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Development of Work Centre Selection System for Process Planning in Manufacturing Using AHP With Sensitivity Analysis.

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Abstract

The selection of appropriate work center is one of the most critical decision in process planning of a successful production environment. In this study, a user-friendly decision support system is proposed for work center selection. This system guides the decision-maker in selecting work-center from available work-centers via effective algorithms, such as the Analytic Hierarchy Process (AHP). .The robustness of the selection procedure may be evaluated using sensitivity analysis. An illustrated example of work center selection using the proposed tool is also provided.

Keywords: Analytical Hierarchy Process (AHP), Decision Support System (DSS), Multi Criteria Decision Making(MCDM), Process Planning, Sensitivity Analysis(SA),Slope, Work Selection System.

1. INTRODUCTION

Manufacturing is the most competitive field in which everyday comes with different challenges. We should optimize our resources to deal with these challenges. The Resources in Manufacturing are 5 M Manpower, Money, Material, Machine & Method. In this study we are concentrating on Machine Resource to optimize its use for welfare of business.

Work center or Machine is basic resource of manufacturing that convert raw material into use full product. Selection of work center for a operation on a job is very critical for production engineer.

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When the product is in development phase, it is the duty of 'Process Planning & Development' department to make decision during preparation of routing sheet of product. And when the part is in regular production, it is the duty of Production Planning and control (PPC) department to select the work center or make changes in existing for operation on the job. It is quite proper to say that in most of the production unit, it is the manual work done by experienced production people of unit by using their past experience on similar products.

Work center selection not only decides manufacturing cost but also decide quality, productivity, reliability, easiness of operator etc. Wrong selection of Work centre can cause customer dissatisfaction & ultimately hurt the business. Machine selection is one of the step of development of product in process planning. Our study is confined for new products under development in process planning phase.

Work center selection is a Multi Criteria Decision Making Problem (MCDM). A decision is a choice made from two or more alternatives. Decision-making is the process of sufficiently reducing uncertainty and doubt about alternatives to allow a reasonable choice to be made among them. Many approaches such as the analytic hierarchy process (AHP), fuzzy multiple-attribute decision-making model, linear and 0-1 integer programming models, genetic algorithms, etc. have been considered for different decision-making problems. Wang et al. [1] suggest a fuzzy multiple-attribute decision- making model to assist the decision-maker to deal with the machine selection problem for flexible manufacturing systems (FMS). A linear 0-1 integer programming model of the machine tool assignment and operation allocation in FMS is proposed by Atmani and Lashkari [2]. A model which is formulated as a 0-1 integer programming to determine machine visiting sequences for all part types for an integrated machine tool selection and sequencing is proposed by Moon et al. [3]. Subramaniam et al. [4] proposes an approach for selection of machines. Haddock and Hartshorn [5] present a decision support system (DSS) to assist in selecting a machine that is required to process specific dimensions of a part. A multi-criteria weighted average approach is proposed by Arslan et al. [6] to select a suitable machine from a database of available machines in the market.

Triantaphyllou and Mann [7] examine some of the practical and computational issues involved when the AHP method is used in engineering applications. Lin and Yang [8] also study the evaluation of machines by the AHP method. This study is concerned with the selection of the most suitable machine from feasible machines for the particular operation on a part. Tabucanon et al. [9] develop a decision support framework designed to aid decision makers in selecting appropriate machines for FMS. Oeltjenbruns et al. [10] investigate the compatibility of AHP to strategic planning in manufacturing. The objective is to develop/explore different planning alternatives and to evaluate these alternatives through economical and technological criteria. Yurdakul [11] presents a model which links machine alternatives to manufacturing strategy for machine tool selection. On the other hand, Cheng and Li [12] claim that although AHP is an effective tool for management decision making, it can be defective if used improperly. This study proposes a DSS form work center selection based on AHP. Sensitivity Analysis included tomake an accurate selection. The overall decision methodology is implemented using Microsoft Visual Basic. The remainder of the paper is organized as follows: Section 2 discusses multi-criteria decision-making as well as Sensitivity Analysis. The AHP methodology is depicted in Section 3 using an example. Section 4 presents the implementation of the methodology and portrays the developed software. Finally, Section 5 gives the concluding remarks and insights for the future research.

2. DECISION-MAKING PROCESS: BACKGROUND

2.1. Multi-Criteria Decision-Making

The basic idea behind multi-criteria decision-making (MCDM) is to construct a decision tree using a selection of criteria relevant to a particular decision and the weighting/ scoring of the criteria and the alternatives for each different criterion. According to Triantaphyllou [13], MCDM is divided into multi-objective decision-making (MODM) and multi-attribute decision-making (MADM).

MCDM is concerned with structuring and solving decision and planning problems involving multiple criteria. The purpose is to support decision makers facing such problems. Typically, there does not exist a unique optimal solution for such problems and it is necessary to use decision maker's preferences to differentiate between solutions.

There are six concepts related to the MCDM: Alternatives, attributes, criteria, sub-criteria, weights of importance, and decision matrix. Despite the criticism multi- dimensional methods have received, methods such as weighted sum model (WSM), weighted product model (WPM), AHP, revised AHP, ELECTRE, and TOPSIS have been widely used. We will briefly summarize AHP and revised AHP and refer the reader to Triantaphyllou [13].

Analytic Hierarchy Process

AHP is a basic multi-criteria decision-making approach introduced by Saaty [14]. In this approach, the decision- maker carries out simple pair-wise comparison judgments, which are then used to develop overall priorities for ranking the alternatives.

In making decisions, deciding what factors to include in the hierarchic structure is the most important task. When constructing hierarchies one must include enough relevant detail to represent the problem. The elements of comparison should be homogeneous. A hierarchy may be divided into sub-hierarchies sharing only a common topmost element.

In practice, AHP has two basic applications (Cheng and Li [12]): (i) assign weights to a set of predetermined elements (e.g. criteria, factors) and make a decision out of several scenarios or alternatives; (ii) prioritize (rank) elements in order to identify the key elements. In general, AHP has five major steps described as follows:

° Define the unstructured problem to decide whether AHP is the appropriate method for solving the problem.

° Decompose the problem into a systematic hierarchical structure. (A hierarchy is similar to a decision tree.)

° Employ the pair-wise comparison method. The relative importance of pairs of objectives can be scored on a 9- point scale as illustrated in Table 1.

Table1: Scale of relative importance (Triantaphyllou [13])

	Definition	Explanation
1	Equal importance	Two activities contribute equal
2	Weak importance of one over another	Experience & judgment slightly favor one over another
5	Essential or strong importance	………………. Strongly favored one over another
7	Very strong and demonstrated	….Strongly favored and its dominance demonstrated in practice
9	Absolute importance	Evidence favoring one over another is of the highest possible order
2,4,6,8	Intermediate values between adjacent scale values.	

Then, an approximate weight vector is calculated. At the end of this step, the weights of the objectives are determined.

° Carry out the consistency measure. Consistency measure is used to screen out the inconsistency of responses. (Refer to Triantaphyllou and Mann [7] for details in consistency.)

° Use the relative weights for different purposes. For decision-making, it involves a set of scenarios or alternatives for which the decision-maker will score the weighted criteria so that the total score can be calculated. For identifying key elements (e.g. critical factors of project success) in only one decomposed level, the elements with higher relative weights are more important. These steps are explained in more details on a machine selection example in Section 3.

Revised Analytic Hierarchy Process

This method is proposed by Belton and Gear [15]. They demonstrate that a ranking inconsistency can occur when AHP is used. When the revised AHP is applied on the new problem (that is, when the data are normalized by dividing the largest entry in each column), the desired solution is reached

2.2 Sensitivity Analysis

Sensitivity analysis investigates the rate of change in the output of a model caused by the changes of the model inputs. There are two closely related sensitivity problems. The first is to determine the smallest change in the current weights of the criteria which can alter the existing ranking of the alternatives (Problem1). The second is to determine how critical the performance measures of the alternatives are in the ranking of the alternatives Problem2). Triantaphyllou [13] discusses the solution methodologies for two problems.

2.3 Application Environment

To implement our work center selection approach we have developed a software using Microsoft Visual Basic (VB). VB is a distinctive programming language providing powerful features such as graphical user interfaces, event handling, access to Win32 API, object oriented features, error handling, structured programming, etc. As the database management system Microsoft Access has been selected since it enables managing all information from a single database file.

3. METHODOLOGY

Our methodology is constructed using AHP, equipped with sensitivity analysis.

3.1 Decision Criteria

In a machine selection process, the decision-maker defines his preferences according to which the best machine from a data set of available machines. The decision-maker first find out the feasible machines according to size & specification of product & operation. and the machines that do not meet these specifications are filtered out. Then, the selection criteria are considered in the rest of the process. There are four main criteria with sub-criteria as shown in Table 2.

Table 2: Criteria and related sub-criteria.

1. Quality – Q	
1.1 Accuracy- AR	1.2 Precision- PC
2. Cost- C	
2.1 Productivity- P	
2.1.1 Machining Time- MT	2.1.2 Handling Time- HT
2.1.3 Setup Time - ST	2.1.4 Break down & other ideal Time- BT
2.2 Machining Cost per unit time- MC	2.3 Maintenance Cost - MTC
2.4 Operator Skill Cost- OC	2.5 Fixed Cost – FC
3. Ergonomics	
4. Reliability- R	
4.1 Machine Reliability- MR	4.2- Relative Tool Reliability- RTR
4.3 Machine Flexibility	

3.3 Source of Pair wise Comparisons

The comparisons of criteria & work centres is based on data collected using Time Study method for Productivity, Cost analysis for other Cost criteria, Departmental Quality data on similar products using the same work centres, Data from maintenance book for Reliability criteria and Maintenance cost & time sub-criteria. Wherever data is not available, Delphi method having some of most experienced production people of plant as experts is used.

3.4 Decision Methodology

AHP is used to rank a user specified number of machines from the best to worst. In some decision-making problems on which AHP is applied, either Alternatives or criteria are pair wise compared using 9 point scale. But in our approach we compared both Alternatives as well decision criteria. AHP enables user to determine the criteria weights by using comparison matrices. Work centres are compared with respect to each criteria. Although determine of weight for decision criteria and after that for Work centres in multi criteria decision methods is critically important, AHP offers simple approach .Let our study on a product a Ø11 mm bolt under development having 5 operations. One of them is Forging. According to size & shape of the bolt hot forging is not suitable. So we concentrate only on Cold forging machines. Out of all Cold forging machines available in plant, we select feasible & most suitable machines according to shape, size other manufacturing consideration of product. After filtering out, we left with 5 most suitable work centres having very close suitability for forging on this product. No we have to rank these work centres & have to find out the most suitable candidate for this operation. We rank these work centres on behalf of up listing 4 criteria, 10 sub criteria & 4 sub sub criteria. But for easiness to understanding we select only main criteria. The procedure is depicted below on this example.

Step 1: Select main criteria

Suppose, the decision- maker selects Cost and Reliability .

Step 2: Select Sub criteria.

Cost have 5 sub criteria. Among these five, four of them are selected (P, MC, MTC & FC). As clear that productivity should be higher & these 3 cost should be lower. But for we have to compare out of higher productivity & lower Machining cost (for eg.) which one is more important for this operation.

Productivity further have four sub criteria but for simplicity of example we does not consider these.

Step 3 : Compare selected sub criteria to calculate score.

For this comparison, the decision maker considers the question: "How important the productivity to Machining Cost ? for this operation (see table 3). The decision- maker uses the following rates for importance: E=Equal (1), EM=Equal-Moderate (2), M=Moderate (3), MS=Moderate- Strong (4), S=Strong (5), SVS=Strong-Very Strong (6), VS=Very Strong (7), VSEX=Very Strong œ Extreme (8), EX=Extreme (9).

Table 3: Cost Sub criteria pair wise comparison

	P	MC	MTC	FC
P	-		S	SVS
MC	EM	-	SVS	VS
MTC			-	EM
FC				-

.

Step 4: Construct pair wise comparison matrix for sub criteria.

Each rate of importance has an equivalent numerical value as given above. These rates are replaced on table 4 by their equivalent numerical values on the pair wise comparison matrix.

Table 4: Numerical values corresponding to data in table 4.

	P	MC	MTC	FC
P	1	½	5	6
MC	2	1	6	7
MTC	1/5	1/6	1	2
FC	1/6	1/7	1/2	1

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Step 5: Normalize the pair wise comparison matrix by dividing the values in each column by the column sum.

Step 6: Calculate the scores (the relative weights) of the criteria by taking the average value of each row.

Table 5: Normalize and average values

	P	MC	MTC	FC	AVG.
P	0.30	0.27	0.40	0.37	0.33
MC	0.60	0.55	0.48	0.44	0.52
MTC	0.06	0.09	0.08	0.12	0.09
FC	0.05	0.079	0.04	0.06	0.06

.

The score of sub criteria of cost are as follows: SP = O.33, SMC= 0.52, SMTC = 0.09, SFC = 0.06.

For Reliability, all three sub-criteria as shown in table1 are selected. AHP is applied as it is done for cost.

Step 7: Compare selected main criteria to calculate score.

Cost and Quality are compared for this particular operation on the job, as shown table 6.

Table 6: Main criteria's comparison and numerical values.

	C	R
C	-	S
R		-

	C	R
C	1	5
R	1/5	1

C= COST, R= Reliability

Step 8: Calculate scores for main criteria as in steps 5 & 6. (Table 7)

Table 7: Normalized and average values for main criteria.

	C	R	AVG
C	0.83	o.83	0.83
R	0.17	0.17	0.17

After each pair wise comparison (for both main and sub criteria) consistency is examined.

Step 9: Calculate the overall score for criteria by multiplying main criteria score with sub-criteria score.

For example, total score of Productivity & Maintenance cost are calculated as:

S Productivity = SP*S cost = 0.33*0.83 = 0.274

S Maintenance Cost= SMTC*S COST= 0.09*0.83=0.075

Step 10: Repeat the above step for each Work centre W1,W2,W3 & W4 using one criteria at a time. For example using Productivity sub criteria compare the all five work centre, as like it for all sub criteria of cost. After it same for Quality's sub criteria. Find out average value for each work centre.

Step 11. Now find the final weight of Work centre corresponding to particular criteria by multiplying the score of Work centre from last step with overall score of criteria from 9th step.

Step 12: Now add up the final weights of Work centre corresponding to all criteria. This is the Final overall weight of Work centre

Repeat step no. 11 & 12 for all five work centres. This is the final overall weight of work centres.

We can use all criteria as shown in table 2 in similar way to obtained accurate & better results.

Determine of best Work centre

As the result from last analysis using AHP, weight of individual work centre is available. Now ranking is given according to their weight, having highest weight will be ranked first and having least weight will be ranked last. Ranking of Work centres is strictly according to criteria included in study.

3.5 Sensitivity Analysis

Comparison value can take value between "Equal" and "Extreme". Sensitivity analysis is used to examine the effects of different comparison values on AHP. First of all, comparison values are increased step by step. For example, the decision maker assumes that cost is strongly important than reliability. This "strong " value is increased one step and the change in machine ranking is examined.. The comparison value & further the weightage value at which the machine ranking changes is taken as a **break point**. Then the original pair wise comparison value is decreased step by step until the machine ranking changes. The comparison value at which the machine ranking changes is taken as another break point.

Slope is the ratio of difference in Alternative Utility of machine to difference in % Criteria Weight.

$$i = \frac{\Delta au}{\Delta cw}$$

i = Slope of sensitivity line

au = % alternative utility

cw = % criteria weight i.e. 100- 0 = 100

so $i = \frac{\Delta au}{100}$

Positive slope indicate that utility of particular work center increase when the overall weightage of concerned criteria increase in study. While negative slope describe decrease in utility.

So slope & break point are two observation point of our SA.The step by step values are used in making the graphs of sensitivity analysis.

4 SOFTWARE IMPLEMENTATION

The proposed methodology is implemented using Visual Basic and Microsoft Access. .The developed software consists of 3 modules as

shown in Figure 1. Selection (SM), sensitivity analysis (SAM), are used for the decision process while sixth module (AM) is used for administrative purposes, define/update a machine manufacturer, or user and to manage default values for each user. In order to use the software, the decision-maker should log-in by entering username, password, and user type. Login option lets decision makers keep track of his decision activities

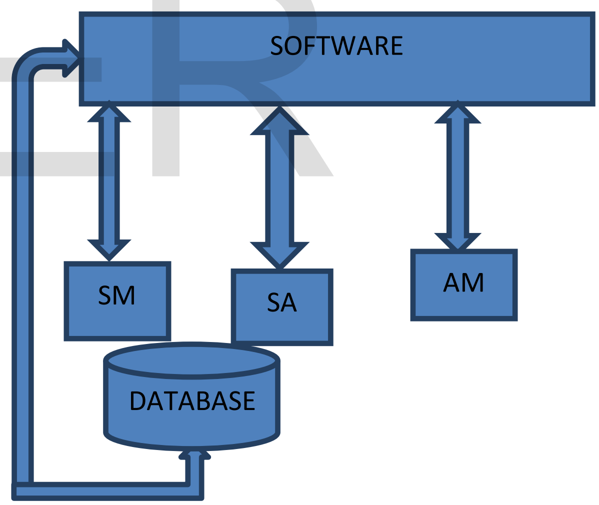

Figure 1: Structure of the DSS.

Selection

SM enables decision-maker to select the most appropriate work center according to his preferences. This module uses AHP methodology in order to rank work center, as described in the previous section. In this module, the decision-maker may also load the predefined selection preferences or add his favorite machines to the candidate list.

At the first step of the selection module, the decision- maker defines work centers that are feasible for the operation and their general properties.

In the next step, the user chooses required criteria for AHP process. After determining the main criteria, the user selects sub-criteria. Then, he defines qualitative comparison values for the desired sub-criteria.

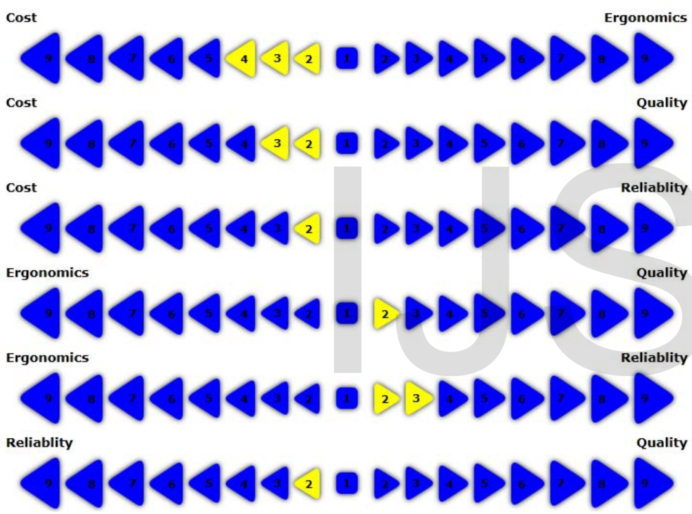

figure2 pair wise comparison of criteria

In the next step, the user compares the main criteria as shown in figure 2

In the last step, the user compares work centers on behalf of all criteria. As a result of selection process, a work Centre ranking is obtained as shown in figure3. The first work Centre in the ranking is the best machine under desired requirement of machine properties, main and sub- criteria.

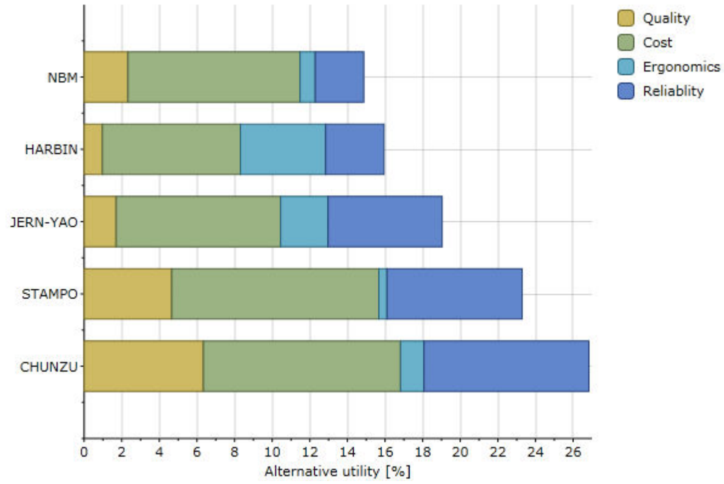

Figure 3: Final ranking of Work Centres

Ranking can also be given with respect to single criteria as given in figure 4 according to cost criteria.

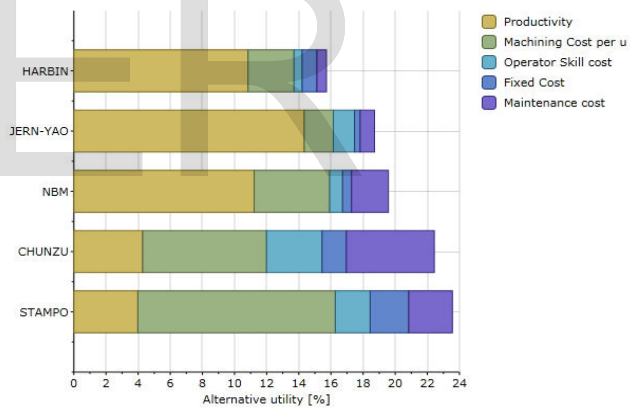

Figure 4 Ranking with respect to Cost

Sensitivity Analysis

The Decision-maker analyzes main pair-wise comparison values of selection in the sensitivity analysis module. First, he loads the desired machine results. Then he defines the number of machines on which the analysis is to be performed. Finally, the selection preferences are loaded. There are two analysis options: (i) the change in the top ranked machine, (ii) the change in machine ranking.

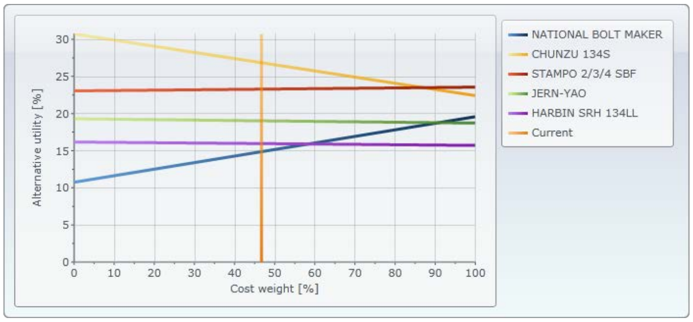

Figure4 sensitivity analysis with respect to cost criteria.

5 CONCLUSION AND FUTURE RESEARCH

Selecting the most suitable machine from the number of available Work Centres is a challenging task. Productivity, precision, flexibility, and company's responsive manufacturing capabilities all depend on the machine properties. In this study, work centre selection problem is addressed and an AHP based methodology is proposed. In order to apply this methodology, work centre and main & sub-decision criteria are investigated.

The proposed methodology is very flexible in the sense that it can be applied to other types of selection problems, e.g. selection of a supplier , vehicle , appliances, etc. The major contribution of this study is in combining the selection methodology based on AHP with sensitivity analysis to evaluate several alternatives and make a good decision.

The suggested methodology is a part of process planning. As a future work, this system may be integrated to the overall manufacturing planning system. The proposed decision methodology may also be used to select appropriate tools for machining, material handling system, robots, materials, etc. Such integration will construct an intelligent computer-assisted process planning system which enables the design and control of overall manufacturing activities

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