enquiries and orders. The alternative to these long queues would mean that most facilities would be idle for most of the time. The general model of the shop floor is thus

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