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Model-supported supply chains for cost-efficient intelligent enterprises

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Abstract

Purpose – The twentieth century brought great competition and complexity to business life. Advanced technologies and new production techniques resulted in shortening product life cycles. Firms that wanted to survive began to implement different strategies directly focused on customer satisfaction. Supply chain management, as a management philosophy, highlighted a new area that has the potential to reduce cost further than production costs. This paper promotes the supply chains for cost-efficient intelligent enterprises.

Design/methodology/approach – Promotes the use of supply chains by means of simulation and allocating the results to solver in Excel for decision modelling in order to integrate the supplier and manufacturer relationship for the cost-efficient enterprise.

Findings – Finds that a manufacturing firm really needs to develop effective co-ordination within and beyond its boundaries in order to maximise the potential for converting competitive advantage into profitability. Good co-ordination with the key suppliers especially will increase product availability.

Originality/value – The synchronisation of activities in supply will create value to both its members (supplier and manufacturer) and in addition it will create value to the end customer by satisfying delivery dates.

Keywords Supply chain management, Simulation, Cost reduction, Response flexibility

Paper type Research paper

Introduction

Since the year 2000 business objectives began to focus on new visions due to greater domestic and foreign competition at all levels of business functions. Firms that wanted to survive or achieve greater competitive advantage defined their visions in the light of strategies like cost reduction, quality improvement, increased flexibility and customer satisfaction.

Everybody has been working on decreasing costs of production for many years so it would be better to deal with a new area which has the most potential to reduce costs further: supply chain management (SCM).

Recent SCM literature focuses on various definitions. In general, all definitions emphasised that SCM is a management philosophy which has both inter-enterprise and outer-enterprise scope. It includes all activities from the raw materials stage through to the end-user by bringing trading partners together with the common goal of optimisation and efficiency (Tan *et al.*, 2002).

This definition of the supply chain highlights the complexity in itself, but to extend this definition the number of members and their relationships should also be taken into

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consideration. So it becomes difficult to set parameters for inter-organisational targets and for performance measurement. This generally finds a solution in literature by means of model-supported analysis. Since experimenting, most of the members use a model-based simulation. However, to develop an effective and efficient supply chain a business must perform all types of decision support capabilities and tactical planning. At this point, the importance of knowledge-based systems in becoming an intelligent enterprise comes into play.

This paper promotes supply chains by means of simulation and allocating the results to solver in Excel for decision modelling in order to integrate the supplier and manufacturer relationship for a cost-efficient enterprise.

Supply chains and model-supported analysis

Effective SCM is the most important competitive strategy in the new business era. In particular the global competition among manufacturers to manage the value chain from supplier to customer emphasises the key role of decision making. To be able to work with sufficient production volumes and also with good quality, highlighting the relationships between supplier and manufacturer becomes inevitable. The rapid advance in information technology is deployed not only to improve existing operational effectiveness of a business, but also to build the new capability to meet today's business environment and complexity (Choy *et al.*, 2003).

In the early twentieth century, businesses generally performed their own manufacturing, sourcing, warehousing, sales and distribution activities by themselves. This means that they are vertically integrated. However, increasing complexity and competition in business life makes them add new external partners to their supply chain such as suppliers, distributors, etc. Within this, it became very difficult to control and integrate the activities. Supply chain integration and supply chain optimisation became vital for most of the organisations. Modern enterprises still have vertically integrated functions, but the result comes with the cost of reduced competitive flexibility. One way to improve competitive flexibility is to integrate these functions virtually (Reddy, 2003a, b, c). Supply chain integration focuses on improving the information between links in the chain and supply chain optimisation focuses on making decisions that reduce the information asymmetry, resulting in excess inventory in the supply chain (McLaren *et al.*, 2002). However, the important point is that to create local optima will not be enough, the entire supply chain should be optimised. Thus organisations make their decisions by thinking about both internal and external partners in order to create value for all involved.

Optimisation and creating value requires decision making at three levels:

(1) strategic (months to years);

(2) tactical (days to months); and

(3) operational (hours to days).

To analyse supply chain problems at all these three levels, interconnected modelling systems are needed (Shapiro, 2002).

The connection between the supplier and manufacturer, contributes to the competitive advantage of the manufacturer in improving business processes, efficient production scheduling, through decreasing cycle times and increasing throughput. Further advantages through this relationship will be substantial cost reductions, quick response to changing customer demands and increasing customer service levels. These all together will serve today's only important competition factor which is customer satisfaction.

We are living in an environment which is surrounded by uncertainties and risks. Therefore, managers should have to make decisions in a situation that is determined by uncertainties and risks, indeed without having enough information on the results and effects of these decisions.

Model-supported decision making provides a business environment free from risks and helps to analyse the effects of critical business decisions. This virtual environment will increase the decision support capabilities of the business and management.

Thus, the advantages of a model supported procedure are (Kaczmarek and Stüllenberg, 2002):

- saving of time;
- minimising the risk; and
- a higher transparency.

Also, while making plans about the future no real system exists. Therefore, decision modelling and simulation will be the only alternatives in generating results about the actions of the plans. Figure 1 shows the steps for simulation modelling.

Advantages for applying simulation can be as follows:

- improvement of business functions through service times, costs, throughput, flexibility and time;
- the analysis of the effects of various decisions; and
- the visualisation of the benefits and costs.

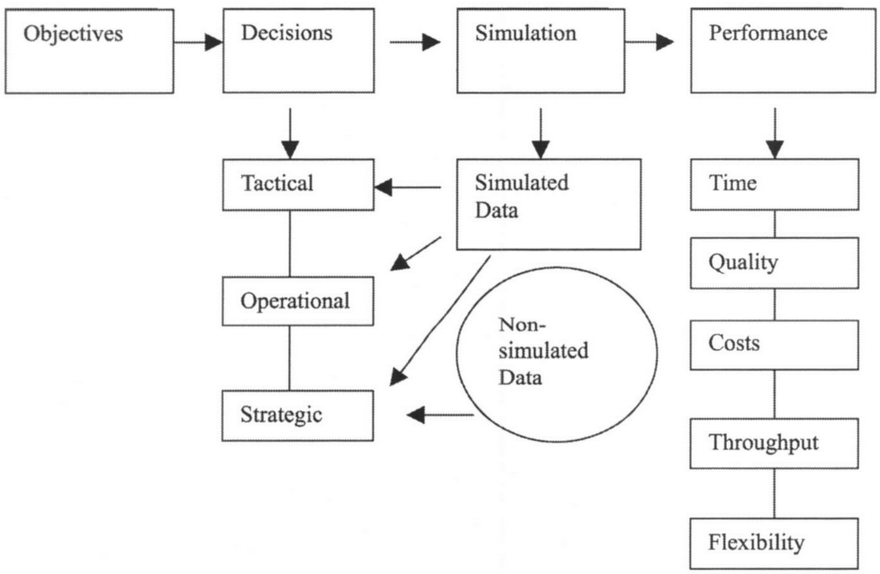

Figure 1. Using simulation to evaluate performance

It is important to remember that simulation cannot always be the best tool. Simulation studies must be economical. Sometimes the cost of using the simulation may be higher than its expected benefits due to insufficient information or to complexity. In this case, other analysis tools can be chosen. The cost measures that are the basis for decisions must always be integrated into the modelling process. Also, the non-simulated data that have the possibility to affect decisions should be incorporated to the evaluation process.

Within these, there are some factors that should be taken into consideration while using simulation models:

- setting the objectives truly;
- determining the causes of the problems;
- evaluating all the inputs and absorb the ones which are related to the decision;
- analysing the data correctly;
- assigning the experienced and correct staff;
- setting the exact model with the exact dimensions; and
- searching the other tools besides simulation.

Effective co-ordination and other advantages come with the simulation. Co-ordinating suppliers, manufacturers, distributors, third-party logistic providers and retailers will be the key for achieving competitive flexibility. Negative aspects of poor co-ordination include (Simatupang *et al.*, 2002):

- higher inventory costs;
- longer delivery times;
- higher transportation costs;
- higher levels of waste; and
- lowered customer service.

In order to provide system-wide and co-ordinated optimisation in SCM, a single objective function for optimisation during all the stages of supply management should be used. The objective for the manufacturer should be maximising throughput. Without such an objective it is impossible to determine the most effective techniques based on cost benefit in achieving this goal in a manufacturing system and SCM.

Simulation model

As mentioned before, within SCM delivery speed and customer satisfaction have become the key factors for competitiveness. However, efficiency requires not only delivery speed, but also lower costs and reduced cycle times supported with detailed capacity constraint analysis.

This study includes a modelling with simulation that provides a relationship between supplier and manufacturer within SCM. The partners of the chain follow individual aims and try to maximise their own profit. In the framework of simulation studies a very simple model is developed. Also, to support the management decisions, the information supplied by the simulation was processed in the context of an Excel-based decision modelling. Utilisation of resources integrated with the Excel-based logistics costs optimisation.

Within this integrated model, three performance measures are especially taken into consideration:

(1) cycle times;

(2) levels of capacity utilisation; and

(3) cost reduction.

Reducing cycle times and determining levels of capacity utilisation is regarded as tactical decision making, but cost reduction should be regarded in the context of strategic decision making. Integrating simulation and Excel also helps us to integrate tactical and strategic decisions simultaneously.

In recent years, many models have been developed. Most of these models focus on minimising work in process (WIP) to reduce cycle times and to reduce inventory costs. However, to be both efficient and effective, reducing WIP is not enough. The system should optimise the material flow as a whole. Therefore, as in Figure 2, reducing WIP should be supported with the optimisation of manufacturing cycle time and buffer controls.

Supporting optimisation with capacity constraints and buffer management developed by Goldratt in the mid-1980s and evolved from optimised production timetables (OPT). This concept as a whole became known as Theory of Constraints (TOC). Goldratt determined the "throughput" as the most important performance measure, but supported it with reduced cycle times and reduced costs.

Rahman (2002) performed the causal relationships between SCM and customer satisfaction with TOC's thinking process as:

- long cycle times;
- less flexible supply chain;
- low in responsiveness; and
- low customer satisfaction.

Figure 3 illustrates the simulation model constructed by using a simulation package Extend LT (Prentice-Hall, 2002). This model is the visualisation of a manufacturing flow including scheduling by using buffer management. The raw materials coming from the supplier are assumed to be exponential and they arrive at an average rate of one unit per second.

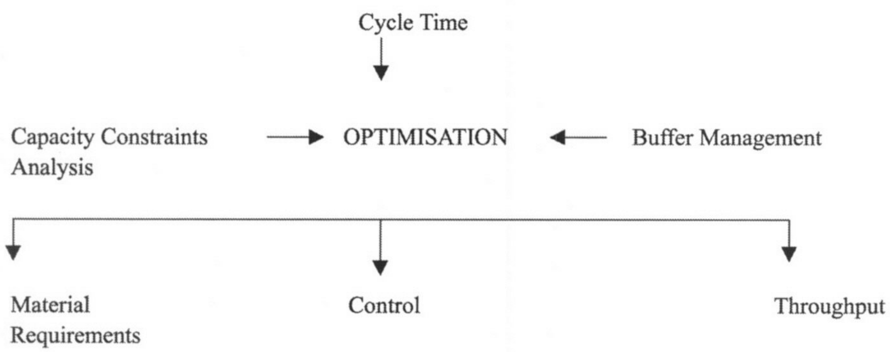

Figure 2. Optimisation-based production scheduling

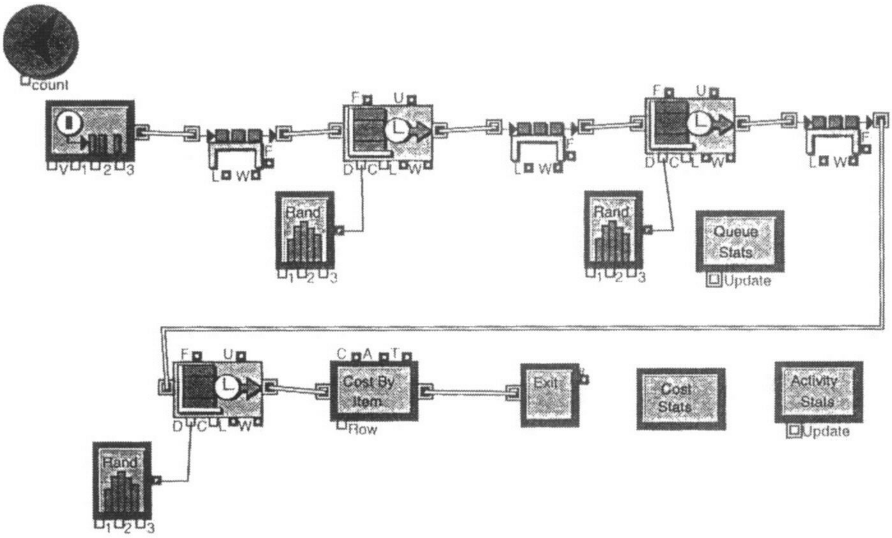

Figure 3.
Simulation model

In the simulation model, the buffer represents a protective time period. Regarding buffer management, activity multiple blocks (representing production units/stages) are connected with input random number blocks in order to find the most efficient buffer time. The main reason is to determine the time period that results within most efficient production flow. The buffers set before and after the activity multiple blocks that have the capacity constraint, will help to balance production flow. By doing this, they prevent the delays in the production due to the capacity constraints.

In Table I, the capacity of the three production units in three different plants of the same organisation is given. According to these capacities, the simulation model is run for three of them. Table II gives the results of the simulation and the raw material requirements are determined for each plant.

Table I.
Production capacities

Production stages	Capacity of Plant 1 (unit/hr)	Capacity of Plant 2 (unit/hr)	Capacity of Plant 3 (unit/hr)
1	1,200	1,500	1,000
2	900	1,200	1,300
3	1,300	1,400	1,400

Table II.
Material requirements

Plant	Material requirements (units)
1	9,627
2	12,362
3	9,020
Total	31,009

After this point, the importance of co-ordination with the supplier comes into play. Co-ordinating the rate of order to match the required raw material consumption will result in on-time deliveries, which means customer satisfaction. If the company shares the sales and stocking data with its suppliers and also if the supplier shares the raw material stocks data with their main customers (manufacturers), the result will be increased flexibility and reduced costs. Table III shows the raw material which is ready in the suppliers' stocks.

From the simulation model, raw material requirements have already been determined and, with the help of the co-ordination, the key suppliers' stocks are also known. This knowledge-based, two-sided information flow will enable the manufacturer to perform an Excel-based integrated decision model. The requirement for an integrated model is to visualise the situation in Excel. This enables a quantitative description of the transportation link between manufacturer and supplier as well as a basis to perform an optimised transportation model.

Given the data of the unoptimised situation in Table IV, the basis for the decision-making process within the Excel transportation model was performed.

When the solver parameters are entered, the result will be an optimised decision model which is shown in Table V for the efficient material flow from different suppliers to different plants. Addition to this evaluation, Figure 4 can help give a better representation of the comparison of unoptimised and optimised models based on the units.

Supplier	Material amounts (nits)
1	8,000
2	14,004
3	9,005
Total	31,009

Table III. Material ready in suppliers' stocks

Supplier	Plant 1	2	3	Total
1	0	4,000	4,000	8,000
2	7,002	1,982	5,020	14,004
3	2,625	6,380	0	9,005
Total	9,627	12,362	9,020	

Table IV. Unoptimised Excel transportation model based on the units

Supplier	Plant 1	2	3	Total
1	0	3,357	4,643	8,000
2	9,627	0	4,377	14,004
3	0	9,005	0	9,005
Total	9,627	12,362	9,020	

Table V. Optimised Excel transportation model based on the units

The decision-making process can be effectively supported, if the management also obtains the necessary evaluation of the transportation costs. For an efficient and effective decision-making process, cost measures should also be integrated with the results of the simulation and the Excel transportation models.

In order to achieve the results of the cost optimisation, a second group of data that includes the unit transportation costs is given in Table VI. On the basis of these data the total cost performance of the Excel transportation model is analysed. To achieve a better comparison, the cost model is performed for both unoptimised and optimised transportation models. Tables VII and VIII show the total cost performance of these models.

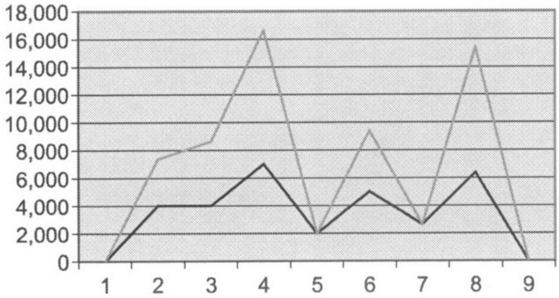

Figure 4. Performance graph for Excel transportation model based on the units

Table VI. Unit transportation costs for the optimised Excel transportation model

Supplier	Plant 1 (TL)	Plant 2 (TL)	Plant 3 (TL)
1	85,000	70,000	70,000
2	60,000	75,000	60,000
3	90,000	80,000	95,000

Table VII. Total cost performance of unoptimised Excel transportation model

Supplier	Plant 1	Plant 2	Plant 3	Total
1	0	280,000	280,000	560,000
2	420,120	148,650	301,200	869,970
3	236,250	510,400	0	746,650
Total	656,370	939,050	581,200	2,176,620

Table VIII. Total cost performance of optimised Excel transportation model

Supplier	Plant 1	Plant 2	Plant 3	Total
1	0	234,990	325,010	560,000
2	577,620	0	262,620	840,240
3	0	720,400	0	720,400
Total	577,620	955,390	587,630	2,120,640

Figure 5 can be a better representation of the comparison of the total cost performance of unoptimised and optimised models based on the units.

To highlight the development of the Excel-based models and the performance results, the optimisation and sensitivity reports for the solver parameters are given in Tables IX-XII.

Simulation and optimisation models allow managers to evaluate different alternatives, to give strategic decisions and to visualise the constraints. These are the analytical tools capable of solving complex problems at all levels of business operations. Using an integration of simulation-Excel, in most cases, utilisation of resources and cost minimisation can be achieved at the same time.

Conclusion

A manufacturing firm really needs to develop effective co-ordination within and beyond its boundaries in order to maximise the potential for converting competitive advantage into profitability. Tight co-ordination especially with the key suppliers

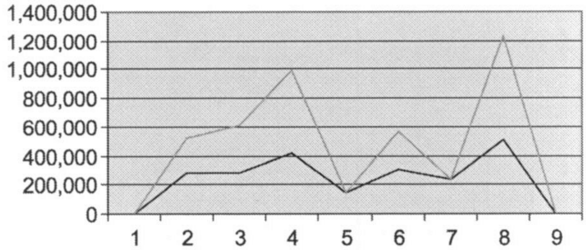

Figure 5. Performance graph for Excel transportation model based on the costs

Cell	Name	Original value	Final value
Target cell (min)			
E28		2,176,620	2,120,640
Adjustable cells			
B18	Supplier 1: Plant 1	0	0
C18	Supplier 1: Plant 2	4,000	3,357
D18	Supplier 1: Plant 3	4,000	4,643
B19	Supplier 2: Plant 1	7,002	9,627
C19	Supplier 2: Plant 2	1,982	0
D19	Supplier 2: Plant 3	5,020	4,377
B20	Supplier 3: Plant 1	2,625	0
C20	Supplier 3: Plant 2	6,380	9,005
D20	Supplier 3: Plant 3	0	0

Table IX. Optimisation answer report certainly will increase product availability due to on-time deliveries and reduced inventory and logistics costs. This synchronisation of activities will create value to both members of the supply chain (supplier and manufacturer) and also, it will create value to the end customer by satisfying delivery dates.

So far, many organisations may choose many different methods to create value in their supply chain. If the cost-benefit approach allows choosing the simulation as an alternative, it can be easily said that, model-based analysis provides the suitable and

Table X.
Constraints

Cell	Name	Cell value	Formula
\$B\$21	Plant 1	9,627	B21 ≥ B22
\$C\$21	Plant 2	12,362	C21 ≥ C22
\$D\$21	Plant 3	9,020	D21 ≥ D22
\$E\$18	Supplier 1	8,000	E18 ≤ F18
\$E\$19	Supplier 2	14,004	E19 ≤ F19
\$E\$20	Supplier 3	9,005	E20 ≤ F20

Table XI.
Sensitivity report – adjustable cells

Cell	Name	Final value	Reduced cost	Objective coefficient	Allowable increase	Allowable decrease
B18	Supplier 1 Plant 1	0	15	85	1E + 30	15
C18	Supplier 1 Plant 2	3,357	0	70	10	10
D18	Supplier 1 Plant 3	4,643	0	70	10	15
B19	Supplier 2 Plant 1	9,627	0	60	10	80
C19	Supplier 2 Plant 2	0	15	75	1E + 30	15
D19	Supplier 2 Plant 3	4,377	0	60	15	10
B20	Supplier 3 Plant 1	0	10	90	1E + 30	10
C20	Supplier 3 Plant 2	9,005	0	80	10	10
D20	Supplier 3 Plant 3	0	15	95	1E + 30	15

Table XII.
Constraints

Cell	Name	Final value	Shadow price	Constraint RH side	Allowable increase	Allowable decrease
B21	Plant 1	9,627	80	9,627	0	4,643
C21	Plant 2	12,362	80	12,362	0	9,005
D21	Plant 3	9,020	80	9,020	0	4,643
E18	Supplier 1	8,000	−10	8,000	9,005	0
E19	Supplier 2	14,004	−20	14,004	4,643	0
E20	Supplier 3	9,005	0	9,005	1E + 30	0

sufficient statistical, financial and economical information. To establish a knowledge-based intelligent enterprise simulation can be the first step to evaluate the performance and the Excel-based optimisation can be the second step to supporting the decisions considering the performance results. To reduce ineffectiveness in supply chains and in organisations, integration, co-ordination among members, flexibility within and beyond the organisation should be maximised in order to turn customer satisfaction to profitability.

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