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Theoretical and Conceptual Aspects of Innovation: Supply Chain Management of Automobile Manufacturing Industry

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Abstract: As the business environment of automotive manufacturing grows in complexity, management decision making of manufacturer becomes more difficult. Vast sources of information become available that often add to the decision-maker's confusion. The purpose of this paper are two folds (1) to develop a conceptual model of process of innovation in auto industry and (2) to discuss the various symbolic models and techniques available for Automotive Production Coordinator (APC) use in decision-making towards planning and controlling responsibilities of auto manufacturing. The mathematical model comprises four types, namely heuristic, algorithmic, mathematical programming, network and simulation. It should be noted here that most of the mathematical models to be considered in this paper are essentially algorithmic models. It is envisaged that this theoretical model provides a useful tool for decision rules in assisting the auto production coordinator in planning and management of purchasing, manufacturing and distribution of automobile.

Key words: Decision-making, management, mathematical models, production, supply chain, transportation

INTRODUCTION

Supply chain strategy involves the effective management of supply in order to meet demand. In the consumer products industry today, for example, there is a push towards demand-side management, which implies managing demand at the store level and working backwards to better manage and anticipate demand has tremendous implications for the transportation industry. The question arises, what is Supply Chain Management (SCM)? Kay[1] defined SCM as the practice of coordinating the flow of goods, services, information and finances as they move from raw materials to parts supplier to manufacturer to wholesaler to retail consumer. Notwithstanding, coordination between the various players in the chain is key in its effective management. Cooper and Ellram[2] compare supply chain management to a well-balanced and well-practiced relay team. It should be noted that such a team is more competitive when each player knows how to be positioned for the hand-off.

Breitman and Lucas[3] developed a conceptual model of a production-distribution system, PLANETS, that is likely to be used to decide what products to produce, where and how to produce it, which markets to pursue and what resources to use. Cohen and Lee[4] also developed a conceptual framework for manufacturing strategy analysis, where the authors describe a series of stochastic sub- models and use heuristic methods to link and optimize these sub- models. Furthermore, in 1988 the authors developed an integrated and readable exposition of their models and methods. In 1989 Cohen and Lee present a normative model for resource deployment in a global manufacturing and distribution network.

Arntzen, *et al.*[5] provide the most comprehensive deterministic model for supply chain management which focuses on the objective function and minimizes cost and time elements.

The auto sector has been dramatically transformed in recent years by changing market needs, new technology and globalization. In this climate of continuous change and increasing competition, suppliers to the transportation industry (automobile, bus/mass transit, aviation) are striving to meet the needs of their customers with an increased emphasis on the design and development of new innovative auto products.

Supply chains continually face challenge of efficient decision-making in a complex environment coupled with uncertainty. The purpose of this study are two folds

- To identify the primary components of Supply Chain Management (SCM)
- To discuss the various symbolic models and techniques available for Automotive Production Coordinator (APC) use in decision-making for planning and controlling responsibilities of auto manufacturing.

CONCEPTUAL MODEL OF PROCESS OF INNOVATION IN AUTOMOBILE INDUSTRY

A process of innovation and supply chain in auto industry is a network of facilities and distribution options

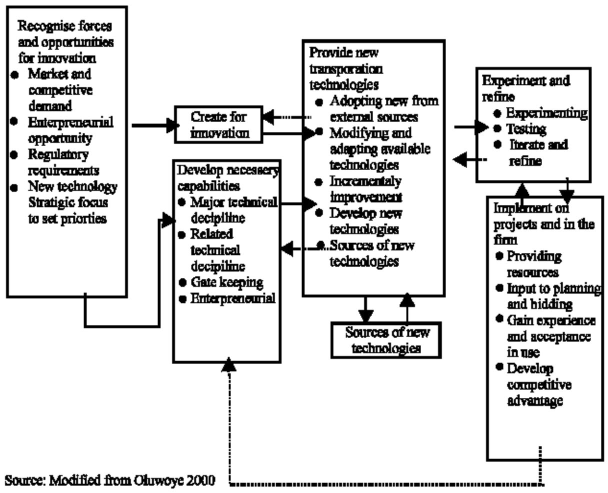

Fig. 1: Process of innovation in the management of automobile manufacturing industry

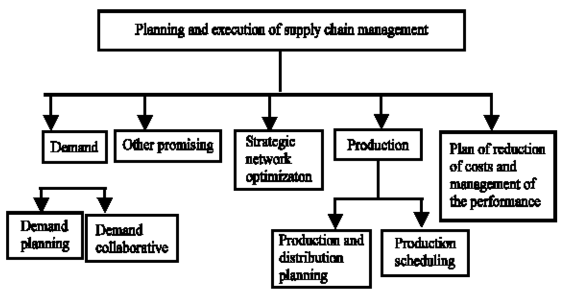

Fig. 2: Components of supply chain management planning and execution

that performs functions of procurement of materials, transformation of these materials into intermediate and finished products, distribution of these finished products to customers.

The analysis of the conceptual model below presents a process for innovation in the management of automobile auto manufacturing industry utilizing new supply chain methods.

The process in Fig. 1 above consists of the following elements:

- Recognizing forces and opportunities for innovation market demands, regulatory requirements etc.
- Creating climate for innovation commit resources, foster autonomy, tolerate failure
- Developing necessary capabilities related technical disciplines major technical discipline, related technical disciplines, gate keeping, entrepreneurial;
- Providing new transportation technologies by adopting, modifying and adapting, incrementally improving, or developing

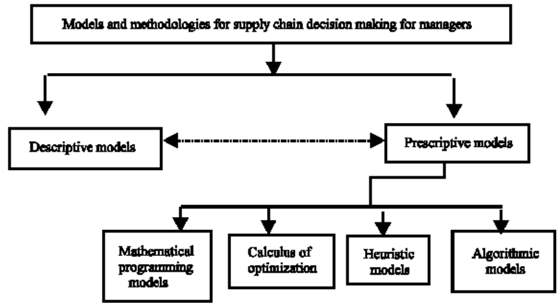

Fig. 3: Mathematical models for supply chain

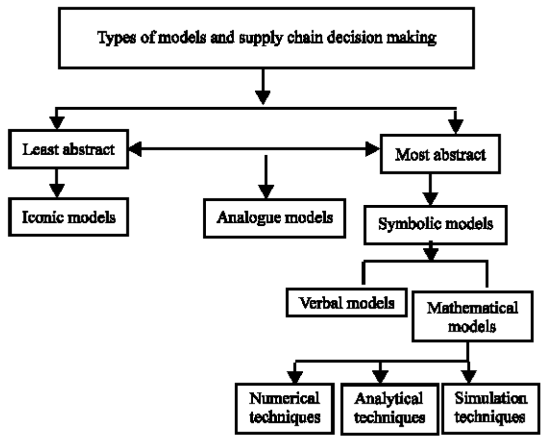

Fig. 4: Types of models for decision making in auto industry

- Experimentation and refining experiment in yard or laboratory, test with lead, produces, test on projects, iterate and refine
- Implementation on projects and in the industry. Once this platform is established, the level of innovation that occurs is dependent on four key factors:
  - The client's recognition of the need for innovation;
  - Contractual incentives to encourage innovation;
  - Creation of symbiotic learning environment;
  - Open communication at all levels are conductive factors in effective innovation.

In each instance, the two parties assumed a symbiotic relationship, where each gained from the knowledge and experience of the other. Moreover, in these instances, rather than driving innovation the principal role of the client was to create an environment conducive to innovation and learning.

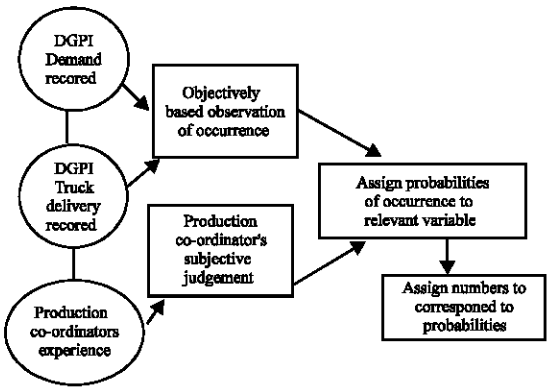

Fig. 5: Stochastic relationship

CONCEPT AND SUPPLY CHAIN MANAGEMENT OF DELIVERY SCHEDULES OF AUTO PARTS PACKAGING CONTAINERS

Supply chain planning: In practical terms planning is the process of preparing and implementing objectives strategies and policies for the future. Supply Chain Planning (SCP) involves looking ahead with the view to making provision for the future event of purchasing, manufacturing, logistics, distribution, marketing and delivering value to customer destination.

The above figure 2 shows the components of Supply Chain Management (SCM) that deals with the planning and execution issues involved in managing a supply chain. SCM involves several elements such as location, production, inventory and transportation.

According to Dormer *et.al.*[6] a supply chain manager constantly face the task of making numerous decisions such as amount of raw material to purchase, routing, marketing and shipping finished products to distribution centers, inventory control issues, etc. As the business environment grows in complexity, management decision making becomes more difficult. Vast sources of information become available that often add to the decision-maker's confusion. Management scientists have concentrated on developing mathematical models and decision rules that effectively summarise the information need for the decision-maker and thus enable management to concentrate on the selection of a particular course of action.

At Parts Packaging Industry (APPI), the coordinator operates in a complex business environment. During operations numerous decisions need to be made and it is essential that coordinates has the summarised information necessary for making an intelligent, methodical decision in the shortest possible time. The production decision may be the synthesis of various sub-decisions concerning product characteristics, demand, time constraints, production costs, distribution and personnel. Models are available that provide the framework to effectively assist the production coordinator to evaluate the various alternatives (Fig. 3).

Models and methodologies for supply chain decision making for managers: The model is a representation of the system, a representation that leads itself to use in predicting the effect on the system's effectiveness of possible changes in the system. Of the three broad types of models, the iconic, analogue and symbolic, only the latter is considered here to be of importance for auto parts packaging industry.

An iconic model pictorially or visually represents certain aspects of a system (as does a model of the printer-folder-gluer). An analogue model employs one set of properties to represent some other set of that the system being studied possesses. Graphs are very simple analogues. In graphs one need to use distance to represent such properties as time, number and percentage. The symbolic model by proper mathematical or logical operations it can be used to formulate a solution to problem at hand. Symbolic models may be classified as either mathematical or verbal models.

Mathematical techniques for deriving a solution or optimizing the system are essentially of two kinds-analytical and numerical. In certain symbolic models, there are terms that cannot be evaluated exactly. In such case's simulation techniques are used. Figure 4 summaries the types of models highlighted in this section.

Heuristic models: The simplest kind of symbolic model is a verbal model. Heuristic models are good examples. They are usually simple guidelines for decision-making that are justified by appeals to intuition, reason, precedent or ethical principles. In a larger sense, any mathematical model that cannot be for the behavior of at least some of the relevant factors may be considered heuristic. Heuristic model formulated to devise the planned delivery schedules of a large Auto Parts Packaging Containers (APPC) truck. The model incorporates all the relationships and considers all constraints the available options in attempts to solve the problem. The model enables production coordinator to predict the effect of possible changes in the distribution system.

Algorithmic Models are basic types of mathematical models. Algorithms are often based on heuristic thinking being a formalization of the previous logical structuring of the problem. An algorithm, by definition is an iterative procedure that leads to an optimal solution whereby a procedure is repeated again and again until the best desired option is obtained. Most of the mathematical models to be considered in this paper are essentially algorithmic.

Mathematical programming models: These types of models have wide applications useful for the production coordinator. Mathematical programming could be linear or non-linear. One type of mathematical programming model of which benefits the operations of APPC is the allocation model. This model can be used to problems in which a number of activities are competing for limited resources. It enables the decision-maker to optimize the company's resource-allocation to produce the maximum return. The resources may be limited in two ways.

First in a given time period, there may be a limit on the quantity, beyond which resources cannot be purchased or employed. Second, they may be limited in the sense that within the boundaries of the problem each coordinator usually cannot be allocated for the given resources in the most efficient way or an individual basis. For example, assume that during a particular time period, APP Industry is planning to manufacture three different products X, Y and Z.... each yielding a specific contribution to overhead and profit.

Assume further, that two auto parts different machine processes are required in manufacturing each of these products. The allocation problem is to determine a programme of production or a product mix, which will maximize not the individual contribution of a given product but the overall effectiveness of the production programme.

The mathematical programming technique suitable for solving allocation problems is linear programming. Linear programming refers to techniques for solving a general class of optimization problems dealing with the interaction of many variables subject to certain restraining conditions. In solving these problems, objectives such as profits, costs, quantities produced, or other measures of effectiveness are to be obtained in the best possible or optimal fashion, subject to certain restraining conditions (which are linear functions). In mathematical terms, linear programming solves problems such as:

$$\text{Maximise } Z = C_1 X_1 + \dots\dots\dots + C_n X_n = \sum_{Auj} Cj\, Xj$$

$$\text{Subject to: } a_{ii} X_1 + \dots\dots\dots + a_{ln} >/< b_l$$
$$a_{ml} X_1 + \dots\dots\dots + a_{mn} X_n >/< b_m$$
$$X_1, X_2, \dots\dots\dots, X_n >/< 0$$

Where,

C_j = Profit or cost per unit of controllable variable J, by convention called "costs"

b_i = Amount of resources i available

a_{ij} = Amount of resources i used per unit of controlled variable J

For example, at APP Industry, certain containers may be obtained in a plant by combinations of raw materials and cutting printing, slitting, creasing and stitching operations. For optimal programming decision, all possible combinations of these operations must be considered simultaneously. Here profit might be the objective, which is to be optimized and the restrictions imposed on the processes could include:

- Capacity limitations of each operational facility
- Production requirements, both as to quality and quantity
- Delivery requirements
- Limitations on the availability of raw materials

Network models: In the production area of APPI the production co-ordinator may be faced problems with complex that are not immediately clear whether they can be formulated as a programming model. Most production problems calling for optimal scheduling of activities fall into this category. Scheduling problem calls for optimal planning of the allocation of identical goods from different supply sources to different consumers.

Although the optimum scheduling of activities in time and space can sometimes becomes increasingly complex when restrictions arising from interdependence of activities must be met.

For example, if one activity cannot commence until two others are completed, or if limitations exist on the means of transporting dangerous goods, so that a particular set of consumers cannot be served from a particular supply point, then it becomes extremely difficult to arrive at a good solution by 'commonsense' means while keeping these special restrictions in mind.

The basic tool for the manipulation towards solution of such problems is temporal and spatial scheduling using the network model. It is a conceptual tool for visualizing the complex interaction of many related activities.

Two types of network models are the critical path method and pert: The critical path method is based on the observation that the minimum overall time to proceed from one event to another in an activity network is given by the length of the longest path between the two events.

PERT is an activity network model, together with a computerized critical path analyzer and report generator. Pert involves an application of statistical estimation techniques to critical path analysis. It is intended for use in analysing those systems of activities where times, costs, productivity's, etc. are much more uncertain than would be the case, say with a straightforward manufacturing operation.

It is suggested that these Network Models have major applications for the APP Industry operation and their usefulness should not be limited to the production area of the company.

Analytic techniques: Another type of mathematical model, which could assist the production co-ordinator by providing the facilities to solve detailed problems, is queuing models.

A Queuing problem arises when either units requiring service or the facilities, which are available for providing service, stand idle. These problems require solutions specifying the optimal number of service facilities or the optimal arrival rate, or both. Waiting may involve a cost of delay in shipments, or on the other hand there may be excessive gaps between arrivals of things requiring work or service, so that facilities are idle for the part of the time. This idle time also involves a cost.

For example, assume that APP Industry have a queuing problem, because there is too much demand on trucking facilities at certain times, in which case there may be an excess of waiting time. Solution should be formulated to manipulate the scheduling trucks so that an optimum balance is achieved between the cost of idle time and the cost of waiting time.

While some critics may suggest that distribution problem may be solved on the basis of past experience or on the facts of the current situation, realistically the problem is often too complex for one's intuition. The problem can be approached by either a mathematical model procedure, queuing models or by simulation.

The former is considered below while the simulation approach is discussed in a later section. If one assumes that the transportation problem is at depot only, then a model must be developed for a single service facility situation. It will also be assumed that

- the trucks are emanating from an infinite universe
- the truck arrivals and services occur in accordance with a poisson process.
- the trucks are serviced on a 'first-come, first-serviced' basis.

The relationships of special interest for the APP Industry problem are listed below:
First, let

A = The average number of trucks arriving in one unit of time.

S = The average number of trucks the service facility completes in one unit of time, assuming no shortage of trucks.

n = The number in the queue

pn = The probability of having n trucks in the system

t = The time a truck must wait for service

$po = 1 - A/S \quad (1)$

$pn = (A)n/S\,P_0 \quad (2)$

$pn = (A/S)\,pn\text{-}1 \quad (3)$

The expected number in the waiting line or being serviced is

$$E(n)=A/(S-A)$$

The expected number of trucks in the queue is

$$E(w)=A2 / S(S-A)$$

The average waiting time (in the queue) of a truck arriving is

$$E(t)=E(w)/A$$

By obtaining the number of trucks, which may be serviced, an hour and the truck arrivals per hour the above model can be utilized to calculate the total cost of waiting for all the trucks. From this calculation, the production co-ordinator may make certain changes to the trucking schedules or the servicing facilities to reduce unnecessary costs in the system.

Calculus of optimization: This mathematical (analytic) technique may be utilized at APP Industry for optimizing a variable with respect to a constraint. Differential calculus deals with the infinitely small differences between consecutive values of a variable quantity and with their relationship to the constraint on which they depend.

The use of calculus is illustrated in the following example. Consider that APPIndustry decisions have to be made on the optimal order quantity of inventory. The five elements involved are:

Q = order quantity in units

C = price plus variable order costs per unit

I = percentage of annual carrying cost per unit to unit value

S = Set up order cost (fixed per order)

D = annual demand

From these, the following three variables could be derived

Q/2 = average quantity on hand
D/Q = Number of orders placed per year
IC = annual carrying cost per unit

Total v ariable inventory costs (TC) can be defined as:

TC = annual processing costs + annual carrying costs
TC = number of orders per year * cost to place one order + average quantity carried (in units) * carrying cost per unit.

$$TC = DS/Q + Q/Z\ IC \qquad (1)$$

The only policy variable that the production co-ordinator controls is the order quantity Q. To find the Q that minimizes total annual inventory costs differentiate Eq. 1 and set it equal to 0.

$$dTC/dQ = DS/_{Q}2 + IC/2 = 0$$

This yields the following optimal order Q:

$$Q = \sqrt{2}DS/IC$$

Model such as this can take on a variety of mathematical forms and consequently may require different types of mathematical analysis to deriving a solution. Therefore, the derivation of solutions may require a high order of mathematical competence.

Simulation models: Mathematical models are useful for those systems where it is possible to solve by a direct exact, mathematical procedure; however, there are other problems in business for which no closed analytic solution may be found. In such situation simulation models may be used to make decisions. Simulation involves constructing a model, which replicates some aspect of the firm's marketing or production operations and performing step-by-step computations with the model, which duplicates the manner in which the actual system might perform. An individual simulation run can be thought of as an experiment upon a model. Numerous trials or experiments are performed until a workable satisfying solution rather than an optimal solution is reached.

This experimental nature of simulation is an important advantage because the system can be studied under a wide variety of conditions, which might be impossible to do using the actual real world system.

Simulation models may have numerous applications for the production process at APP Industry. For example the production co-ordinator might systematically experiment the production process by altering inputs to the model in order to determine how the output characteristics are affected. The purpose would be to infer from the output data generated by each experiment how the corresponding real-world system would operate under similar variations in input. Specifically simulation models could serve a dual purpose. It could be used to verify the accuracy of the queuing model, which presented solutions of cost savings, enabled the production co-coordinator to advice values for the truck size and available servicing facilities. The simulation technique can also be used when the delivery truck arrivals are not poisson, which is the service time may be fixed to exactly six hours. The various phases of the Monte-Carlo simulation procedure are presented qualitatively below.

Birge and Louveaux[7] reported that stochastic programming techniques are most suitable for supply chain systems because they address the issues of inventory control, optimal decision-making under uncertainty and prepare the manager by hedging against future risks.

CONCLUSION

This study constructs a conceptual framework for auto parts management, provided and discussed the relevance of four essential mathematics models (i.e. Heuristic, Algorithmic and Mathematical Programming. These mathematical models are derived from a relevance literature review of the existing literature on stochastic process. It is envisaged that the conceptual framework will form the underlying basis towards the development of a more comprehensive model in future. The paper also takes the approach of proposing a theoretical framework that can be applied to practical situations in Auto Parts Packaging Industry environment in both developed and less developed countries. It is also hoped that this paper will highlight the importance of mathematical models for use in multi criteria decision-making to packaging industry practitioners. Finally, the paper represents the starting point for more future research, worthwhile theoretical analysis and empirical research lie in proposing a broad and thorough framework for Auto Parts Packaging decision-making.

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