MODELING MANUFACTURING SYSTEMS BY INTEGRATING SYSTEM DYNAMICS AND INFORMATION SYSTEM

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ABSTRACT
Information System approach for manufacturing system involves systematic computerization of all the manufacturing process integrating computer aided manufacturing. Three levels are modeled using system dynamics approach. The need analysis using system dynamics identifies level of automation, level of flexibility and level of integration as the key factors for policy making. Some important issues concerning these decisions are also discussed which give insight to the management for effective decision making during the planning and design phases.

Keywords: Manufacturing systems, system dynamics, integrated systems

INTRODUCTION
Decision support system can be used to manage the total operations of the manufacturing process and on to the distribution; including production and inventory management, as well as financial resource management (Gunasekaran, 1997). The integration and automation of the complete information flow structure of an organization is for enhancing product quality, flexible manufacturing operation, reduction in engineering design costs, job lead times and work-in process inventories etc (Gershwin, 1994). Nowadays computers are being used in the functional areas of manufacturing process, this approach aims to integrate all global factors for automation leading to cohesive operations and effective decision making in the organization (Al-Ahmari et al, 1999).
A system is defined as an aggregation or assembly process of objects joined in some regular interaction or inters dependence (Gershwin, 2000). In a dynamic system these interactions causes changes continuously over the passage of time. Integrated system can be defined as an integrated manufacturing system consisting of various subsystems interacting with each other e.g. procurement, inventory control, production, assembly billing and shipping etc. Each subsystem can further be divided into smaller subsystems e.g. production, production planning and production control etc. For every subsystem the inputs are in terms of data, raw material and problems. These inputs are processed as per the algorithm already defined and processed to output decisions and finished goods over a period of time. The different factors for production, marketing and financial, which aid decision making, are used as input for defining feedback loops and overall system for automation (Vinodrai Pandya, Karlsson, Sega, & Carrie, 1997).

The input to the design department can only come from marketing department as certain requirements of a customer which have been communicated through control subsystem. The output can be in the form of finished goods as per the defined algorithm which processes the input data. When the outcome of an activity can be described completely in the terms of its inputs, the activity is said to be deterministic. Where the effect of the activity varies randomly over the possible outcomes, the activity is thus stochastic in nature (Forgionne, 1983).

All the subsystems, other than demand forecasting subsystem, can be classified as deterministic as their output can fully be described by their inputs. Demand forecasting subsystem output depends upon exogenous factors and is thus stochastic. We can also assume the industry environment as discrete system overall. This paper has limited itself to the mapping of strategy using system dynamics models, which allows the study of the interaction of feedback loops, with its effect on policy from a holistic point of view (Harrison, 1998).

Control theory is concerned with the response of the system and how it can be changed by modifying the signals in the system. System dynamics study the forces operating in the system and determine the influence on the stability or growth of the system (Gordon, 1987). It is expected that the output of the study will suggest some reorganization or changes in the policy or provide guidelines to the existing system against potential problems. SD approach requires event
qualitative data to be transformed and reduced to quantitative form; however, the lack of precision does not diminish the value of study (Ford & Bradbard, 1987; Forrester, 1961).

Feedback Loops for Three levels Identified

We represent the production system for instance in the form of causal loop which comprises of negative and positive loops. The combination of both keeps the system in balance. Various inputs are fed in the production system which produces the output in terms of product (Vakola & Rezgui, 2000).

The higher the production, the higher is the scope of automation. Depending upon the level of automation in an industry, machines and labor, are the major inputs. The higher the labor the lesser the labor required and the loop is therefore negative feedback loop. The higher the automation the higher the machines and the positive feedback loop. Now the product feedback comes from the customer through marketing department and as changes by customer require changes in the existing production system, we modeled this phenomenon by negative feedback loop. The higher the input the higher the production and is thus a positive feedback loop (Grünberg, 2003; Huang, Dismukes, Su, Razzak, Bodhale, & Robinson, 2003).

![Causal Loop for a Production System](image)

**FIGURE 1**
Causal Loop for a Production System
Problem Statement

The manufacturing planning and control in general covers activities like forecasting, planning, estimating, scheduling, material requirement planning, load and capacity requirement, operations planning and sequencing, dispatching, expediting, quality controlling, shipping and inventory controlling. All of these subsystems are to be modeled separately and integrated in a common information system and in this work we aim to model the plant capacity and its utilization and plan to estimate the trend for productivity (See figure 1).

We want to give guidelines for integrated manufacturing system which comprises of information system and system dynamics approach and model plant capacity in order to measure productivity. The work is also of great importance as it gives plant manager an insight for backlogs in production schedule and dynamic behavior of the market. The structure of the Computer integrated manufacturing system address following issues:

- Level of Flexibility.
- Level of Automation.
- Level of Integration.

We will discuss the factors comprehensively in order to conceptualize the need of SD approach for these levels.

**METHODOLOGY INVOLVED AND BASIC MODEL STRUCTURES**

**Level of Flexibility**

The level of flexibility in any integrated manufacturing system signifies the ability of the system to change efficiently and effectively to the new requirements. The changes in the manufacturing environment mainly are:

- Changes in products
- Changes in volume mix
- Changes in delivery dates
- Changes to cope with the manufacturing disturbances such like machines
- Design modifications

The factors that force the manufacturing system to have the high level of flexibility are:

- Material requirements
• Competitors’ flexibility levels

The increased level of flexibility can be achieved by using flexible manufacturing system (FMS) in computer integrated manufacturing system, however with increased level of flexibility, operating expenses and capital cost also increase. Also we have to settle for lower productivity at the start as production and related personnel adapt to restructuring. In SD approach it has negative feedback on manufacturing cost. The level of automation also has the negative effect as benefits get lesser and vice versa. The factors can be specific and may not be general so we may consider some factors varying to some degree from company to company.

![Diagram](image)

**FIGURE 2**
Level of Flexibility in Production Systems

As depicted in figure 2, SD approach can be used to address various issues involved in determining the level of flexibility such as:

• Does increasing degree of flexibility always increase benefits?
• Given the cost constraint, what is the desired level of flexibility in the given situation and competitors’ capabilities?
• If any, what is the threshold value with respect to the degree of flexibility and which may determine the best level of flexibility in the system?

Level of Integration

Management often faces an uphill task of integrating various functions with the manufacturing function. Computer integrated manufacturing system can be used for effective integration. Normally following issues will be addressed in this study:

• Sales integration with manufacturing system so that manufacturing system can respond quickly to the ever changing requirements of the customers.
• Marketing integration with manufacturing system so that marketing of those products can be done effectively for which manufacturing capabilities are the best.
• Engineering integration with manufacturing system so that effective new designs can be produced and planned which aids manufacturing productivity, quality and delivery performances.

The manufacturing competitiveness improves the delivery performance, quality and market-share which in turn will increase the benefits. However, there are costs associated which in turn will decrease the level of integration of sales, marketing and engineering functions with manufacturing system. We want to model the situation by feedback loops so that the factors are related to each other in a quantitative way but the relationship strength varies from company to company and management can have a rough estimate for strategic plan (Askar & Imam, 2003; Harrison, 1998).

It is straightforward to infer from figure 3 that SD approach can aid by answering the following questions for a production system:

• Recommended level of integration.
• The most critical factors to be integrated
• The subsystems to be planned first if the integration is to be done in phases
• The level of integration among various subsystems given the constraining investment

Level of Automation

The level of automation comes as a tradeoff with flexibility. The higher the level of automation the higher will be the resistance to change in the manufacturing system which in turn has a negative effect on the employee satisfaction and productivity. On the other hand, due to higher automation, there will be higher savings and thus have a positive effect on employee benefits. Higher employee benefits further lead to a higher employee satisfaction and lessen the resistance to change. Depending upon the organizational culture, the higher resistance to change can hamper the possibility of fruitful implementation, the higher the productivity and also, higher the level of automation (Doumeingts, Vallespir, & Chen, 1995).
We can see from figure 4 that SD approach is helpful in determining the level of automation required for a production system. The key decisions which have to be addressed while arriving the level of automation are:

- Is the organization geared up to absorb the automation which is being proposed?
- Is the necessary trained manpower available to handle the level of automation?
- How do the other subsystems react and absorb the other subsystems in which the automation is being introduced?
- Is it really beneficial to invest in automation?

In our study system dynamics can be used to study the effect of variance of certain parameters on automation and help in answering the above issues objectively. SD will be used to analyze effect of various parameters on the level of flexibility and level of integration also. This kind of analysis is critical for management decision making regarding level of flexibility, integration and automation to be used in the manufacturing environment.
Based on different decision making criteria, we can define the structure of a manufacturing system which is based on some desired level of automation, flexibility and integration.

**Structure of the Manufacturing System**

We also discuss the industrial productivity enhancement process. We aim to provide some guidelines for the manufacturing, distribution and retail function of the system. The model structure consists of following parts:

- Levels (Stock, Inventories)
- Flows that transport the contents of one level to another
- Decision functions that control the rate of flow between levels
- Information channels that connect the decision function to the levels

This integrated system improves the performance of the company as a whole and financial benefits in terms of financial ratios would depict the immediate effect.

**CONCLUSION**

In this paper we model the manufacturing system and the productivity of an organization using system dynamics approach. We show that the integration of different manufacturing process and modeling through SD provide better understanding to the plant manager. Overall industrial productivity enhancement is achievable by integrating SD with information channels.

**REFERENCES**


