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# Advantages of Flexible Manufacturing Systems

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The production paradigm of our days is the "mass production according to a claim", that a challenge of two kinds sets up the production systems of the manufacturers of the application end products for it: In order to achieve low unit costs for the mass production of like getting stepped, while the output side according to each customer own needs "customized" finished products to serve.

The "tailor-made" products to be produced and delivered to customers, the smallest possible as quickly as possible – the approximate level of mass production – costs.

The constraint requires flexibility, improve utilization of resources, lead times, in-process inventories inventory level reduction and the general downward pressure on. To meet their specific needs, companies are increasingly seeking to seek, only to be manufactured or installed for finished products or plan to manufacture their existing customer orders.

A diverse customer needs quickly responding to these types of production often characterize the agile manufacturing system is called.

Industrial development and the intensification of competition in the market has resulted in the transformation of customer service strategies. The above-mentioned methods of production, the development of approaches also prompted changes in the customer service strategy.

Conflicting requirements for the manufacture of customer needs, production systems only extremely flexible operation (fast changeovers, real-time production scheduling, small batch sizes with and flexible manufacturing and material handling equipment and the associated adaptive management strategies), and the continuous re-design of production systems to resolve. After all, while the output side of each must serve customers "customized" end products for their own use, in order to achieve low unit costs for the mass production of like getting stepped up.

## *Support of demand manufacturing*

The creation of "demand based mass production" and the successful operation of such systems requires the use of to modern information system/equipment according to Gupta and Kohli (2006) which supports the complete company process on an overall way.

The enterprise's managers have to absolve the contradiction to satisfy individual demands with systems planned for mass production. To realize this in first step the previous larger production series have to be divided into smaller production series on every certain technological level. (Gnoni et al., 2003)

We need complex data models to lock out the connection between the customers' satisfactions and the previous principles in the complicate production systems.

According to the demand of mass production's requirement strategy we can add a generalized data model. The model use management and logistics data, as the flexible production's critical elements to sum up the process management and logistics management.

The mass production of the demand's logistics management contains many parallel planning tasks for this reason it is more complicated, such as the traditional mass production (Qiao, Lu & McLean, 2004). Forza and Salvador (2002) (Integrated Order Fulfillment System – IOFS) it determines as a necessary basic condition for the application "ordering configuration" (Configure to Order – CTO) to type of production system developing. With IOFS help the orders processing occur automatically, so the products configured producing can be realized, and we can win real time data from the system (Zhang, Lee & Xu, 2010).

The ERP (Enterprise Resource Planning) systems are also supporting the mass production of the demand, but to this function it is needed to develop the appropriate data model. The up-to-date optimum ERP systems with completed algorithms can cooperate as an exceptional equipment in the producing process planning, scheduling. (Gupta and Kohli, 2006) Other type, but same efficient supporting equipment can be the Manufacturing Execution System (MES) come into existence with the integration of ERP and factory control system.

The ERP systems generally build on location based data model, according to between supply locations streaming fixed on transaction's forms, which transactions connected by other products and resources data, too. However the article center data models treat more efficiently the flexible production. These events joined to individual product identity.

Further secondary information gathered from the parameters of production systems give a useful help to the operation, supervision of MCM systems as well. In these systems the (Build to Order Supply Chain is typical (BOSC).

Important to note, that the technologies based on Internet, object-oriented software of devices, intelligent mobile technologies of developing have recently brought to life the flexible produce supporting Internet based supply chains (Internet-based Supply Chain – IBSC).

Fast developing discipline of computer controlled traditional production technologies, in turn created the necessary knowhow to develop Advanced Manufacturing Technology – (AMT) (Swamidass & Kotha, 1998).

New production philosophies demands the development of new control mechanisms. Numerous technical literature deals with the development opportunities of certain production and material flow control mechanisms. (Production and Materials Flow Control – PMFC) (Fernandes & Carmo-Silva, 2016) The selection of control principles are greatly influenced by the customer service strategy of the company, which in turn determines the supply chain and production system of the company.

To support different strategies developed to satisfy customer needs, numerous material flow and production control system has evolved. (e.g. CONWIP, POLCA, etc.).

Analysis carried out with the aid of queuing models are extremely popular (pl.: Krishnamurthy, Suri & Vernon, 2006; Lambrecht, Chen & Vandaele, 1996), furthermore many numeric models evaluate and compare certain service systems from this aspect. (e.g. Benton & Shin, 1998; Pettersen & Segerstedt, 2009; Rotaru, 2011; Sharma & Agrawal, 2009; etc.)

## *Modelling as a tool*

Modelling can be used as a basic tool for (quick and flexible) mapping of transition(s) planned in production management. There are many sources of simulation usage with regard to performance prediction, comparison of alternatives, and optimization of system design. Law and Kelton made his well-known work on discrete-event simulation in 1991, which talks about the simulation of manufacturing systems. In several cases, simulation studies have been used to give insight into the behavior of manufacturing systems operating with different types of management rules (such as various startup rules) or to determine the accuracy of analytical models. For example, Vollmann, Berry and Whybark (1997) have studied a number of results.

Management choices of flexible manufacturing systems are more complicated than other (simpler) manufacturing systems (Stecke, 1983). Mathematical models, however, help in designing and organizing production in a flexible manufacturing system. Mathematical models can be divided into four groups by the used tools.

### *Queuing models*

Queuing systems are based on the mathematical bases of waiting rows. Both the process of arrival and the service process are regarded as stochastic processes. The specialty of flexible manufacturing systems is that the process of getting individual machines can be derived from the departure process of other machines.

Queuing models can be used to test the operation of the manufacturing system even before the system is built or before the completion of the detailed schedule. There are a number of researchers and studies dealing with queuing models of manufacturing systems.

Table 1. Major queuing models

| *RESEARCHER* | *YEAR* | *MODEL* |
|---|---|---|
| Stecke and Solberg | *1985* | multi-server queuing model |
| Yao and Buzacott | *1985* | multiple server channels, limited line length |
| Shanthikumar and Stecke | *1986* | open queuing model |
| Yao and Buzacott | *1987* | queuing model with line capacity |
| Solot and Bastos | *1988* | MULTIQ process |
| Bitran and Tirupati | *1988* | the link between capacity and inter-production inventory |
| Dallery and Stecke | *1990* | closed queuing networks |
| Eliyahu Goldratt | *1990* | general theory of restrictive conditions (GTC) |
| Sarkar and Zangwill | *1991* | feedback, loop material flow systems |
| Vonderembse and White | *1991* | Optimal Production Technology Concept (OPT) |
| Gunasekaran | *1993* | minimum number of machines required, cost reduction for JIT |

*(Source: made by author based on Juhász, 2006)*

## *Mathematical programming models*

The Operations Research in Mathematics helps complex decisions, so mathematical programming models are important tools for production planning. The programming models for flexible production systems can be characterized by three factors (Atlihan et al., 1999):

- With the finite capacity of available resources.
- Rules used with the organization of (flexible) production systems, with technological constraints.
- The target function of the selected mathematical model, which is the result of strategic production. According to the target functions, we can distinguish three more types of the models. It is possible to maximize emissions, minimize material handling and minimize cost factors.

Table 2. Major mathematical models

| | | |
|---|---|---|
| *MODELS TO MAXIMIZE EMISSIONS* | | |
| Stecke | *1983* | ideal fabrication tool with the weighting assigned to the tools |
| Shanker and Tzen | *1985* | maximizing system utilization |
| Wilhelm and Shin | *1985* | minimizing lead time |
| Rajagopalan | *1986* | reducing lead time on the tool capacity |
| Kiran and Tansel | *1986* | increase the number of actions you can take with resource constraints |
| Hwang | *1986* | minimizing workpiece bundles |
| Afentakis | *1988* | reducing the lead time of product production |
| Co et al. | *1990* | sorting workpieces into batches |
| Liang and Dutta | *1992* | focusing on the available capacity of machines |
| *MODELS TO MINIMIZE MATERIAL HANDLING* | | |
| Stecke | *1983* | maximizing successive operations on one machine |
| Shanker, Rajamarthandan | *1989* | minimizing workpiece movement |
| *MODELS TO MINIMIZE COSTS* | | |
| Sarin and Chen | *1987* | the principle of sharing tools |
| Leung et.al. | *1993* | reduce production costs in resource-restricted cases |
| Kusiak and Finge | *1988* | tool and workpiece fixing palettes |

*(Source: made by author based on Juhász, 2006)*

## *Simulation models*

During the simulation, we analyze the outputs of a system on a real-world production system by selecting the inputs correctly. It is a popular method for analyzing complicated manufacturing systems that are difficult to test with traditional analytical methods. The simulation should be applied when constraint models and mathematical modelling constraints narrow the motion when modelling the production system. The simulation methods can be classified according to Law and Kelton (1991) in three different ways:

1. The simulation method may be static or dynamic. Static simulations illustrate and analyze the status of the system at a specific time. Dynamic simulation represents a change in system performance.
2. The simulation model may be deterministic or stochastic. If the model does not contain a random element, it is deterministic, but if contains random input data, it is a stochastic model.
3. Continuous and discrete simulation models can be distinguished. For the discrete model, the states of the system may vary over time in counted points of time. In the case of a continuous model, the state of the system may change as a continuous function of time. These models describe the values of each variable in the system using continuous functions. Generally discrete models are used during simulation of production.

### *Heuristics*

When mathematical models are too complicated to solve a particular problem, or their solution is too lengthy, then we can turn to heuristics. Heuristics either gives a result for a production management decision or simplifies the calculation process of an existing process. Many heuristics were created in the production management of flexible manufacturing systems. From these, clustering procedures should be highlighted.

Group Technology (GT) is a manufacturing philosophy based on gathering and grouping similar machines or operations, thus simplifying system analysis (Salvendy, 1982). Clustering helps to analyze the operating processes of complex manufacturing systems such as flexible manufacturing systems. Chandrasekharan and Rajagopalan (1986) have developed a clustering process for grouping similar workpieces into groups and machining cells.

## *Simulation models*

### *Computer Simulation*

One of the special applications of discrete simulation is computer simulation where we can dynamically examine the operation of the system. For simulations used in production management we can apply some general or special programming language or simulation program. In 1986, Pritsker introduced how to apply the simulation to design manufacturing operations for flexible manufacturing systems.

In the 90's, SIMAN appeared, and simulation programs such as TAYLOR and ARENA became commonly used. These softwares can be used to simulate complex manufacturing conditions and service processes, and complex evaluation and reporting is also possible.

Simulation modelling of different types of production systems can be used to examine responses to different customer needs (Law and McComas, 1992).

The „state of the art" tools for the development of such production systems for this purpose are the so-called real-world mapping of the real production environment, the so-called „digital production" software tools.

These software tools are capable of producing realistic digital duplication of production processes (modelling function) as well as different input parameters (capacity, time base, market demand, availability, production scheduling, batch size, manufacturing and material handling device structure etc.) to calculate the results of running the process using a given parameter combination (simulation function). Typically, the simulation function can be accelerated, so long-term events can be easily manipulated within a short timeframe.

The software tools supporting the „digital production" principle (typically discrete event-oriented modelling and simulation environments) are developed for a general purpose and have a wide range of functionalities, some of which are easily accessible to average users, while most of them only have deeper computing / programming skills recyclable.

### *Petri nets*

It is necessary to mention one of the tools of graphical process modelling, the Petri net, as many researchers use the Petri net to analyze the production processes of flexible manufacturing systems - for example, Alla and Ladet (1986), Lewis et al (1995), Moore and Gupta (1995), Yu et al., 2003; etc.). Using the Petri Nets, we can statically analyze the system with measurements of individual states, and on the other hand, we can dynamically simulate system processes. The various Petri nets have three significant advantages (Alla & Ladet, 1986):

- Because of the graphical presentation, modelling of complex problems is easy and transparent.
- Detailed features of the system can be easily checked using the network structure.
- Before implementing the system, it is possible to use the simulation to test its dynamic operation.

There are a number of Petri nets (for example, a colored Petri net, a timed Petri net), but they all developed from the original Petri net, developed in 1962 by Petri. The Petri net is based on simple principles, which makes it easy to model its operating processes (Petri, 1962).

## *Simulation of transitional management strategies*

All these references demonstrate the usability of the simulation to analyze the equilibrium performance of the production control rules. Simulation usually focuses on the stable performance of the models. Modern simulation methods and software tools are used to measure the transient effects especially in the measurements. Therefore, a promising area of study is the simulation of the behaviour of transient systems that pass from one production control rule to another: my goal is to examine the effects of changes in production management policy in manufacturing systems.

These types of changes are important for manufacturers implementing lean production initiatives. The literature recommends optimization-based simulation: not only the production control rule of the optimal term, but also the series of intermediate production control rules that are optimized for the lowest cost.

The simulation models only provide approximation measurements for the performance of the production systems. As a result, automated optimization algorithms, which are used in conjunction with simulation models, should be carefully designed to provide credible results. Simulation Optimization is a technique that uses simulation to solve stochastic optimization problems. This can be done because it is impossible or at least difficult to explicitly evaluate objective target functions. For an overview of the simulation optimization techniques analyse the works of Banks and Gibson (1998), Fu (1994) and Pflug (1996). For example, Pflug identified two types of methods: black and white box methods. The black box method simulates the definition of objective functions and an optimization algorithm to find the best solution. The white box method uses a more sophisticated simulation program that is able to estimate gradients. Consequently, the optimization algorithm is a gradient-based technique.

Most of the presented techniques take into account the solutions given by continuous variables. For example, the finite differential stochastic approximation (FDSA) introduced by Kiefer and Wolfowitz (1952) was widely used for continuous optimization. Spall (1998) described the implementation of simultaneous random perturbation (SPSA - simultaneous perturbation stochastic approximation) for continuous optimization problems.

Local searching techniques go from one feasibility point to another while searching for the optimal solution. These techniques are in the selection of the adjacent structure, in the decision strategy when they move from the current into the next alternative and in the method of determining the optimum solution estimates. See, for example, Andradottir (1995 and 1996), Alrefaei and Andradottir (1995, 1999) and Yan and Mukai (1992).

Gradient-based discrete optimization techniques give the discrete parameter an estimate of the gradient of the expected system performance. Common techniques for gradient estimation include finite differences and concomitant perturbation methods. Gerencsér, Hill and Vágó (1999) proposed a fixed profitable SPSA version and applied it to a discrete resource allocation problem for a class, set up by Cassandras et al. (1998).

These research backgrounds show that simulation-based optimization is an effective tool for finding optimum design of manufacturing systems. However, this method has rarely been used in transient systems. In my research, I want to use optimization-based simulations to reduce the effect and / or cost of transient behavior in manufacturing systems to support flexible manufacturing processes.

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