ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering, Volume VI (XVI), 2007

CONSIDERATION REGARDING THE CHOOIS OF THE MACHINES TOOLS FOR FLEXIBLE MANUFACTURING SYSTEMS

Ioan BÂRSAN, Ilie-Octavian POPP

"*Lucian Blaga*" University of Sibiu, Faculty of Engineering "*Hermann Oberth*"
Departaments of Machine and Machinery, Emil Cioran St. no. 4, Sibiu-2400
E-mail**:** ioan.barsan@ulbsibiu.ro**,** Tel. 0269-216062/454

Key words: FMS, criteria analysis, analytic hierarchy process.

Abstract: The paper describes an interactive decision support framework designed to aid decision makers in selecting the most appropriate machines for a flexible manufacturing system (FMS). The framework can be used in the prescreening stage of the planning process, after a decision has been made, in principle, to build an FMS. The framework mainly consists of two parts. The first part is called the prescreening stage, which narrows down all possible configurations by using the analytic hierarchy process (AHP).

The second part uses the goal-based activity programming model (GBAP) in order to select the machine-tool from the list left after restricting the configurations (done in phase 1). After applying the GBAP method, AHP is used again for a precise analysis. This approach helps the managers in assessing the costs and benefits of various configurations of FMS and of (system) flexibility levels.

1. INTRODUCTION.

The shortening of product life cycles and the fierce competition in the market have made manufacturers increasingly wary of the types of manufacturing system technologies and thus they must establish so as to maintain a competitive edge for long-term survival. In recent years, the flexible manufacturing system (FMS) has been widely considered as an effective instrument toward this end. However, implementing an FMS is very costly, and this investment tends to be irreversible, thus necessarily requiring careful consideration before a decision can be made.

Decision-making concerning the implementation of an FMS is not only strategic but also involves issues at the tactical and operational levels. The decision situation is characterized by the presence of both qualitative and quantitative criteria involving social and economic factors. In view of the multiplicity of criteria inherent in such decision-making situations, the methodology of multiple-criteria decision making (MCDM) is used as the framework of analysis.

The decision framework as proposed in this paper is made up of two phases, namely the prescreening phase-strategic phase-and the evaluation stage-tactical approach. The overall methodology is depicted in Figure 1 and data flow diagram in Figure 2. The figures consider both quantitative and qualitative criteria.

2. MODEL DEVELOPMENT.

As shown in Figure 2, the model has two main parts: the prescreening phase and the evaluation phase.

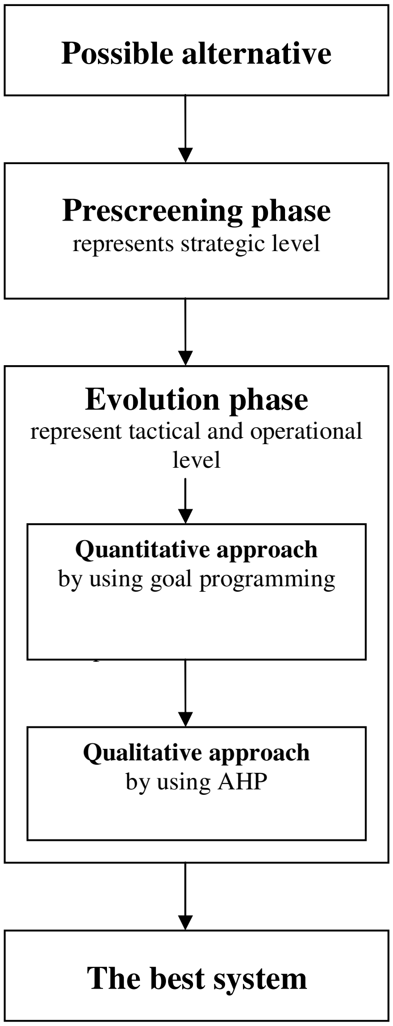

Fig1 Overall procedure of the model

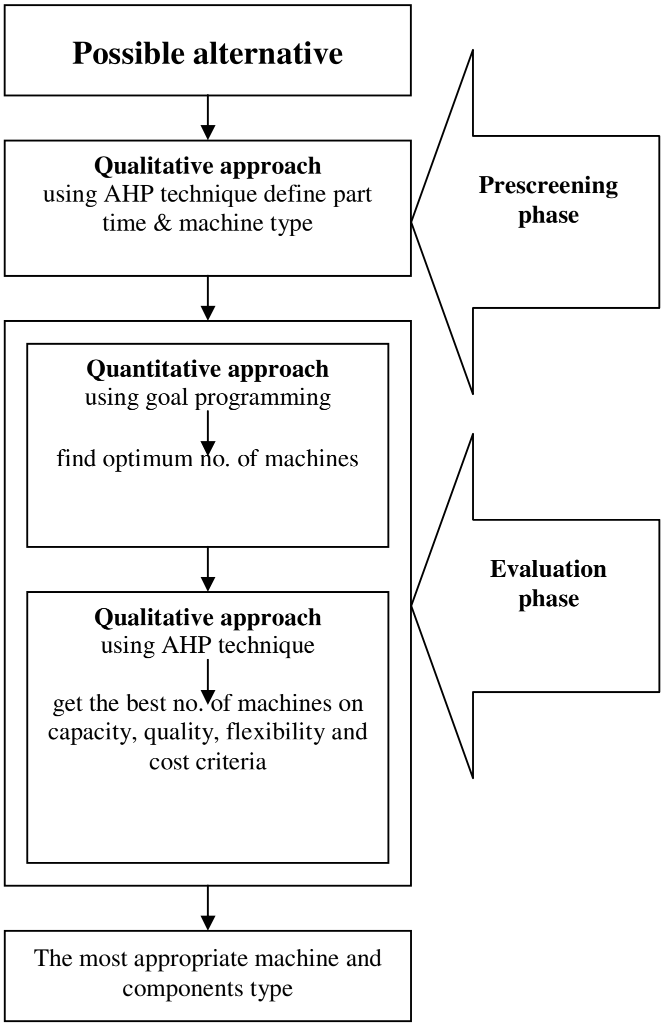

Fig.2 Data flow diagram of the model

2.1 Prescreening phase (Phase 1)

The prescreening phase mainly considers the strategic level. At this level, there is a set of plans and policies by which manufacturing seeks to consider- cost, performance, performance, quality, delivery, flexibility and innovativeness.

The strategic analysis targets two elements:

- the alternatives proposed to fit into the general production strategy;
- the organization (company) must be capable to successfully exploit the new system.

At the first level, the types of products are classified according to four different characteristics as follows:

1) *Introductory demand situation*
    a. -the products are planned to be produced with the new system
2) *Increasing demand situation*
    -the products fave already been produced with the existing syste, and introduced in the market
3) *Constant demand situation*
    -the product have already been produced with the existing system and market demand is constant and stable
4) *Declining demand situation*-the products have already been produced with the extinding system and demand is declining with stable condition but is still considered profitqble.

The criteria taken into account are: investment cost, capability, flexibility, usage ratio, unit cost and economic risk. After determining the criteria, it is necessary to choose possible alternatives that depend on specific situations and on the type of products planned to be realized with the selected system. The main alternatives are combinations of various types of machine-tools, transfer systems and computers. Accordingly, the overall diagram of the first-phase model is shown in Figure 3.

2.2 . **Evaluation phase** (Phase 2)

The results obtained from the prescreening model are taken into the evaluation phase, which aims to evaluate the system using quantitative and qualitative criteria. The evaluation phase is mainly divided into two parts. The first part employs a quantitative approach to find the best number of units of each type of machines already selected from the prescreening phase. The other is to find out the sensitivity of the results using qualitative criteria by changing the types of machines obtained from the the quantitative criteria analysis.

3. QUANTITATIVE CRITERIA ANALYSIS- The goal programming model

The validity of the model is based on the following assuptions:

(1) Each product type's set of operations is known and has a prespecified production goal.
(2) Operations are defined by the tools and machine characteristics. Thus, operational time is dependent on the type of machines.
(3) Each type of part requires one type of pallet and fixture.
(4) The total number of pallets equals three times the number of machines in the system [3].

The requirement is to find the number of each type of machines and pallets according to the corresponding demand characteristic of products to obtain maximum profit.

The goals considered are follows:

-maximize profit to cover the cost of automation

-to minimize the cost of investment, it is needed to minimize the total number of pallets, fixtures and AGV.

-to fulfil the demand of products

-balancing loading in machines.

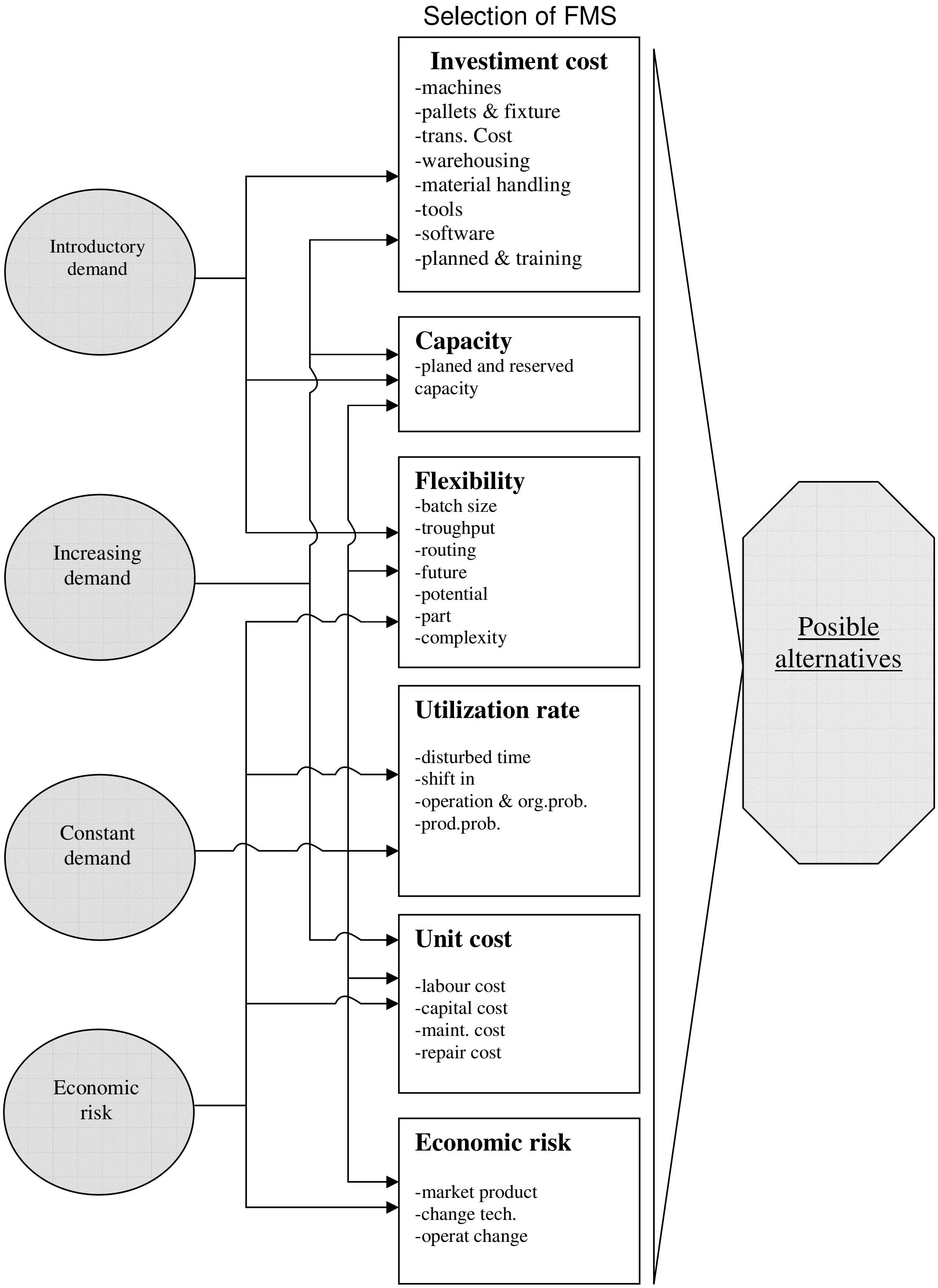

Fig.3. Hierarhical structure of the decision problem

After defining the goals of the sistem, the goal constraints can be formulated as follows

- a-***Profit***

$$\begin{aligned}&\sum_{i=1}^{I} B_i N_i - \sum_{j=1}^{J} MMC_j NM_j - AC * NAGV - CC * (TNC_j + THC)\\ &- CL * BL - \sum_{j=1}^{J} TOL_j * TTC_j + dr^- dr^+ = T,\end{aligned} \quad (1)$$

$$i = 1,2,...,I,$$

where Bi is the expected profit from product i, T the target profit , TTCj the tool cost at type j machine, AC the AGV cost, MCCj the type j machine cost, CC the computer cost and CL the belt cost.

- b-***Total number of fixtures***: to minimize the cost of production, the total number of fixtures should be minimized:

$$\sum_{k=1}^{K} F_k + dc^- - dc^+ = NPP, \quad (2)$$

where NPP is total number of available pallets.

- c-***Demand***:

$$\sum_{k=1}^{K} N_i N_{ki} + d_1^- - d_1^+ = D_i \quad (3)$$

$$i = 1,2,...,I,$$

where Di is the demend of product type i.

- d-***Machine loading***: minimize the overloading and underloading of machine capacity in each type of machine:

$$\sum_{k=1}^{K} \sum_{i=1}^{I} N_{ki} t_{kj} + dm_j^- - dm_j^+ = MC_j * C_{j,} \quad (4)$$

$$j = 1,...,J,$$

where MCj is the type j machine capacity.

The goal objectives are proposed in the fowing order of priority:
- maximize profit
- minimize the number of fixtures and pallets in the system
- maximize production to satisfy demend
- minimize overloading and underloading of machine capacity.

Then the overall obiective goal can be presented as:

$$\min\left[P_1 dr^- + P_2 dc_i^+ + P_3 \sum_{i=1}^{I} d_i^- + P_4 \sum_{j=1}^{I} dm_j^- + dm_j^+\right]. \quad (5)$$

4. QUALITATIVE CRITERIA ANALYSIS.

After making quantitative parameter considerations, the AHP technique is used for precision analysis. Under the AHP model, four main criteria are used –capacity, flexibility, quality and economic consideration

- **Capacity criterion**

For the capacity criterion, we used the closed queue model (CQM) [6] and made modification on the consideration of machine failure as a failure customer. The arrival of the failure customer a Poisson distribution [5]. To make the model more realistic by considering machine failure, the following assumption should be made.

(1) –queue of breakdown is not permissible
(2) –failure distribution followed the Poisson process with rate λ
(3) –the service time for the failure customer arriving at the station is equal to the mean repair time of that machine and follows an exponential distribution with rate μ
(4) –the arrival of the failure customer is preempted by other customers until the machine is repaired
(5) –the closed failure customer chains are mutually exclusive
(6) –the marginal queue length distribution of the preemptive failure customer classes is independent.

After stating the above assumption, we can develop the following equation for mean waiting time due to the preemptive failure customer arrival situation:

$$R(m,p) = R1(m,p) + R2(m,p), \quad (6)$$

With

$$R1(m,p)=\frac{[T(m,p)+W(m,p)+L_m r_m]}{1-\lambda_m O_m r_m} \quad (7)$$

$$R2(m,p)=\frac{T(M+1,p)W(M+1,p)+L_{M+1}r_{M+1}}{1-\lambda_{M+1}O_{M+1}r_{M+1}} \quad (8)$$

where T(m, p) is the mean machine time of part *p* in the machine group *m* for each visit to machine group *m* for *m*=1,2,3,…..,*M*, *W(m ,p)* is the mean waiting time of part *p* at machine group *m* due to other station and parts including machine failure, $L_m r_m$ is the average number of failure observed b_j a job *p* on arrival to resource m, X_m is the frequency of machine group *m* failure, *M+1* is the transportation and *Om* is the number of machines active in machine group *m*..

- **Flexibility criterion**

For a flexibility criterion, some concepts of flexibility from [3] were adapted and the total flexibility index was developed as follows:

$$\alpha Q + (1-\alpha)E \quad (9)$$

Where – α is the weight

-Q is the normalized factor of quick response –measured with time

– E is the normalized factor of economic response to change- measured in cost.

In the evaluation model, the total flexibility index can be defined with hierarchical structure (in next figure). According to the above situation, it is necessary to define the flexibility index from the point of view of both cost and time. Therefore, it can be defined as follows.

1. Defining pure component machine flexibility:

$$\text{Fmp (i)} = \frac{C(i)}{\max[C(1), C(2), ..., C(M)]}, \quad (10)$$

$$\text{Fmt (i)} = \frac{Op(i)}{\min[Op(1), Op(2), ..., Op(M)]}, \quad (11)$$

Where C(i) is the maximum cost added dy machine I to part family, Fmp(i) is the machine flexibility for machine type I and Op(i) is the minimum operation time type i.

2. Defining the overall and pure component part family flexibility index (Fdo(i,j), Fdp(i,j), Fpt(i,j) and Fpf(i,j))

$$\text{Fdp(i,j)} = \frac{\dfrac{C(i)}{S(i,j)}}{\max\left[\dfrac{C(1)}{S(1,1)}, \dfrac{C(2)}{S(2,2)}, ..., \dfrac{C(i)}{S(i,j)}\right]}, \quad (12)$$

- **Quality criterion**

It is measured as a qualitative parameter by the decision-maker in the A.H.P. evaluation model.

Economic analysis

For the economic criterion, the net present value method is used. The following assumptions are made:

(1) The salvage value of the equipment equals the book value of each asset at the end of the planning horizon.
(2) With company funds for investment, no additional external funding source is necessary.
(3) Each group depreciation is used for each piece of equipment.
(4) Annual increase of unit market price, direct material cost and labour are directly attributed to the annual inflation rate.

Then, the following factors are calculated for the economic analysis:

(a) revenue and,
(b) production cost (operating cost, raw material cost, inspection cost, setup cost), maintenance cost, initial investment, depreciation salvage value.

5. CONCLUSION AND FURTHER STUDY.

Before developing new technology in a company, it is necessary to perform, the investment analysis. The high level of investment in machine-tools and in transfer systems for the blanks from a FMS requires the making of careful decisions for selecting the types and number of machine-tools and of blank transfer systems.

It is necessary to make a detailed analysis on the decision-making model.

There are many approaches to this problem. In this paper are developed a two-phase model to cover quantitative and qualitative criteria and dynamic situation of system.

It is very interesting to link the flexibility index to demand patterns of products. The researcher is now developing a model based on the flexibility index for product design by using concurrent engineering concepts. Finally, defining the quality criterion as a quantitative parameter by using a quality deployment function or developing a new function to catch customer voice is very interesting in decision making.

References:

[1]. Barsan, I. *Some aspects regarding of a flexible Manufacturing System*, Acta Universitatis Cibiniensis, Technical Series Vol. LII, Sibiu, 2005.
[2]. Lawley, M. *Structural Analysis and Control of Flexible Manufacturing Systems*, PhD Thesis, University of Illinois at Urbana-Champaign, 1995.
[3]. Mynt, S., Tubacon, M. T. *A multiple criteria approach to machine selection for Flexible Manufacturing Systems*, International journal of Production Economics, 33, Elsevier, 1994.
[4]. Popp, I., *Consideration regarding model Architecture for Scalable Flexibility in Manufacturing*, International Conference on Manufacturing System, Buletinul Inst. Politehnic din Iaşi, publicat de Universitatea Tehnică “Gh. Asachi”, Tomul LI, secția Construcții de maşini, Iaşi, 2005
[5]. Reveliotis S., *Structural Analysis and Control of Flexible Manufacturing Systems with a Performance Perspective*, PhD Thesis, Univ. of Illinois at Urbana-Champaign, 1996
[6]. Sanchoy, K., D. *The Measurement of Flexibility in Manufacturing Systems*, International Journal of FMS 8, Kluwer Academic Publishers, Boston, 1996.