

A conceptual framework for managing congestion in manufacturing

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Abstract

This paper discusses the management of congestion in manufacturing. Tougher competitive situations have led to increasing attention being paid to customer satisfaction, of which timely and customized services are the key concepts. The decisions on how firms should trade off these expectations against high utilization of capital equipment and limited inventories are important to manage congestion effectively. A conceptual framework is presented in this paper for solving the problems of congestion in manufacturing. This framework takes into account the (i) role of cost accounting, (ii) presence of network externalities, (iii) evaluation of customer queueing costs, (iv) impact of entry regulation on congestion levels, and (v) pricing, competitive issues, and strategic implications in solving the problems of congestion. In addition, the role of new production concepts and technologies in the management of congestion is discussed in this paper.

Keywords: Management of congestion; Manufacturing; A conceptual framework

1. Introduction

In this paper, congestion is defined very broadly as anything that causes delay during the product life cycle. Obviously, delays can arise in design, testing, product launch and manufacturing, but this paper also considers all non-value-adding activities ranging from a mismatch between the corporate and business strategy and the manufacturing strategy, through to cost accounting methods which may misdirect management priorities, to manufacturing quality where defects can delay the supply

of goods and to the use of better scheduling or increasing capacity which can reduce queueing time.

To reduce congestion requires investment, perhaps into advanced manufacturing technology such as FMS or different scheduling methods, in which case there is a need to consider the trade-off between the costs and benefits. The purpose of this paper is to (i) identify the causes of congestion, (ii) develop a framework for solving the problems of congestion, (iii) examine the role of new production concepts and technologies in reducing congestion, and (iv) show how cost accounting can help to identify congestion. The first two are dealt in Sections 2 and 3 and the last two are dealt in Section 4 in the context of a strategic approach to managing congestion.

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2. Congestion in manufacturing

Top management plays an important role in the management of congestion which can arise at any part in the organization including administration, design, personnel selection, marketing, distribution, production, engineering, etc. The problem of congestion varies during the product life cycle, that is, from the product planning stage to the product logistics support stage. The implications of congestion will be different during various stages of the product life cycle. The major problems are to identify and determine the level of congestion at each functional area which may be due to the congestion at other functional areas in manufacturing. Congestion in manufacturing may also be due to the quality of personnel in terms of skills, management ability, education, training, etc. The facilities available such as computers, and other administrative facilities also influence the level of congestion. Congestion leads to confusion, delay, quality problems, longer manufacturing cycle time and inventory. Because of the dissatisfaction among customers, the company potentially faces a crisis to survive in the business.

Most manufacturing organizations consist of networks of manufacturing and distribution sites that purchase raw materials, convert them into intermediate and finished products, and distribute the finished products to customers. These networks are called supply chains or value-added chains. A typical supply chain network in manufacturing and the causes of congestion are shown in Fig. 1.

Usually, managers of various functional areas such as manufacturing, operations, logistics, material, distribution, and transportation have the responsibility for different parts of a chain in a manufacturing organization. The management of a complex supply chain is very difficult as the stock/inventory at various points of the supply chain, including both incoming materials and finished products, have complex interrelationships. The efficient and effective management of congestion throughout the supply chain will significantly improve the customer service.

Nowadays, the *time element* is given increasing attention in order to obtain faster product development and shorter lead times in procurement, production and distribution. The integration of business operations within and even between industrial enterprises in the form of networks has treatments influence on congestion and time management in manufacturing organizations. Effective networking (which consists of various supply chain nodes) in business operations can reduce congestion and shorten the lead times to give “Lean options for the enterprises” strategies and organizational structures [1]. Also, the strategies for managing congestion should be based on the position in the product life cycle. The problems of congestion should be solved before production actually starts. If firms can improve customers’ perceptions of the time they spend waiting to be served, then customers will experience less frustration and may feel more satisfied with the service encounter.

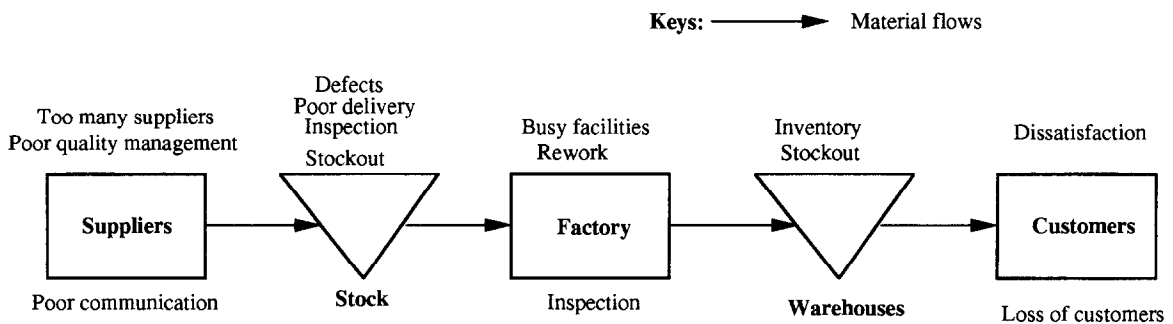


Fig. 1. A typical supply chain in manufacturing and the reasons for congestion.

3. Management of congestion in manufacturing

Researchers have approached the management of congestion from a variety of perspectives, using a wide range of tools. The purpose of this paper is to bring together the various tools available to manage the congestion problems in manufacturing. A strategic approach is gaining importance in managing congestion in manufacturing organizations. A conceptual model is presented in Fig. 2 to discuss the major aspects of the management of congestion in manufacturing and service organizations. The details of the conceptual model are discussed below.

3.1. The role of cost accounting in management congestion

Managers in companies selling multiple products are making important decisions about pricing, product mix and process technology based on distorted cost information. Alternative information rarely exists to warn the managers that product costs are badly flawed. Most companies detect the problem only after their competitiveness and profitability have deteriorated. Today, product lines and marketing channels have proliferated. Direct labour now represents a small fraction of corporate costs, while expenses covering factory-support

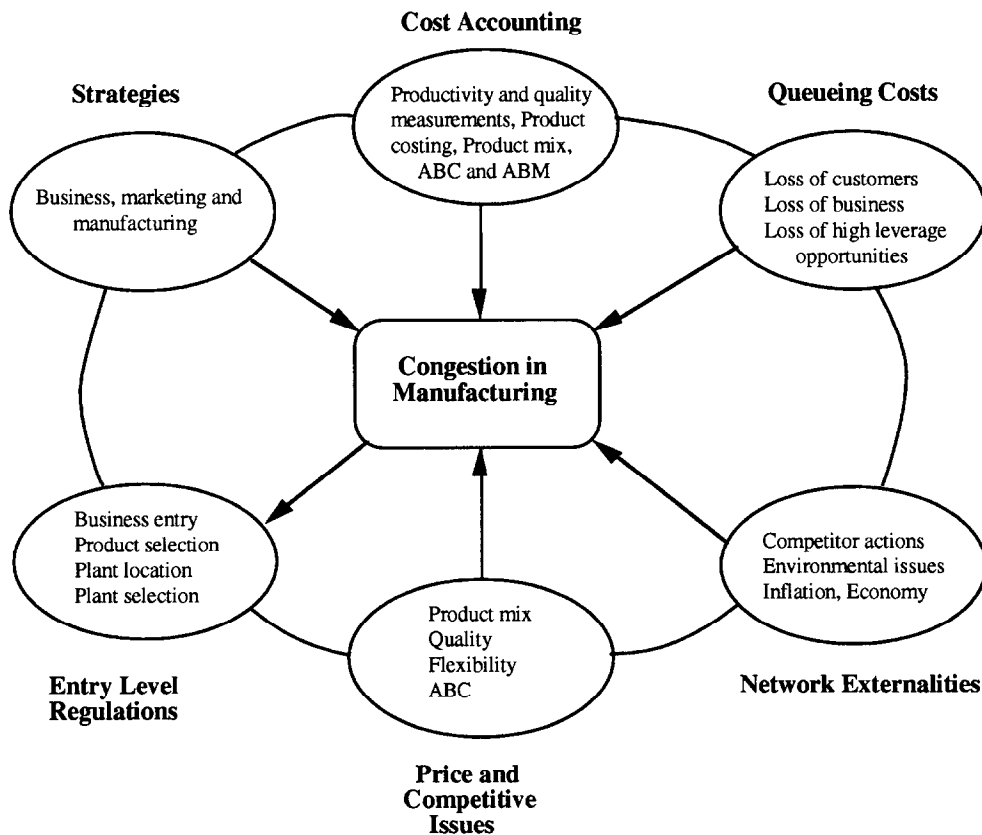


Fig. 2. A conceptual model to illustrate the elements of congestion in manufacturing.

operations, marketing, distribution, engineering and other overhead functions have exploded. This explains how important it is to reduce the congestion in these functional areas with an objective to reduce the cost of overhead activities and hence the cost of production needed to improve competitiveness. The activity-based costing (ABC) system will help to identify the causes of congestion in manufacturing by measuring the delays (non-value added) in marketing, design and engineering, production and distribution [2, 3]. Primrose [4] has reported the effect of Advanced Manufacturing Technology (AMT) investment on costing systems. The author points out that one of the reasons for carrying out the investment proposals is to quantify all the costs and benefits so that the investment can correctly be reflected in the company's costing system.

The discounted cash flow (DCF) approach accounts only for short-term financial benefits and does not account for long-term non-financial benefits such as innovation, flexibility, productivity and quality. For example, companies underinvest in CIM because they fail to evaluate properly all the relevant alternatives [2]. Congestion may appear because of the incorrect evaluation and design alternatives of CIM taking the strategies for improving productivity and quality. Therefore, there is a need to evaluate correctly the total costs involved in installing and operating the system in order to avoid any accumulation of inventory or idle facilities in CIM. A solution for evaluating the projects is to choose an appropriate discount rate and evaluate correctly all relevant investment alternatives.

The most effective strategy for improving responsiveness to customers is to eliminate congestion (non-contributing time) by reengineering business processes. Non-contributing time is any time in the total product or service life cycle that could be eliminated without diminishing the product's value [5]. Time is a competitive element; companies can manage time better if accounting and financial analyses support the goal of reducing and eliminating non-contributing congestion. Methods for eliminating non-contributing time include consolidating redundant activities, compressing the supply chain cycle, and synchronizing lead times and capacities [6].

One of the most valuable attributes of an activity-based cost management system is the enhanced

visibility that it can bring to the "hidden factory" that contains many of the overhead services (required for managing congestion) provided in an organization [7]. While evaluating advanced manufacturing technology projects' proposals, one should account for the following: technical issues, tangible benefits such as inventory savings, less floor space, higher quality, and intangible benefits such as greater flexibility, shorter throughput and lead time and increased learning. Traditional cost accounting measures only the costs of producing. It ignores the costs of non-producing, whether resulting from machine downtime or from quality defects that require scrapping or reworking a product or part. This suggests that a role of cost accounting is to measure the causes of congestion and to minimize the congestion in any form

3.2. Congestion in the presence of network externalities

The factors external to the network or supply chain such as government policies, environmental aspects, inflation, overall economic situation in the country, competitors' actions, etc., will influence the congestion. Therefore, there is a need to give importance to these externalities of the network when discussing congestion in manufacturing. All these externalities will act as constraints for the manufacturing system to function with certain level of congestion, which again depends upon the adjustment of other associated factors of congestion. The use of reliable forecasting methods and market research will help to alleviate the problems of managing congestion in manufacturing. Econometric models can be used, especially when we deal with external factors to the organization. It is very important that the cost of capacity should also be considered while formulating the policies for the management of congestion in manufacturing. There are many mathematical models such as queuing models, inventory models, network theoretic models, linear and non-linear programming models and transportation models that can be used for solving the problems of congestion in manufacturing, but each from a narrow perspective. In addition, simulation has been a powerful tool to

model the manufacturing systems taking into account more realistic features. Therefore, the simulation methodology can well be used for studying the implication of congestion in manufacturing and related cost behaviour [8].

3.3. Evaluation of customers' queueing costs

Evaluation of customers' queueing cost in manufacturing/service industries will provide a tremendous opportunity to improve the system performance. For example, in the supply chain management each functional department such as marketing, design and engineering and production becomes a supplier and customer to one or more functional departments. Therefore, the impact of a delay or congestion in one department on other functional departments should be evaluated to study the overall performance of the organization. In manufacturing companies, delay in design and engineering may lead to producing products with a particular set of design parameters that may not satisfy the requirements of the customers and, therefore, there is congestion in the form of finished goods inventory or lack of finished goods inventory. This might ultimately lead to the loss of customers and shut down of the production facilities. Within the factory a breakdown of machines, because of poor maintenance, can cause blocking and hence an inventory accumulation that may lead to poor delivery performance of products. The following costs may be involved in the queueing of customers: loss of customers, loss of revenue, loss of competitiveness, loss of high leverage opportunities such as new products, promotion, expansion and automation, and the impact on the society as a whole. However, these cannot be overcome free of cost. One has to pay to avoid the above situations by investing in the research and development, organizational restructure, automation and the capacity of the facilities.

3.4. The impact of entry regulation on congestion levels

Entry regulation explains the policies related to the selection of business, market products, release

of orders into the production system, etc. There are many different entry level policies possible with a view to manage the congestion in manufacturing such as business entry, market entry, product entry, process entry, skills selection, facilities selection, automation, etc. For example, a product that has a major share of the business may be given entry priority in all functional areas of manufacturing for both the development and production. Furthermore, aspects such as marketing, manufacturability and financial implications should also be considered while deciding the entry policies in manufacturing. The acceptance of different entry regulations again depends upon the impact of congestion and hence the performance of the overall manufacturing system performance in terms of improving productivity and quality.

3.5. Pricing, competitive issues and strategic implications

The pricing of goods and services depends upon the customers waiting time and the price they can offer. However, the company should set as its objective to increase the profit by reducing the cost, not by increasing the price of the product. In that case, the company may lose its competitiveness. The general competitiveness of a company evolves around the following: price, quality, after sales service, product specialization, delivery performance, etc. The strategic aspects play a predominant role in improving productivity and quality of the manufacturing organizations.

The company should identify its core competencies and accordingly has to formulate the business and productivity and quality improvement strategies. A gap between business and productivity improvement strategies may lead to congestion at different stages of manufacturing. Similarly, non-alignment between marketing and manufacturing strategies leads to delay and hence there is congestion and corresponding inventory accumulation or shortage [9]. The JIT concept aims to eliminate any sort of congestion in manufacturing. This situation is very idealistic when you see the market behaviour [10]. Therefore, there is a need for trade-offs between

appropriate costs in manufacturing taking into account the effective management congestion. For example, FMS will help to manage the congestion using the concept of alternative routeing, set-up time reduction, unbalanced material flow, etc. At the same time, the trade-off between investment in FMS and the savings in production cost should be taken into account.

4. A strategic approach for managing congestion in production

In this section, a systemic framework is presented using a conceptual model for managing congestion in manufacturing. The management of congestion involves the efficient and effective supply chain management in manufacturing organizations. Usually, the congestion problems have been discussed at the strategic, tactical and operational levels. If there is a mismatch between business and productivity improvement strategies, then there is congestion downstream both at the tactical and

operational levels of the organization. The same situation arises when there is a conflict between tactical and operational level decisions. Fig. 3 presents a conceptual model for solving the problems of congestion in manufacturing. The model indicates the integration of various functional areas such as marketing, research & development, design & manufacturing, purchasing, production, personnel, finance & accounting, distribution and plant and maintenance. As indicated earlier, supply chain management is synonymous to the management congestion. For example, the congestion in manufacturing due to rework and poor quality and unnecessary inspection can be avoided by research and development with the help of concurrent engineering, CAD, CAM, MIS and QFD. Similarly, the congestion due to personnel can be overcome by quality circles, major education to instil JIT, better communication, knowledge workers and matrix organization. Moreover, traditional cost accounting systems may cause congestion by failing to recognize the long-term benefits in terms of flexibility and quality and evaluation of

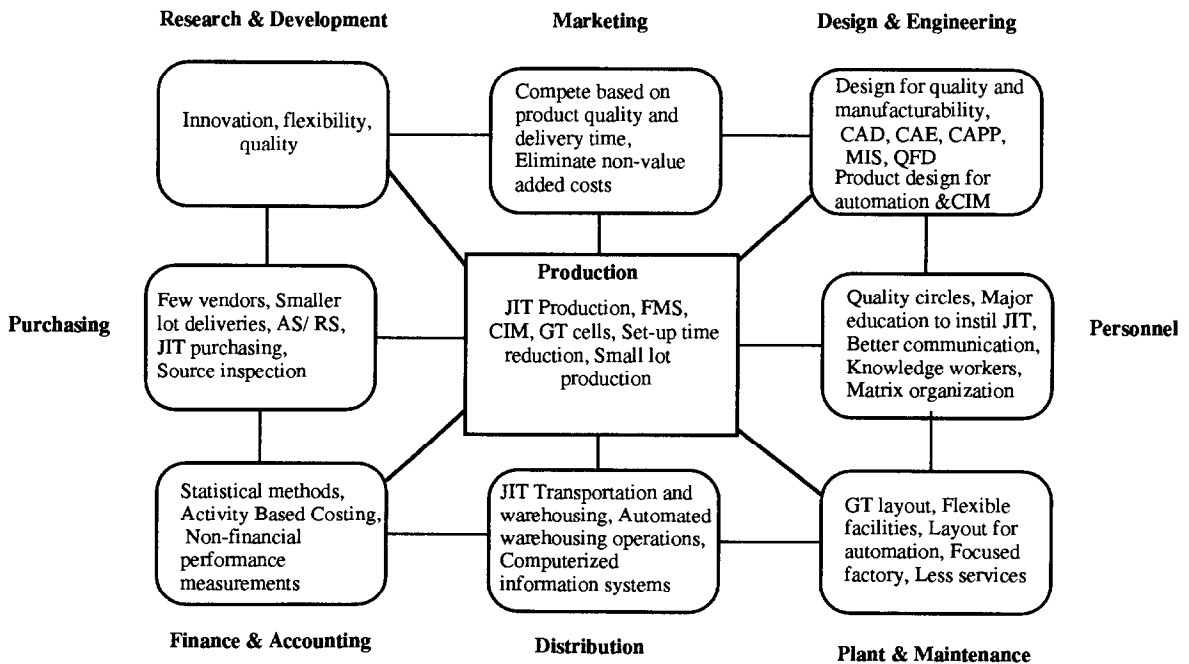


Fig. 3. A conceptual model for solving the problems of congestion in manufacturing.

customers' queueing costs, the impact of entry regulation on congestion levels and pricing, competitive issues and strategic implications.

The conceptual model presented in Fig. 3 explains the role of new manufacturing concepts and technologies in managing congestion in each of the functional areas of manufacturing. Each functional area should concentrate on reducing the congestion in its operations so as to reduce the manufacturing cycle time and to improve productivity and quality. The model indicates that there is a need to integrate all the functional areas to improve the management of congestion in the whole organization. The congestion in each functional area is influenced by other interacting functional areas. Therefore, there is a need to improve the management of congestion in an integrated framework. The problems of congestion can greatly be reduced by properly aligning the business strategy and manufacturing strategy. The manufacturing strategy should be formulated based on the business strategy and other characteristics of the firm such as skills and capital available, etc. For instance, marketing department should provide more accurate forecast for the demand and feedback from the customers about their quality and other performance requirements. This will help to reduce congestion in all other interacting functional areas. The design and engineering can contribute to the effective management of congestion by using CAD, QFD, CAE and CAAP. Integration of functional areas by computerized information systems can reduce the level of congestion. Purchasing department should have few vendors, smaller lot deliveries, automated storage/retrieval systems, JIT purchasing with a view to reduce congestion not only in purchasing, but also in other downstream functions of manufacturing. Concepts such as JIT and TQM and technologies such as FMS and CIM can be employed to reduce the congestion in production function. Also, they facilitate a reduction in congestion in the upstream functions, that is in the activities before production.

An effective personnel management strategy can contribute to the reduction in congestion almost everywhere in the manufacturing organization. For example, team work, better communication, knowledge workers and quality circles will improve the integration of all the functional areas and hence

provide effective management of congestion. Activity-based costing (ABC) system will help to identify the non-value added activities which perhaps determine the level of congestion in manufacturing. Also, activity-based management (ABM) will support the elimination of all non-value added activities with a view to improving the effectiveness of the manufacturing organization in producing quality goods and services. Total preventive maintenance (TPM) will provide reliable equipment for manufacturing activities which ultimately helps to reduce the level of congestion and hence an improved material flow in the system. Most manufacturing organizations consist of networks of manufacturing and distribution sites that purchase raw materials, convert them into intermediate and finished products, and distribute the finished products to customers. The problems of congestion can be overcome by strategies such as (a) design for management of congestion in the supply chain, (b) integrate databases throughout the supply chain, (c) integrate control and planning support systems, (d) redesign organizational incentives, (e) institute congestion measurement in the supply chain, and (f) expand view of congestion in the supply chain [11, 12].

The business strategy and productivity improvement and quality strategy should match each other in order to manage congestion in a cost-effective manner [13]. For example, when a product is in the decline stage of the product life cycle, the business strategy should focus on the development of new products and the corresponding productivity improvement strategy could be the installation of a FMS. A summary of the strategic options available for the purpose of managing congestion in manufacturing is presented in Table 1. Due attention should be given at the early stages of the product life cycle for activities such as innovation and flexibility with an objective to minimize the congestion through the supply chain in manufacturing [14]. The product manufacturing practice for managing congestion should include consideration of such approaches as enterprise, integration, shared databases, multimedia information networks, product and process modelling, intelligent process control, virtual factory, design automation, super-computing, product data standards,

Table 1

A list of suggestions for reducing the congestion in manufacturing

Functional areas	Strategies for reducing the congestion
Marketing	Computerized information systems, QFD competitors' position, and standardization of products
Maintenance	Total productive maintenance
Distribution	JIT delivery, JIT transportation, automated warehousing operations
Personnel	Knowledge workers, flexible work force
Accounting	Activity-based costing (ABC)
Design and engineering	CAD, CAE and concurrent engineering
Purchasing	JIT purchasing
Production	JIT, FMS, CIM, OPT and TQM.

paperless transactions through electronic information interchange and the high-speed information highway.

A number of ways in which congestion may be reduced have been discussed in this section. At the same time, these could involve a major investment in systems or resources. There is thus a need to identify, by experience or through systematic analysis (including possibly simulation) which will be the most effective set for improving the operations of a particular company.

5. Concluding remarks

In this paper, an attempt has been made to (i) identify the causes of congestion in manufacturing, (ii) develop a conceptual model for illustrating the various aspects of congestion, and (iii) present the strategic options available for the effective management of congestion with the help of a suitable conceptual model. The issues of congestion have been discussed from different perspectives, but the main focus has been on how to review those tools and methods available for improving the productivity and quality of the manufacturing organizations by managing congestion effectively. The new manufacturing concepts such as JIT, TQM and Business Process Reengineering (BPR), and technologies such as FMS, CIM and Automated Storage and Retrieval Systems (AS/RS) can be utilized to manage congestion in manufacturing. Manufacturing performance measures using ABC and

non-financial measures such as quality, flexibility, inventory and productivity would help to identify the congestion areas in manufacturing. In addition, the concept of OPT can be used to identify the bottleneck operations or implications of congestion. Quantitative models should be developed for evaluating congestion and related trade-offs. Also, other concepts such as design for engineering, quality and manufacturing would facilitate the effective management of congestion.

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