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METHODOLOGIES ANALYSIS TO REDUCE TIME TO MARKET IN MAKE-TO-ORDER ENVIRONMENT

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TABLE OF CONTENTS

ABSTRACT

The strategy of Make-to-Order (MTO) is to build each product based on the likes and requirements of each customer individually.

MTO companies are in the competition with other companies, on the basis of price, technical expertise, reliability; and one of the most important production characteristic required to a MTO implementation is a short lead time between an order placement and its delivery to the customer.

Lead time can be defined as an effective competitive weapon because the ability to deliver sooner than the competitors can make the difference between a successful or an unsuccessful sale with increasing or losing market share.

The main focus, lies in analyzing the time to market in MTO environment and showing how to improve it.

Keywords: Make-To-Order (MTO); Lead Time; Time to Market.

INTRODUCTION

With Make-to-Order (MTO) the products are not produced until the actual order comes in.

MTO enterprise accepts only backorders and keeps no inventory for finished goods.

Product and process designs are made to customer specifications, after the order is placed.

This ensures low costs of stock, since there is no stock, and requires short lead times in production.

We have to think about the complete cycle of a customer order [2] :

- Receipt of the order via phone, fax, mail, or e-commerce methods; from sales reps, distributors, dealers, and/or directly from the customer.
- Receipt and handling of the order including review (customer service, engineering, credit, sales/marketing), and entry into the system.
- Possible design or engineering activities.
- Scheduling, allocation/acquisition of materials and parts.
- Production, including the aforementioned non-active portions of lead-time.
- Testing, packaging, handling, and shipment preparation.
- Transportation/delivery to the customer's location.
- Invoicing and collection.

Production lead time, made up of material handling and non-production (wait or queue) time as well as real production activities, is what comes to mind, it may not be the largest element on this list.

Shorter lead-times:

• reduce the time it takes to respond to a shift in customer demand

• reduce the interval over which a forecast is used to commit to purchase and production plans, making the forecast more accurate and increasing the ability to respond to detected forecast errors

• reduce material and work-in-process inventory investments which are proportional to lead time

• reduce obsolescence and rework risk; being caught with large investments in materials and WIP as demand changes

It is a fact that the majority of the time that elapses between the start of a manufacturing order and its completion is not consumed by "active" production-time on the machines or in the hands of workers-often called "touch time".

CHAPTER 1
Make-To-Order

Definition

Make-to-Order (MTO) is a production strategy which can be described as follows:
"Companies produce products in response to actual customer orders, so they carry little finished goods inventory. They can produce many kinds of products (many hundreds) each in small quantity by using different combinations of relatively few kinds of components" [1].

This definition is open for discussion as not all MTO based production can be caught in this phrase. For example the production of a boat is MTO, but there are some fundamental differences with the definition stated above. For example there is no finished inventory, production of boats is done in very small quantities and boats consist of several thousand components. However, this definition can be used in mass production environments.

Starting with success of Dell Inc. in the early 90s, MTO has become interesting for many companies and industries as computer and automobile industry [3].

In today's business environments, firms try to achieve competitive advantages by satisfying customer's requirements in minimum lead-time and with the highest degree of customization and a little inventory is exactly what the management has in mind.

There is, however, a risk involved as disturbances in production leads to longer waiting times for the customer [1].

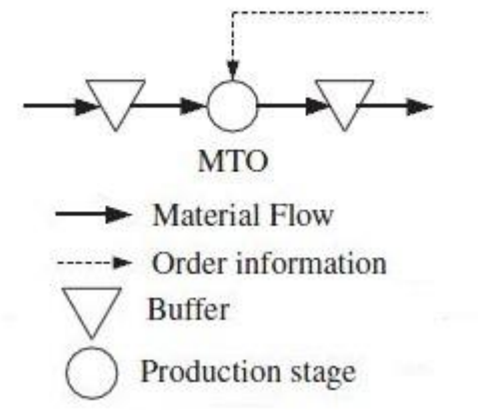

Fig. 1

What is?

Generally speaking, In a MTO system, work releases are authorized only according to the external demand arrivals so for long time it has been employed for high end, highly specialized and low volume products. It would be surprising to find a Ferrari, for example, that is not built to customer order.

The core strategy of MTO is to produce each good based on the likes and requirements of each customer individually. This means for production and supply chain, that there is no action until a customer order comes in and triggers the production process for one specific product assigned to the customer.

This in fact sounds very simple, but it means huge problems especially for industries, which mass produce and need economies of scale to be productive. The automobile industry is a very good example, since expensive machines require high capacity utilization to be profitable [3]. For such equipment it would be best to produce only one standardized product to avoid long, productivity destroying changeover times.

In today's business environment, a production system that is able to fill customer orders quickly, as well as offering custom products, has the benefit of a competitive advantage. However, the requirement to a have high product diversity and quick response time places conflicting demands on the production system [4]. For this reason, businesses that compete on response time concentrate on producing a limited portfolio of products.

While this system eliminates finished-goods inventories and reduces a firm's exposure to financial risk, it usually results in long customer lead times and large order backlogs [5].

Meaning of MTO System

Supported by the IT revolution in the early 90s, MTO received new attention and companies. Dell Inc. triggered the MTO popularity through its direct sales concept and is considered as the prime example for successful MTO adoption [3].

But at the same time there were many other companies, who encountered huge problems in transforming towards MTO and Mass Customization strategies, because drastic changes were required for that transition. Most crucial is the flow of information within the company and among supply chain partners, since in a MTO company the customer order triggers the whole operational process. The most difficult part adopting a MTO operation is to reduce order lead time, since customers of mass products usually do not want to wait long for their order to be delivered but also machines, the factory lay-out, planning and employees need to change [6].

Since the internet has evolved so rapidly, to reach the customer and enable him to place an individual order is not the largest problem anymore. The challenge is to process and physically carry this order all through the supply chain fast and cheap.

When MTO Makes Sense

Some parameters are summarised :

Demand

The first parameter is demand; MTO is efficient if demand is unpredictable and unstable[7] since stock runs the risk of becoming obsolete (either due to change, or lack of, demand). Product characteristics, which make forecasting extremely difficult and expensive, are mainly an high demand variability. Another aspect of demand is the required quantity, required package size and change in demand for new products [8].

Lead times

The second prerequisite is the lead time; the definition which we refer is: the delivery lead time is the lead time agreed upon by the customer and the production lead time is the required time for the company to finish an order.

So if the production lead time is larger than the delivery lead time, production on an MTO basis is impossible since then the delivery lead time will never be achieved.

MTO, environments are
more conformable with customer demands, so there might
be more purchase and therefore higher return of
investment.

Stock

Stock is also a parameters. MTO is adopted if there is little capacity for stock. Also the cost of stock is important, especially when compared to the cost of production. If stock is much expensive than production, it is efficient to apply a MTO strategy.

Production

Other parameters concerning production are the possibility of disturbances, number of changeovers, flexibility and machinery. Customers should not suffer from production failure, therefore the risk of disturbance should be as small as possible when producing based on MTO. If there is stock available with production based on MTO, there is no room for error since the customer will no instantly. The number of changeovers dictate the speed of production, especially if the time involved in these changeovers is considerable, this, in combination with the need for flexibility.

MTO requires a lot of flexibility and therefore a lot of changeovers. If this is not possible, or too expensive, we cannot apply a MTO so to solve this problem, companies have been most creative in reducing response time and increasing production flexibility.

Quality

Quality usually is more important in MTO system because in MTO systems firm's reputation is more noticeable.

Working with natural raw materials result in changes of quality of these materials as one has no influence on weather and climate. This results in the fact that the first batches in a production run are often not up to standard. Many changeover result in relative high amount of loss due to this changing quality.

Market

If the market in which a company is operation is changing regularly, either in size or in sorts of products, is a perfect environment for a MTO. If one works based on MTO, there isn't any problem about stock because there is not present as one has no stock.

Product

The higher cost of each item, large number of variants, short product life, high inventory holding costs aren't a problem in a MTO system, because if the product demand volatises, the firm confronts less cost.

If the possibility of product obsolescence or perishability is high, we are inclined to MTO systems, like computer industries.

About the product design, having minimum number of parts, forging, or supplier for each product and a computerised design database with designs that can be customised for new orders are some MTO system characteristics.

Holding and backorder cost

When holding and backorder costs are high, we prefer to apply MTO system

Human resource flexibility

Being flexible in skills and able to work on any machine are characteristics related to MTO environments. MTO systems need employees in understanding all the product specifications, product design rework and purchasing process/knowing their suppliers.

Equipment flexibility

In MTO systems, we seek simple, flexible, movable, low-cost equipment in multiple.

The next Table 1 explains all parameters that we have discussed so far:

Parameter	
Demand	
Variety in number of orders	High
Variety in total amount	High
Variety in products	High
Variety in packaging	High
P/D ratio	**Low**
Stock	
Available capacity	Low
Cost	High
Production	
Chance of disturbance	Low
Amount of changeovers	High
Need for flexibility	High
Presence of expensive machinery	Low
Planning flexibility	High
Cost	High
Variety in quality	Low
Market	
Changing specifications of the product	High
Presence of a changing market	High
Need for fast delivery	Low

Table 1

The following aspects are very important when thinking of a MTO transformation [9]:

Customer commitment

Having long-term relationship with customers and helping customers define their goals and needs are reasons of applying MTO system.

Supplier commitment

Just in time concept is very important in MTO environment, therefore long-term commitment of suppliers is an indispensable factor for utilizing MTO system.

Integration the functions of production and marketing

Initial understanding between production and marketing is an important requirement. Having a systematic database that enables MTO system to respond to customer enquiries is another requirement.

Shop floor

MTO systems need a simplified shop floor comprising simple and efficient storage system, minimum distances for movement of raw materials and tools, etc.

Information flow

Having systematic methods to communicate the plan, this could be a manual system such as a planning board or ‘‘work to lists’’ produced by an appropriate software package, and having information about quality, cost, orders, delivery, and design that is readily available anytime to all in the factory are essential in MTO systems.

Rewards, recognition and pay system

Having a systematic performance appraisal system, systematic public recognition/celebration of achievement and rewarding for skills and knowledge are some requirements of MTO systems.

Customer feedback

Gathering customer-satisfaction data and competitive samples, review customer complaints and make continuous improvement on products and services are some requirements for MTO systems.

Build-To-Order Objectives and Goals

The following objectives are the major incentives companies look at when thinking of a MTO transformation [3]:

Reduction of Inventory

Forecasts are always wrong! To buffer mistakes in forecasting companies carry a lot of inventory in their warehouses and in their production pipelines, tying up a lot of capital. If it would be possible to be independent from forecasts just by reacting fast on actual demand, inventory would become obsolete.

Days of Inventory represents a good indicator for inventory level change, since it accounts for cost and sales fluctuations.

Depending on availability within each case, inventory data is segmented in: Total Inventory, Raw Materials Inventory, Work in Progress Inventory and Finished Goods Inventory.

All four of those variables are utilized to calculate the days of inventory for each type to detect changes in inventory levels across any part of the production process.

Increase of Profit Margin and Revenue

For products that are exactly what the customer wants, companies can charge more than for products that were designed to attract as many people as possible, but do not match the preferences of particular individuals.

This logic generates a problem especially in computer and automobile companies [3]. New cars are often discounted multiple times before they leave the retailers lot, just because they were not exactly what the customer wanted.

With customized products, the car industry hopes to decrease discounting and sustain prices at higher levels.

Reduction of Operating Costs

After restructuring their supply chains for MTO processes, manufacturers expect to reduce costs for order processing and communication among supply chain members. An overall increase of operating efficiency and accuracy is supposed to come along with the adoption of MTO principles.

Without any doubt, there are more goals involved with the MTO transformation, but the goals mentioned above were consistently stated among companies applying MTO.

An example of a proposed planning system for MTO environment [12] is in Fig. 2 :

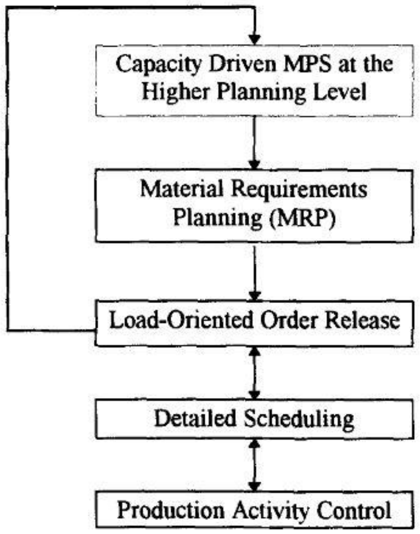

Fig. 2

Although customer enquiries can arise in a variety of ways, dealing with enquiries is a four stage process as illustrated [10] in Fig. 3 :

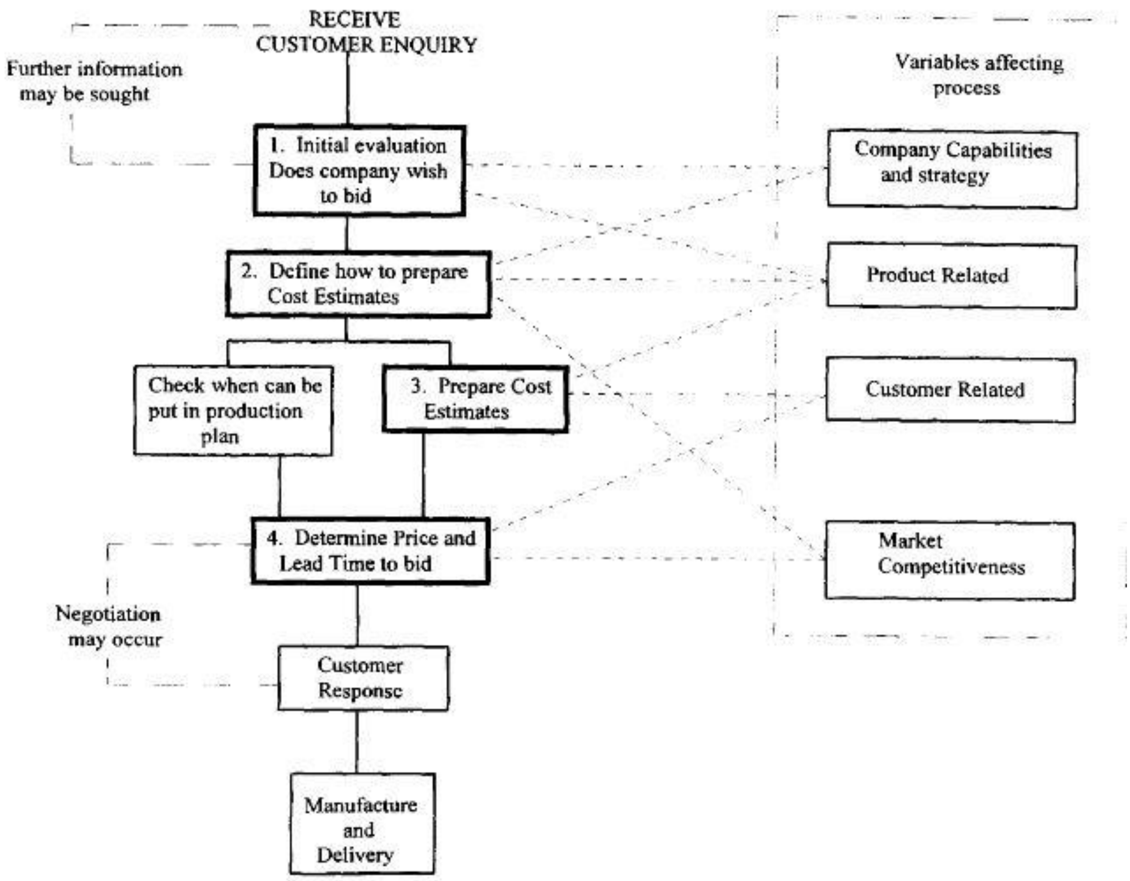

Fig. 3

CHAPTER 2
State of Art

Lead Time

Lead time was identified by every company as the most critical factor for success of their MTO program.

The aim is to ensure that all the works now in the system are completed and delivered before the end of the planning horizon.

MTO firms risk penalties for late (tardy) deliveries and the loss of future business if they are unable to maintain the lead times promised their customers.

In fact, delivery date setting is described by several authors as the most critical activity for MTO.

Turbide [2] claim shorter lead-times:

• In production, reduce batch sizes and/or reduce queue time.

• Outside of production, the solution is often to streamline procedures, eliminate non-valuable activities, coordinate departments more closely, and overlap activities for parallel completion wherever possible.

• Additional good fortune results from the deyelopment on the market of a veritable flood of new and improved tools under the umbrellas of PDM/PIM, CM, SFA, ISS, and other acronyms. I Once again, the software industry has identified needs and responded with tools to address them. These products and ERP will bring even more benefit to manufacturers.

Kleinau et al. [3] study the computer industry and the automobile industry. MTO requires fast and streamlined operations among supply chains and should therefore increase operational efficiency, which should decrease lead time, operating costs and increase operating income.

<u>Channel Relationships</u>

The initial action is the connection of customers through a special internet website and other channels.

Instead of following the successful Dell approach of direct sales without any middlemen, Apple, Compaq and HP intensified their existing relationships with distribution channels and incorporated them into their MTO concept.

<u>Dealer Network</u>

Most of the car makers initiated their MTO programs with the launch of dealer network systems to reach each individual customer.

Each dealer connected to the system can place orders for customers directly to the production plant (through a website).

This system combines both consulting and services from the dealer and establishment of a direct link to the customer.

<u>Supply Chain Aspects</u>

To increase responsiveness and decrease lead times, MTO approaches were focused on pushing product configuration downstream.

HP started to assemble desktops in its own distribution centres, Compaq and Apple involved their resellers in configuration and assembly of their computers.

<u>Partnerships</u>

Especially, Ford and GM relied on joint ventures and outsourcing of operations to restructure their production, sales and distribution process.

Kingsman et al. [10] say that a lack of co-ordination between sales and production at the customer enquiry stage often leads to confirmed orders being delivered later than promised and/or being produced at a loss.

<u>Overtime</u>

may have to be worked and/or work subcontracted at short notice to complete the job on time.

<u>The time the operations</u>

would have to be completed at each work centre, to meet the agreed delivery date, can be calculated from the set-up and processing times on each of the work centres needed by the enquiry, plus the buffer transfer times between work centres.

<u>The capacity</u>

to provide each week at each work centre.

Alternative lead times for an enquiry can be generated by reducing the buffer transfer times, giving priority in processing at work centres over other jobs.

<u>Reducing planning time</u>

the capacity planning module, the marketing module and an initial approach to the final decision making on the price and lead time to bid have to operate quickly.

<u>Priority at work centres</u>

One way of giving short lead times is to allow some orders to have priority at work centres, not having to queue for the normal time. However, as the proportion given such priority increases, then control is lost.

Haskose et al. [7] show how MTO manufacturing in its widest sense can be modelled as an arbitrary queuing network with limited buffer capacities to store jobs in front of each workstation.

The manufacturing lead time is thus the sum of the set-up and processing times at each of the workstations in the job's routing sequence plus all of the time spent waiting in queues in front of the workstations.

It is well known that in the produce-to-order sector an order can spend up to 90%of the total time in production waiting in front of or between workstations.

Almost every product is unique and produced in a different way, production tends to be via a job-shop layout.

Queuing networks, modelling manufacturing systems and workload control as mentioned, the queuing theory result most widely used in analysing and planning manufacturing systems is Little's Law.

One of the consequences of Little's Law is that increasing the WIP level by accepting more jobs to the shop floor will normally initially increase the production rate and the manufacturing lead time.

As the job arrival rate approaches the capacity of at least one workstation in the system, the production rate stabilises so further WIP increases result in longer manufacturing lead times.

This simple fact demonstrates why the workload control (WLC) concept provides a basis for improved production planning and control in MTO manufacturing situations.

The principle of WLC is to control the length of the queues in front of the workstations on the shop floor.

If these queue lengths are kept short, queuing times and therefore manufacturing lead times will be controlled.

The improvement of manufacturing performance measures including decreasing manufacturing lead times is the major aim of WLC concepts.

WLC acts directly to ensure that the loads of work at all workstations and over time do not exceed limits determined from the maximum lead times set by the manufacturer and related to the capacity or processing rates of each workstation at future times.

A solution may be to turn work away, or delay the release of jobs onto the shop floor or onto the next station in their routing.

Thus adopting WLC ideas to control both order acceptance and job release will achieve major reductions in lead times and stockholding costs but at the expense of lower throughputs.

Easton et al. [11] say that many of the important operational decisions that we ordinarily associate with MTO, like capacity planning and scheduling, do not begin until a customer places an order.
MTO firms with fast delivery times tend to have a powerful marketing advantage over competing firms.
If a MTO firm's faster delivery times are enabled by shortened flow times, then its lower work in process inventories and inventory carrying costs may provide another competitive advantage.
In labor limited systems, for example, capacity may be increased by subcontracting, by hiring and training new employees, or by extending the working hours of existing employees.
Contingent orders represent a new, and largely under-researched, source of lead time variability that complicate the determination of valid lead times.
The actual lead time, of course, depends on the work content of the job and the MTO firm's production sequencing and scheduling decisions.
Queue time represents a substantial portion of total lead time.
A possible solution is that, work centres may be able to operate at both regular and overtime pay rates, or certain processes may be available both internally and through subcontractors.

Ijzdamar et al. [12] say that, actually the time during which an order is backordered represents the production lead time for that order.
The production lead time depends on the current work-in-process in the shop which is in turn a consequence of the ratio of delivered orders to released orders.
They claim that lead times are determined by both order backlogs (input/released orders) and capacity (output/delivered orders). Kingsman et al. [10] define backlog length as the difference between accumulated input and output and state that for successful lead time management backlog length must be controlled.
Lead time management at the order release level should be supported by a higher level planning tool, the reasons being the following: (i) If the capacity load is not balanced over time at the higher planning level, then even the best order release strategy will not work; (ii) The higher level planning tool should assume the role of aggregate lead time manager with features which explicitly penalize the extension of lead times.
Additionally, it should consider capacity constraints while preparing a production schedule see Fig. 2 .

An order is assumed to be backordered if it is delivered after the period of its arrival. Notice that the standard definition of backorder (delivery past the due date) is not used here, since due dates are to be determined by the MPS.

Thus, the time during which an order is backordered actually represents the production lead time.

The objective is the minimization of backorder and overtime costs.

Penalizing backorders enforces shorter production lead times.

However, overtime is also a cost factor and in the optimal solution the trade-off between short lead times and overtime is optimized.

The formulation has attempted to level the work load as much as possible by minimizing overtime and save on setup times.

The MPS acts as a capacity and lead time manager and provides order due dates as well.

Mustafa et al. [13] claim the aim of supply chain management (SCM) is to improve the overall performance of the network by creating a series of coordinated activities and efficient control and management of the flows taking place across the supply chain network.

A supply chain network has been modelled using systems dynamics.

Following a systems dynamics approach enabled the modelling of a complex structure such as that of supply chain networks and shed light on the interactions of its key system parameters.

If lead times are reduced, customer service can then be increased without maintaining higher inventory levels.

There is a close relationship between WIP and manufacturing lead time.

If the average inventory for example is above 40 then the lead time will be reduced by a day; if there is a backlog greater than 40 then the lead time will be increased by a day.

If the production time is increased then the lead time will be longer.

Working with unreliable manufacturer or unreliable suppliers and an high demand uncertainty increase the lead time.

The advantages of the information enriched supply chain results in significant reductions in lead time thus making the entire network more agile.

The results obtained by the two scenarios concerning the production time and the manufacturer's reliability mainly affected by the machine breakdowns, impact the network's performance in a similar manner.

This is mainly due to the fact that in both cases the normal production flow is disrupted and hence the lead time is prolonged at the same echelon level, i.e. the manufacturer that becomes less responsive to demand and suffers from excessive build up of inventory.

Betrand et al. [14] say the lead-time costs are proportional to the lead-times quoted per order.

Under stationary conditions the average lead-time costs per period is equal to λGl, where λ is the order arrival rate, G the lead-time costs per unit lead-time and l the (constant)lead-time.

Note that if tardiness costs T are equal to lead-time costs G, the optimal lead-time to be quoted would be zero, and the average tardiness will be proportional to the average order throughput time.

Inspection of the results of this numerical analysis suggests that controlled work order release should be considered if the shop size is small or if work-in-process costs are high relative to the lead-time costs.

For large shops or for low relative low work-in-process costs, the cost benefits to be obtained from controlled work order release are small and unlikely to be sufficient to compensate for the costs of operation of controlled work order release.

Zorzini et al. [15] claim that there are too few empirical studies describing the practices adopted for capacity and delivery lead-time management in industrial contexts.

The delivery lead time is the fundamental order-winning criterion in MTO contexts and there is an interaction between delivery date quotation and capacity-planning processes.

Focusing on job-shop contexts, the literature analysis shows that the delivery date estimation can be carried out according to two main perspectives: exogenous and endogenous.

Exogenous methods consider delivery dates as external to production planning activities and support order acceptance decisions allowing the firm to evaluate the possibility to accept customer orders with certain DD specifications.

It is necessary to analyze the interaction existing between delivery date decisions and the high levels of capacity planning activities.

They underline the difficulty in managing trade-offs for decisions related to delivery lead time and capacity management, resulting from the conflicting objectives of sales and marketing and production units (profit criteria versus cost criteria).

The capacity planning can improve the delivery lead time, fabrication lead time, assembly lead time.

Jodlbauer [16] introduce a model for customer order driven production planning.
The main idea is to combine the required customer delivery lead time with the required capacity to meet the customer orders.
An important prerequisite is to reduce the inventory. Improvements in plant layout, processes, organization and production planning and control methods can lead to a decrease in inventory.
The real lead time is caused by a minimum necessary lead time and the inventory.
The minimum necessary lead time is caused by processing time, transport time, transport lot size and technically or organizationally necessary waiting times.
In practical usage the queuing time caused by the inventory is essentially greater than the minimum necessary lead time.
Of course because of changing inventory the lead time is not a constant figure.
For every machine as well as for the finished goods the open but expected customer orders or shorter time before the delivery date will cause a backlog.
The only possibility to prevent this backlog is to keep extra stock for that purpose.

Yucesan et al. [17] reports an experimental study conducted to assess the interaction between order release mechanisms and lead times with a special emphasis on customer service.
In particular, the behaviour of push, pull and long-pull systems are investigated.
Lead times are made up of queue time, processing time, batching time, and transportation/handling time.
Affected by many factors such as capacity, loading, scheduling, and batching, lead times have, in turn, a big impact on control, hence, on costs, of manufacturing systems.
Lead times also affect the level of safety stocks in finished goods inventories.
Lead time information is also needed in Material Requirements Planning (MRP) systems to generate time-phased requirements.
In MRP, lead times are typically set heuristically since queue time, a principal component of lead time and a function of the system load, is hard to estimate.
A more recently emphasized impact of lead times is on quality management.
If the lead time between production and inspection (or, more generally, between the creation and the detection of a quality problem) is long, the number of nonconforming pieces in the system may also be proportionately large.

Furthermore, large lead times between production and inspection would make it harder to trace the root cause of quality problems.
In MTO environments, response time is virtually equal to the lead time, assuming that the time between the order receipt and production authorization (i.e., order processing time) is negligible.
In an MTO environment, since these measures are virtually equivalent, customer service is synonymous with manufacturing effectiveness; that is, quick response requires short production lead times.

Leng et al. [18] consider game-theoretic models of lead-time reduction in a two-level supply chain involving a manufacturer and a retailer.
The lead- time consists of three components: setup time, production time and shipping time, each being in a range between minimum and ‘‘normal’’ durations.
The first two lead-time components are naturally determined by the manufacturer, whereas the shipping lead time may be chosen by the manufacturer or the retailer.
They note that, in practice, the setup and production lead times are naturally determined by the manufacturer but the shipping lead-time may be chosen by the manufacturer or by the retailer.
They consider the following two situations: (1) the manufacturer chooses the optimal shipping lead-time decision and absorbs a crashing cost if the resulting shipping lead time is less than some ‘‘normal’’ duration; (2) the retailer decides on the optimal shipping lead-time and incurs the crashing cost.
The lead- time decision of a supply chain member has significant impacts on the performance of the member’s upstream and downstream parties.

Slotnick [19] presents a model of lead-time policies for a production system, such as an integrated steel mill, in which the bottleneck process requires a minimum batch size.
The computational study also provides insights into the relationship between lead-time quotation, arrival rate, and the sensitivity of customers to the length of delivery promises.
To ensure on-time delivery, the steel producer must take into account processing time, as well as potential delays, from when an order arrives at the facility until the finished material is loaded for transport.
Accurate internal lead-time quotations are necessary to determine external delivery-date promises that are both realistic and acceptable to customers.

On-time delivery is of vital strategic importance for this market: while some customers are flexible with regard to delivery performance, other customers will not accept late orders.
Shorter delivery promises should be assigned to orders for which the customer is unlikely to place an order if s/he will wait too long for delivery, and also when other customers are relatively more impatient.
Higher arrival rates for the current order will result in shorter lead times, and so delivery promises should be adjusted accordingly.
However, higher arrival rates of other customers require a longer lead time, because of added congestion in the caster system.
One motivation for this project was the development by the steel mill of an automated order entry system to be used by their customers.

Treville et al. [20] says the long lead times hindered the company’s ability to move into custom markets, where profit margins were considerably higher than for standard products.
The information flow throughout the chain was to be made more transparent through installation of an Enterprise Resource Planning (ERP) system.
The main focus of the project was on improving the flow of information through use of technology and partnerships.
Management believed that an improved information flow would naturally lead to an improved product flow.
They defines a demand chain is a supply chain that emphasizes market mediation to a greater degree than its role of ensuring efficient physical supply of the product.
A given supply chain can be decoupled into an upstream chain focused on supply integration and a downstream chain focused on demand integration (i.e., a demand chain) through a decoupling point.
Results from lead time reductions led to identification of a competitive strategy based solely on speed, referred to as “Time-Based Competition”.
They also proposed the “Theory of Swift, Even Flow,” claiming that companies emphasizing flow—which implies a focus on speed and on reduction of variability—would have higher productivity than companies emphasizing productivity.
She compiled a set of the mathematical principles determining lead time—based on queuing theory—which they referred to as “factory physics.”
A simultaneously developed a manufacturing strategy called Quick Response Manufacturing that addressed implementation of lead time reduction principles in manufacturing environments.

Factory physics and Quick Response Manufacturing formalized the relationships of bottleneck utilization, lot sizes, and variability to lead times.
Another approach is based on reducing the production cycle.
This required improvement in the consistency of the process after each grade change, but that improvement was accomplished without major difficulties.
The lot sizes were much smaller and were more likely to respond to actual customer demand.
The reduced lead times encouraged chain participants to work together to exchange information.
They says that managers in many companies believe that reducing lead times is difficult
and expensive, and that information systems will make lead time reduction easier.
Manufacturers whose ability to respond to demand information is hindered by longer lead times (resulting from, for example, high capacity utilization) should concentrate their efforts on integrating their planning and forecasting with their customers.
In general, improvement of relative supply lead times should be prioritized over demand information transfer.

Johnson [21] is focused on the analysis of manufacturing throughput time per part (MTTP).
With some information obtained from case studies of lead time reduction efforts at four different plants.
He says that manufacturing throughput time reduction can often be a daunting and confusing task due to the large number of factors that can be changed and the interactions between them.
Production and transfer batch size reductions offer the largest potential for MTTP in most plants.
If the plant has a job shop/functional layout in place, significant reductions in batch size.
High workstation utilization is a major contributor to long MTTP, especially in cases where variability is high.
Many causes of long MTTP are a result of policies and procedures implemented in the past that are used to control production batch sizes, transfer batch sizes, workstation utilization, resource access, and so on.

Hendry et al. [22] analysis the workload control (WLC) concepts are a new group of production planning and control methods designed to control queues in a job shop manufacturing environment.

Their importance lies in the need to maintain this type of flexible manufacturing environment in make-to-order (MTO) companies, which manufacture different products for different customers.

They present a simulation model designed to test the effectiveness of one of the most comprehensive WLC concepts.

They are focused on the control of the length of the queues in front of the workstations on the shop floor.

If these queue lengths are kept short, waiting times and therefore overall manufacturing lead times will be controlled.

There are three levels at which this control of queues can be attempted:

• Priority dispatching level: the day-to-day shop floor control level.

• Job release level: the short term production planning level.

• Job entry level: the medium term production planning level.

While the priority dispatching level has received most research interest, it is a relatively weak mechanism for the control of queues if used alone.

Thus, WLC concepts use a stronger instrument, that of controlled job release.

This means maintaining a 'pool' of unreleased jobs, which are only released if it would not cause the planned queues to exceed some predetermined norms.

This, in turn, reduces the work-in-process and the task of priority dispatching is made easier.

They suggest that the WLC concept is indeed an effective management tool for MTO companies who wish to control aspects of performance such as manufacturing lead time.

To be implemented effectively, this concept requires greater integration between the marketing and operations functions of the MTO firm.

Gunasekarana et al. [23] are focused on the build-to-order supply chain management (BOSC) strategy has recently attracted the attention of both researchers and practitioners, given its successful implementation in many companies including Dell computers, Compaq, and BMW.

The objective of a BOSC strategy is to meet the requirements of individual customers by leveraging the advantages of outsourcing and information technology.

Companies rely on strategic alliances based on core competencies and information technologies to achieve flexibility and responsiveness in their supply chain.

Designing to defer product differentiation is a strategy whereby the final configuration of a product is postponed as much as possible, usually until a customer's order is received, to offer a large variety of products.

Additional requirements for a BTO system include ending the day with empty tables (no work-in-process), maintaining zero inventories on finished goods, and building products to order only.

The lead times are longer in MTO than in BTO.

In MTO, components and parts are made and then assembled. In the case of BTO, the components and parts are ready for assembly.

A traditional supply chain operates on longer lead times for delivery from suppliers, while BOSC operates using a collaborative and responsive approach to reduce the lead time.

In the next Table there is a little summary about all literatures studied so far.

Authors	Year	Batch	Queue	Ship	ERP	Collaborative	PP	Customer	Partner	WLC	Planning	WIP	QRP
Turbide D.	2009	x	x	x	x	x							
Kleinau S.	2005					x	x	x	x				
Kingsman B. et al.	1996		x			x				x	x		
Haskose A. et al.	2004		x							x			
Easton F. F. et al.	1999		x								x	x	
Ijzdamar L. et al.	1997										x	x	
Mustafa O. et al.	2007					x		x				x	
Betrand J. W. M. et al.	2008		x									x	
Zorzini M. et al.	2008										x		
Jodlbauer H.	2008			x							x		
Yucesan E. et al.	2000	x	x	x				x			x		
Leng M. et al.	2009			x		x							
Slotnick S. A.	2011		x					x					
Treville S. D: et al.	2004	x			x	x			x				x
Johnson D. J.	2003	x	x										
Hendry L. C. et al.	1998		x							x	x		
Gunasekarana A. et al.	2005					x	x						

Legenda:
Batch = Reducing Batch Size and Manufacturing Time
Queue = Reducing Queue Time, Manufacturing Time and Control Priority on Work Centers
Ship = Reducing Transportation and Shipment time
ERP = adopting of Entreprise Resource Planning Software
Collaborative = Improving Information Flow with Suppliers and Distributors
PP = Postponement Strategy Based on Pushing Product Configuration Downstream
Customer = Connection with Customers for Direct Sales by Web and Customer Service
Partner = Partnerships, Joint Ventures and Outsourcing
WLC = Work Load Control controls the Length of the Queues in front of the Workstations on the Shop Floor
Planning = Reducing Planning Time or Increasing Capacity (by Overtime or other) or Adopting MPS and MRP
WIP = Controlling the Work-In-Process and the Backlog
Backlog = Controlling the Difference between Accumulated Input and Output
QRP = Quick Response Manufacturing on Lead Time Reduction Principles in Manufacturing Environments

Tab. 2

CHAPTER 3

Lead Time Reduction with Case Studies

I'm focusing on analysis of the works and the case study reported by Johnson [21].
That article presents a conceptual framework that illustrates the factors that influence manufacturing throughput time, the actions that can be taken to alter each factor, and their interactions.

Overview

Manufacturing throughput time is defined as the length of time between the release of an order to the factory floor and its receipt into finished goods inventory or its shipment to the customer.
Reductions in manufacturing throughput time can generate numerous benefits, including lower work-in-process and finished goods inventory levels, improved quality, lower costs, and less forecasting error (because forecasts are for shorter time horizons).
That article first uses a simple hypothetical manufacturing system to illustrate the basic factors that determine manufacturing throughput time and explain why each factor occurs.
That article presents the information obtained from case studies of lead time reduction efforts at four different plants focused on the manufacturing throughput time per part (MTTP).
The factors more important for the throughput time are: the processing time per part, the setup time, the move time, the production batch size, the transfer batch size, variability,
The wait-for-lot time incurred by each part in this case is linearly related to the size of the production and transfer batches used.
This causes MTTP to also increase in a linear fashion as production and transfer batch sizes increase.
Variability can be a result of either controllable or random variation.
Controllable variation is a result of decisions made and includes such things as differences in the processing time of different parts due to design differences, differences in wait-for-batch time due to production and transfer batch size decisions, and so on.
In contrast, random variation is a result of events beyond our immediate control.

The variability generates the possibility that a batch of parts arriving to the workstation will find the workstation still busy processing a previous batch.
When this happens, the new batch must join the queue and wait its turn for processing.
Increases in variability cause queue size and its associated queue time to increase.
Variability has less impact on queue time when workstation utilization is low than when workstation utilization is high.
However, as utilization increases and less slack capacity is available, it becomes more difficult for a batch to arrive when the workstation is idle.
This increases the probability that the batch must join the queue, resulting in longer queue times and MTTP.
The magnitude of the impact that utilization and variability have on MTTP will vary from system to system.
However, queuing theory indicates the general pattern of results holds for all systems, namely that queue time and its associated MTTP increase at an increasing rate as utilization increases.

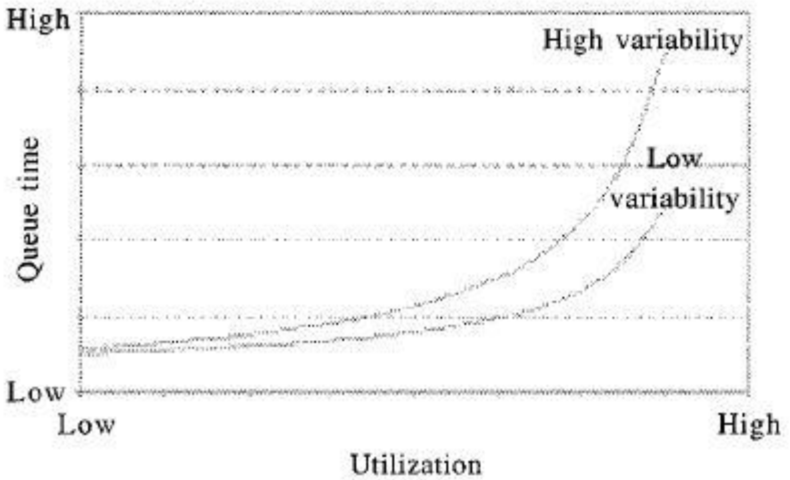

Fig. 4

Factor Interactions

The preceding discussion indicates that MTTP is equal to the sum of the processing, setup, move, queue, wait-in-batch, wait-to-batch, and wait-to-match times.
Because queue, wait-in-batch, wait-to-batch, and wait-to-match times all involve waiting, and because actions to reduce one type of waiting may also reduce other forms of waiting, they are collectively referred to as waiting time in the MTTP reduction framework.

Reductions in MTTP thus require reductions in one or more of these components. While setup time, processing time per part, and move time are independent of each other (i.e., a reduction in move time does not affect setup time or processing time per part, and so on), changes in any of these three components can affect waiting time.
Consequently, one way to reduce waiting time is to manipulate the other three components of MTTR.
Considering a simple manufacturing system consisting of two workstations (a workstation is either a machine or a workbench where a worker performs the job) that manufacture parts X and Y.
Both parts must first go through workstation 1 (WS-1) and then through workstation 2 (WS-2).

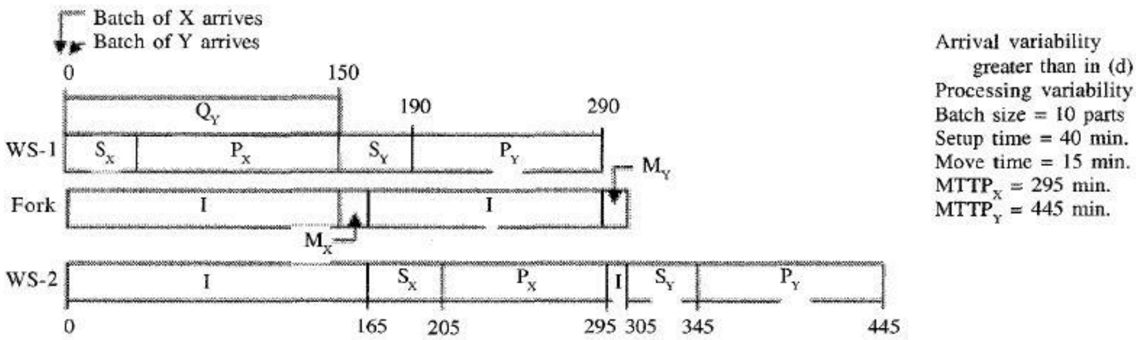

Fig. 5

For example, if the average processing time per part is reduced to 5 minutes for each part type at each workstation in Fig. 5 while all other conditions remain the same, Y would only wait 100 minutes at WS- 1 and the MTTP would be 295 minutes (see Fig. 6).
Reducing batch processing time by 100 minutes for each part (i.e., 50 minutes at station 1 and 50 minutes at station 2) in this case actually caused a 150 minute reduction in MTTP for Y due to the additional impact on waiting time at WS-1.

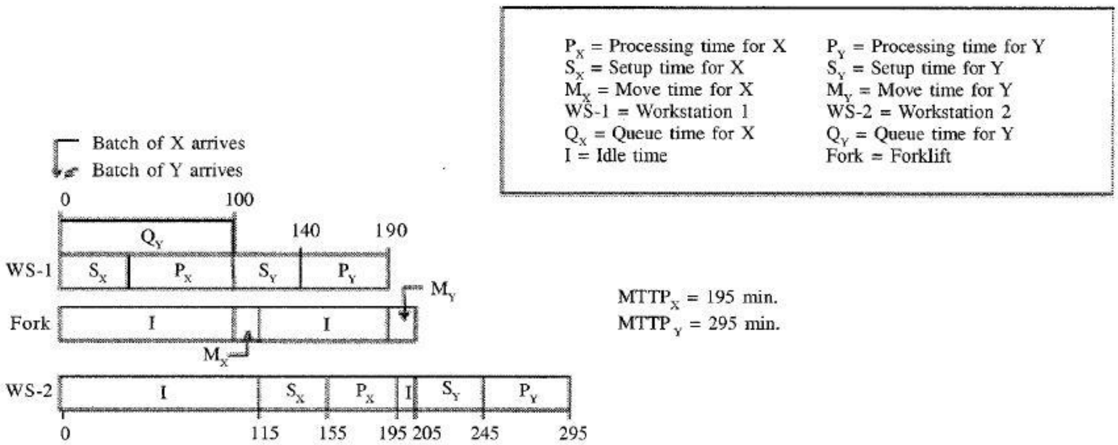

Fig. 6

Overview of Framework

Fig. 7 presents the MTTP reduction framework.

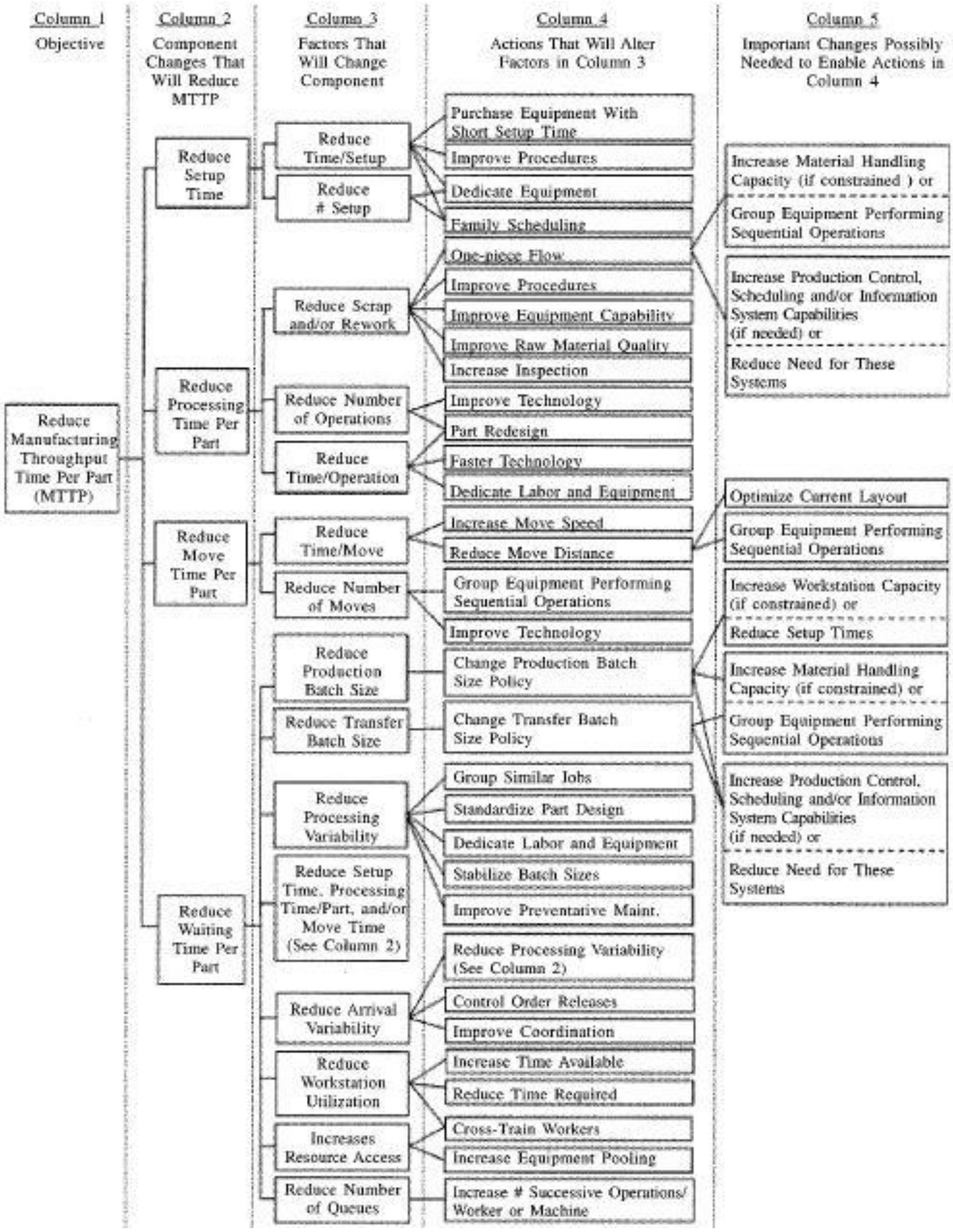

Fig. 7

Column 1 lists the objective of the framework as the reduction in MTTP.

Column 2 presents the components of MTTP.

Setup time is the sum of the times spent setting up all workstations required to process the part through the production system.

Processing time is the sum of the times spent processing a part at each workstation required in the production routing for the part.

Move time is the sum of times spent moving a part between each workstation in the production routing for the part.

Waiting time is the sum of the queue, wait-in-batch, wait-to-batch, and wait-to-match times at all workstations in the production routing for the part.

Waiting time is usually the largest of the four components, accounting
for as much as 90% of manufacturing lead time in some systems.

Column 3 illustrates the factors that will reduce each component.

Column 4 specifies actions that will alter each factor shown in column 3, and column 5 presents important changes that might be required to enable some of the actions shown in column 4.

The feasibility of accomplishing some of the actions and changes shown in columns 4 and 5 are directly related to the type of production layout used (i.e.,job shop/functional layout, cellular layout, or product layout/assembly line).

The issue of layout choice will be included in the following discussion where appropriate.

Based on these definitions, one or more of these four components must be reduced in order to reduce MTTP; by following the flowchart from left to right, actions that will reduce each component can be identified.

This flowchart is intended to provide a structured way to examine the types of actions that can be taken to reduce MTTP and the relationships between these actions.

Setup Time Reduction

Column 3 of Fig. 7 indicates that setup time reductions can be accomplished by reducing the time per setup and/or the number of setups.

Time per setup can be reduced by purchasing equipment with short setup times, improving setup procedures, dedicating workstations to families of parts with similar setup requirements so that common fixtures can be used and developed, and/or by using family scheduling to group batches that have common setup requirements.

Processing Time Reduction

Column 3 of Fig. 7 indicates that reductions in processing time per part can be accomplished by reducing the number of operations required, reducing the processing time per operation, and/or reducing scrap and rework.

The number of operations per part may be reduced through the adoption of new technology that allows a single operation to do what was previously done by several operations, or by redesigning the part so that fewer operations are required.

Processing time per operation can be reduced by redesigning the part to require less processing, incorporating faster technology to process the part (if available), or dedicating labor and equipment to a family of parts with similar processing requirements.

The best way to reduce scrap and rework is to improve raw material quality to prevent defective material from entering the system, and to improve equipment capabilities, processes, and procedures to prevent scrap and rework from happening in the first place.

Using very small transfer batches can also reduce scrap and rework because defective parts can be quickly detected at the next operation.

As a last resort, increased inspection of the parts to identify defective units and prevent them from being transferred to the next operation can be used to improve scrap and rework.

Move Time Reduction

Column 3 of Fig. 7 indicates that reductions in move time can be accomplished by reducing either the time required per move or the number of moves required.

The time required per move can be reduced by increasing the speed of the material handling equipment (which may not be possible due to safety implications), or by reducing the move distance required.

While move distance can sometimes be reduced by reorganizing the equipment to optimize the material handling between departments in a job shop layout, the amount of reduction is greater if the equipment performing sequential operations on a part is grouped to form manufacturing cells.

If a job shop or functional layout is currently being used, the number of moves requiring material handling equipment can often be reduced by grouping workstations performing sequential operations into manufacturing cells.

In some cases, technological improvements that allow more sequential operations to be done by a single machine can achieve the same result.

Waiting Time Reduction

Column 3 of Fig. 7 indicates that reductions in waiting time can be accomplished by reducing setup time, processing time per part, move time, production batch sizes, transfer batch sizes, processing time variability, arrival variability, resource utilization, and/or the number of queues.

It can also be reduced by increasing access to resources.

Reductions in setup time, processing time per part, and move time have already been discussed.

The remaining factor changes will be discussed in the following sections.

Production Batch Size Reduction

Production batch size reduction is often the easiest and most cost-effective way to reduce waiting time and MTTP in most plants.

Not only does it reduce the wait-for-lot time for the part in question, but it also reduces queuing time for parts in other batches as well.

To reduce batch sizes, the plant needs to implement a policy to schedule production of smaller batches.

However, if demand stays constant, smaller batch sizes increase the number of setups required.

As the number of setups increases and more of the available capacity is used for setups, workstation utilization increases, which causes queues to grow.

Eventually, the increased queues negate any benefit to be obtained from batch size reduction and MTTP increases rapidly (see Fig. 8).

Reducing setup time would allow further batch size and MTTP reduction.

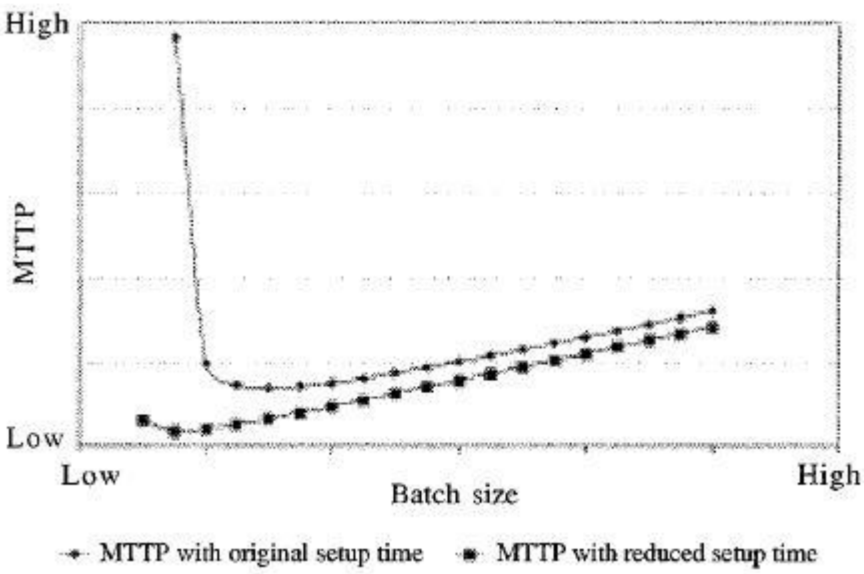

Fig. 8

Batch size reduction also increases the number of different batches of product on the shop floor at any one time, which may increase the load on the production control, scheduling, and/or information systems.

Based on this discussion, if MTTP is to be reduced through batch size reduction, one or more of the following changes are often required (see Column 5 in Fig. 7):

1. Workstation capacity must be increased (if capacity is constrained) or setup times reduced.
2. Material handling capacity must be increased (if capacity is constrained) or the workstations required to process a batch be consolidated so that material handling equipment is not needed as often.
3. The capabilities of the production control, scheduling, and/or information systems must be increased (which may included increases in both labor and computer capacity) to handle the increased requirements or the need for these systems reduced.

If production is performed using a job shop/functional layout, the spatial separation of workstations and labor resources required to produce the batch of parts will likely require increases in workstation and material handling capacity and production control, scheduling, and/or information systems capabilities as batch sizes are reduced.

In contrast, if cells are formed, workstations and labor are dedicated to families of parts and grouped in close proximity.

Thus, converting a job shop/functional layout to a cellular layout would likely allow batch size reduction without corresponding increases in machine capacity, material handling, production control, scheduling, and information system capacity/capabilities.

In fact, the use of cells may result in less need for these systems, even though batch sizes are reduced.

Transfer Batch Size Reduction

If production batch sizes cannot be reduced, waiting time can still be reduced through the use of transfer batches smaller than the production batch size.

It does not influence the number of setups required if all transfer batches of the same production batch are processed consecutively before parts of a different type are processed.

Transfer batch size reduction also has less impact on material handling capacity, production control, scheduling, and information system capacity if manufacturing cells are used versus a job shop layout.

Processing Time Variability Reduction

Variability in processing time comes from several sources: variance in setup time for a workstation, variance in the processing time per part, variance in the size of the batch processed, and variance due to unplanned downtime and repair of the workstation.

Reducing any of these sources of variability will reduce processing time variability and, consequently, waiting time as well.

Grouping similar jobs based on part family affiliation, dedicating equipment and labor to these part families, and/or standardizing part design will help reduce the variance associated with setup times and processing time per part.

Stabilizing or establishing similar batch sizes for all jobs in the family will help reduce variance associated with batch size differences. Improvements in preventive maintenance will help reduce variance associated with unplanned downtime and repair of the workstation.

Arrival Variability Reduction

Reductions in arrival variability will also reduce waiting time.

Arrival variability is more complex than processing variability and is dependent on the variability of new orders released directly to the workstation, as well as the departure variability from any upstream workstations that feed the station in question.

When workstation utilization is high, each job is extremely likely to arrive when the workstation is busy and, consequently, is likely to have to join the queue.

As a result, the departure variability from the workstation is primarily dependent on the processing variability at the station.

In contrast, when workstation utilization is low, the workstation is idle a substantial portion of the time and each job arriving to the station is more likely to find the station idle.

In this case, variability in the time between arrivals tends to directly impact departure variability.

Variability in the time between the arrivals of new orders can be reduced through the use of controlled order release mechanisms.

Such mechanisms stabilize the production schedule by releasing new orders to the workstation when the queue reaches a set level.

Workstation Utilization Reduction

Workstation utilization can be defined as "the total workstation time required per period divided by the total workstation time available per period.".

In this framework, the total workstation time required per period is equal to the sum of the times spent setting up the workstation, processing parts, waiting for labor to become available, and waiting for the equipment to be repaired.

The time available per period can be increased by adding equipment if capacity is machined constrained, adding workers (and possibly extra shifts) if capacity is worker constrained, and reducing absenteeism.

The capacity or time required can be reduced by reducing the arrival rate of jobs to the workstation (which will reduce output), and/or by reducing setup time, processing time per part, equipment downtime, scrap and rework, and delays due to unavailability of workers.

Reducing delays due to unavailability of workers may require adding additional workers (which also increases capacity), reassigning worker responsibilities to better balance the load, or cross-training workers to handle multiple tasks.

In the case of cross-training, workers can float to the workstation or resource experiencing the most delays and resource availability is increased without increasing utilization, and wait time goes down.

Increase Resource Access

Fig. 7 indicates that waiting time can also be reduced by increasing access to resources.

While resource access can be increased by purchasing equipment, hiring workers, working overtime, etc., the intent of this factor is to increase resource access without incurring these additional costs.

Using cross-trained workers and increasing equipment pooling can sometimes accomplish both of these goals.

If two Work Center were pooled (i.e., resource pooling is increased) by locating them in close proximity and feeding them with a common queue of work.

This can reduce waiting time and MTTP, provided the increase in equipment pooling doesn "t increase setup times, processing times, move times, variability, etc., to the point where the impact of these increases overcomes any potential waiting time reduction resulting from the pooling increase.

Reduce Number of Queues

The final way to reduce waiting time is to reduce the number of queues by increasing the number of successive operations that the same worker or machine performs.

Cross-training workers to perform multiple assembly tasks that were previously done by separate workers will reduce MTTP, provided any increase in task time resulting from the loss of specialization is less than the waiting time eliminated.

CLOSURE

Reductions in manufacturing throughput time can generate numerous benefits, including lower work-in-process and finished goods inventory levels, improved quality, lower costs, and less forecasting error (because forecasts are for shorter time horizons).

More importantly, reductions in manufacturing throughput time increase flexibility and reduce the time required to respond to customer orders.

This can be vital to the survival and profitability of numerous firms, especially those experiencing increased market pressures for shorter delivery lead times of customized product.

In conclusion, the literature analysis does not allow us to exhaustively describe managerial practices actually employed by firms for capacity and delivery lead-time management and the main criticalities in field.

Whereas much of the literature on lead time reduction had been largely anecdotal and exploratory.

The lack of clarity in a large portion of the lead time reduction literature, concerning such fundamental aspects of lead time reduction.

Customer delivery time is the time between when the customer places an order and the customer receives the order.

Production lead time is the sum of the processing time of converting raw materials to finished goods and the delivery time from the manufacturer to the customer.

Intuitively, production lead time can be viewed as an internal performance measure that monitors the efficiency of the production control system.

On the other hand, customer delivery time can be viewed as an external performance measure because it represents the manufacturer’s commitment on customer satisfaction and it is the performance that the customer really cares about.

Of course, shorter production lead time increases the service level to the customer, which leads to a higher market share.

But this may lead to a higher supply chain cost.

In some cases, the order handling on the front end and/or shipment and transportation at the other end may exceed actual production time significantly.

In all situations, it is important to identify where the opportunity is and focus any improvement efforts where they are most likely to deliver real results.

When looking for lead-time reduction opportunities, we don't have to ignore every factor.

After production is complete, there may also be convoluted processes for completing the paperwork, inspection and movement of goods to stock, picking, packing, and shipping.

Follow an order or a product through its complete cycle.

Manufacturing throughput time reduction can often be a daunting and confusing task due to the large number of factors that can be changed and the interactions between them.

Johnson [21] provides a brief tutorial that illustrates the basic factors that determine MTTP and explains why each factor impact occurs.

Following these guidelines it can be possible a reduction on Lead Time:

1. Production and transfer batch size reductions offer the largest potential for MTTP in most plants or eliminate non-active (queue) time.

2. High workstation utilization is a major contributor to long MTTP, especially in cases where variability is high.

3. Many causes of long MTTP are a result of policies and procedures implemented in the past that are used to control production batch sizes, transfer batch sizes, workstation utilization, resource access, and so on.

Outside of production, the solution is often to streamline procedures, eliminate non-valuable activities, coordinate departments more closely, and overlap activities for parallel completion wherever possible.

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