An Integrated Methodology For Strategic Selection Problems

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Abstract:

Strategic selection problem is a multi criteria problem which includes conflicting tangible and intangible criteria. In order to select the most appropriate strategic alternative, it is necessary to make tradeoffs between these criteria, as well as taking into account the resource limitations which may exist. Available methods neglect the distance concept which exists between the alternatives' weights with regard to a single criterion and its target value. In this paper in addition to applying the Analytical Hierarchy Process (AHP) as a stand-alone methodology, an integration of the AHP and Zero-One Goal Programming (ZOGP) is proposed. In this integration, each single criterion viewed as a constraint in a ZOGP model which enable the model to take into account not only the distances but also to consider the real resource limitation for tangible criteria.

In order to justify the methodology, it is applied to selection of Advanced Manufacturing Systems (AMS).

keywords: Strategic, selection, multiple, AHP-ZOGP, AMS

1. Introduction

Strategic decisions are decisions whose implementation has a long term effect on an organisation (Ordoobadi and Mulvaney 2001). Strategic benefits are often intangible (such as improving flexibility and improving the standards) and cannot be realised in a short term period, especially in the early stage of implementing the decision (MacDougall and Pike, 2003). In addition, strategic decisions require the intervention of multiple stakeholders within an organisation and customers outside the organisation because of their different viewpoints (Nagalingam and Lin, 1998).

The strategic selection problem is an important task for companies. Choosing the best manufacturing process, choosing between different advanced manufacturing technologies and choosing between different suppliers are some examples of this situation. In these situations, those alternatives should be selected which are are best and consistent with the company's strategic objectives. The selection process is the activity of narrowing down the set of alternatives under consideration (Chen and Lin, 2002; Green, 2000). A large set of alternatives should be initially screened down to a smaller set because some are clearly not feasible for obvious reasons, such as infeasibility for manufacturing or the cost of production (Lovatt and Shercliff, 1998). Using rational decision making techniques which compare the remaining alternatives, a dominant alternative can be chosen (von Winterfeldt and Edwards, 1986).

The strategic selection process is a complex task because of the conflicting tangible (such as cost) and intangible criteria (such as flexibility), sub-criteria, different stakeholders, and real constraints. An alternative which is best from the point of view of, for example, the manufacturing department, may not be the best from another department, for instance, marketing, because each individual department has its own perception, viewpoint and criteria. In general, this sort of problem should be investigated in the Multiple Criteria Decision Making (MCDM) environment (Khatami Firouzabadi and Henson, 2004). In this situation, decision maker(s) is unable to decide between a numbers of alternatives not only because of the presence of different objectives but also because there are often multiple conflicting criteria and multiple stakeholders. To make a decision, decision maker(s) should make tradeoffs between the conflicting criteria in order to prioritise the goals and criteria for selecting one alternative. In this situation, decision makers should decide which criteria have most effect in the decision (Galloti, 2002).

This paper suggests a methodology based on integration of AHP and Zero-One Goal Programming (ZOGP) for selecting the most appropriate alternative among available conventional and strategic alternatives, considering the distance concept.

AHP is used because of its simplicity, ability to address and analyse discrete alternative problems with the ability of considering both qualitative and quantitative criteria, ability to create a measure of inconsistency for judgements, and its successful applications of broad arrays of problems.

The overall philosophy of the AHP is to provide a solid, scientific method to aid in the creative, artistic formulation and analysis of a decision problem. The AHP starts of subdividing a problem into a hierarchy of an overall objective, criteria, sub-criteria, sub-sub-criteria, etc., until reaching on the bottom level the discrete alternatives. Then, starting at the bottom level, pairwise comparisons are conducted between the elements immediately below each other element. The pairwise comparisons on the rating levels are done for the lowest level sub-criteria. The ratio is then transformed into a value scale. It should be noted that in every comparison, just two alternative or criteria are compared. The pairwise comparison procedure is equivalent to assigning numbers to criteria which sum to one under its parent node. AHP uses the usual nine-point ratio for pairwise comparisons, in which, assigning 9 means that, for example, alternative A is extremely preferred to alternative B with regard to a criterion, while assigning 1 means there is no difference between two alternatives with regard to another criterion. The AHP provides a measure of inconsistency between the judgements to detect whether the pairwised comparisons are done correctly, as well as a method to reduce this measure if it is deemed to be too high (Saaty, 1980).

Completing each level and then working up the tree in order to establish a priority ranking for each alternative taking all criteria concerns into account (Saaty, 1980). A ratio scale score of the alternatives then are produced by adding the weighted priorities of the relevant ratings, one under each criterion corresponding to the alternatives.

In general, the AHP helps decision makers to:

- Identify the critical elements and issues of a problem.
- Eliminate less important elements early in the decision-modelling process.

- Solve problems in a timely manner.
- Inspire confidence and commitment among participants.

On the other hand, Goal Programming (GP) is a procedure for compensation tradeoffs between goals within the general framework of linear programming. The GP models are based on the assumption that for each criterion, a goal target is chosen by decision maker or by the results of other methods, such as AHP, to penalise positive or negative (or both) achievements (deviations) from this target. Deviations are penalised using a direct linear relationship between the penalty and distance from the goal. The gradient in this relationship is the weighting coefficient of the deviation in the objective function. In GP, instead of attempting to maximise or minimise the objective function directly, as in linear programming, the deviations between goals and what can be achieved within the given set of constraints are minimised. Obviously, it is not possible to achieve every goal to the extent desired, because of presence of conflicting goals or criteria. Then, given the usual resource limitations or constraints, the decision maker attempts to develop decisions that provide the "good enough" outcome in terms of coming as close as possible to reaching all goals, based on Simons' "satisficing" philosophy, which implies that decision makers are interested usually only in minimising the non-achievement (undesirable variables) of several goals (Romero, 2001). Therefore, in GP, the most satisficing outcome is sought, which might not be optimum from all of the criteria.

ZOGP is here applied to address the distance concept between the best alternative from point of view of a criterion and the best alternative from viewpoint of all criteria. The large distance means the selected alternative from point of view of a single criterion is not the best alternative when all the criteria are considered. Therefore, an alternative should be chosen to have minimum total distance, taking into account the weight of all criteria. ZOGP have this ability not only to take into account the distance, but also is able to consider the weight of the criteria, in order to obtain that alternative which has the minimum distance.

2. METHODOLOGY

The basic idea in the methodology is to use problem decomposition and explicit value or preference tradeoffs from point of view of each criterion or sub-criterion. When there are multiple criteria for evaluating alternatives, the best alternative from point of view of each criterion is different (Khatami Firouzabadi and Henson, 2006). Therefore, there are distances between the final selected alternative and the best alternative from point of view of each single criterion. The methodology tries to select that alternative which has minimum total distances using the ZOGP model. The distances are minimised with their associated weights, which are the relative importance of each single criterion, obtained by global weights of the AHP. Partial weights are also used to construct the coefficients of constraints.

Global weights refer to the weights which indicate the relative importance of each criterion or sub-criteria against other criteria or sub-criteria (the sum of all global weights regard to objective of the hierarchy should be equal to 1). Partial weights are those weights that will be obtained when alternatives are compared against a criterion or sub-criterion (the sum of partial weights should be equal to 1 when an alternative is compared with all criteria or sub-criteria).

In the methodology, each individual criterion or sub-criterion has a constraint in the ZOGP model. The global weights of criteria become the objective function coefficients of ZOGP model. These coefficients associate with the distance from the left hand side (coefficients of each individual alternative) can be obtained by AHP (if they are related to intangible criteria), and normalization process (if they are related to tangible criteria). When alternatives are compared with regard to a single criterion, they will have partial weights that show the relative importance of the alternatives regard to that criterion. These partial weights become the coefficients of the zero–one variable (non-selection and selection) of an alternative, respectively. The right hand side (the target value) of each constraint is in fact, the best coefficients of left hand sides' coefficients for intangible criteria and normalized target values for tangible criteria. There is also a distance between the left hand side and target value of a constraint. The distances are the slack (surplus) variables' of each constraint. If the best alternative from point of view of a criterion is identical with the final selected alternative, then the distance is zero. Otherwise, there is a distance which impacts the value of objective function. The model minimisation iterative process tries to eliminate those alternatives which related criterion coefficients in the objective function are more than others. The nature of zero–one variables will select one alternative which has the minimum distance.

3. CASE STUDY

To implement the methodology, the problem of AMS selection is considered which has been previously solved by AHP method (Datta et al., 1992).

AMS selection is a strategic decision problem because of its conformity with strategic characteristics. The characteristics of strategic decisions are as follow (MacDougall and Pike, 2003; Noble, 1990; Ordoobadi and Mulvaney, 2001):

- They have a long term effect on the success of the company.
- They are non-repetitive.
- Criteria may conflict. For example, customers want quality but also want something inexpensive.
- There are a large number of intangible and tangible criteria.
- Retaining the status quo cannot be considered as an alternative because in the increasingly competitive world, companies in international markets must continuously improve their products and productivity to survive. Choosing to do nothing causes market share to decrease.

These factors necessitate applying MCDM approach because traditional financial methods are not able to include intangible benefits associated with AMS.

A comparison is made between using AHP and proposed methodology. This problem is selected because all the elements of the methodology such as hierarchy construction, determining criteria, pairwise comparisons, AHP solution, have been identified. The problem involves the selection of one alternative among Flexible Manufacturing System (FMS), Transfer Line (TL), Flexible Manufacturing Cell (FMC), Flexible Manufacturing Module (FMM), and Job Shop (JS) for developing a company.

3.1. SOLVING THE PROBLEM USING AHP ALONE

This problem has been solved using AHP (Datta et al., 1992). All the criteria and pairwise comparisons have satisfied their associated rules. The hierarchy, criteria, alternatives, relative importance of criteria, and final weights of alternatives have been depicted in → Figure-1. Applying AHP indicates that the ranking of alternatives are FMS, TL, FMC, FMM, and JS, respectively. The interested readers are referred to the reference for full description of criteria and alternatives.

3.2. INTEGRATION OF AHP AND ZOGP

To solve the problem using with integration of AHP and ZOGP, it is necessary to construct the constraints and objective function of ZOGP model.

The alternatives should be evaluated by pairwise comparison against a criterion in order to obtain the partial weights which will form the parameters of constraints in ZOGP model. In other words, the winner alternative can be determined from point of view of each criterion by the relative importance of available alternatives. These partial weights can be found in original paper (Datta et al., 1992).

3.2.1. ZOGP MODEL

The ZOGP model of this problem based on minimisation sum of individual relative importance of criteria or sub-criteria and using partial weights for parameters of constraints is as follows:

$$Min\, 0.202d_{01}^- + 0.214d_{02}^- + 0.026d_{03}^- + 0.042d_{04}^- +$$

$$0.038d_{05}^- + 0.068d_{06}^+ + 0.129d_{07}^+ + 0.110d_{08}^- +$$

$$0.014d_{09}^- + 0.123d_{10}^- + 0.017d_{11}^- + 0.017d_{12}^- \quad (1)$$

Subject to

$$0.036TL + 0.499FMS + 0.239FMC + 0.149FMM +$$

$$0.077JS + d_{01}^- - d_{01}^+ = 0.499 \quad (2)$$

$$0.141TL + 0.491FMS + 0.243FMC + 0.086FMM +$$

$$0.039JS + d_{02}^- - d_{02}^+ = 0.491 \quad (3)$$

$$0.149TL + 0.483FMS + 0.218FMC + 0.107FMM +$$

$$0.044JS + d_{03}^- - d_{03}^+ = 0.483 \quad (4)$$

$$0.146TL + 0.537FMS + 0.193FMC + 0.081FMM +$$

$$0.043JS + d_{04}^- - d_{04}^+ = 0.537 \quad (5)$$

$0.150TL + 0.506FMS + 0.210FMC + 0.091FMM +$

$0.042JS + d_{05}^{-} - d_{05}^{+} = 0.506 \quad (6)$

$0.130TL + 0.493FMS + 0.242FMC + 0.098FMM +$

$0.036JS + d_{06}^{-} - d_{06}^{+} = 0.036 \quad (7)$

$0.445TL + 0.284FMS + 0.151FMC + 0.079FMM +$

$0.041JS + d_{07}^{-} - d_{07}^{+} = 0.041 \quad (8)$

$0.462TL + 0.297FMS + 0.126FMC + 0.079FMM +$

$0.037JS + d_{08}^{-} - d_{08}^{+} = 0.462 \quad (9)$

$0.118TL + 0.503FMS + 0.252FMC + 0.087FMM +$

$0.039JS + d_{09}^{-} - d_{00}^{+} = 0.503 \quad (10)$

$0.505TL + 0.261FMS + 0.132FMC + 0.067FMM +$

$0.035JS + d_{10}^{-} - d_{10}^{+} = 0.505 \quad (11)$

$0.027TL + 0.069FMS + 0.136FMC + 0.266FMM +$

$0.502JS + d_{11}^{-} - d_{11}^{+} = 0.502 \quad (12)$

$0.115TL + 0.482FMS + 0.261FMC + 0.100FMM +$

$0.042JS + d_{12}^{-} - d_{12}^{+} = 0.482 \quad (13)$

$TL + FMS + FMC + FMM + JS = 1 \quad (14)$

$TL, FMS, FMC, FMM, JS = 0 \text{ or } 1 \quad (15)$

$All\ d_{j}^{+/-} \geq 0 \quad (16)$

For example, 0.036 in the first constraint (Equation-2) is the relative importance of TL alternative when all the alternatives are compared against flexibility criterion. Objective function coefficients are the relative importance of each criterion which has been shown in ➔ Figure 1 (level 2). The target values of constraints are the best parameters of relative constraint, to reflect that with choosing the best alternative from a special criterion, there is no distance or difference between target value and the chosen alternative. However, when non-optimal alternative is chosen respect to that criterion, there is a distance which is considered with its global weight that is now the coefficient of objective function. It is worth noting that the nature of objective function will minimise the undesirable distances. The result of AHP and AHP-ZOGP approach are shown in ➔ Table 1. As the instance two of them), then the solution of new methodology is differed from AHP alone. The AHP alone selects the FMS and TL, while the new methodology chooses FMS and FMC.

Table 1-Result of AHP and AHP-ZOGP

Alternatives	Orders using AHP	Orders Using AHP-ZOGP
TL	Second	Third
FMS	First	First
FMC	Third	Second
FMM	Fourth	Fourth
JS	Fifth	Fifth

4. CONCLUSION

This paper indicated when making a strategic selection decision involving diverse range of conflicting criteria, integration of AHP and ZOGP could help the decision maker(s) to make a sound decision. AMT selection was applied to justify the methodology because of its strategic nature. The case study demonstrated that the proposed approach can give the decision maker(s) some useful aids in order to make a final decision. These aids include the deviations from each target value which means with selecting a specified alternative, what criteria are satisfied exactly and how much attainability has been occurred for other ones. This methodology introduced resource limitations for tangible criteria (such as budget limitation) and criteria constraints in order to remove the drawbacks of AHP when it is used alone.

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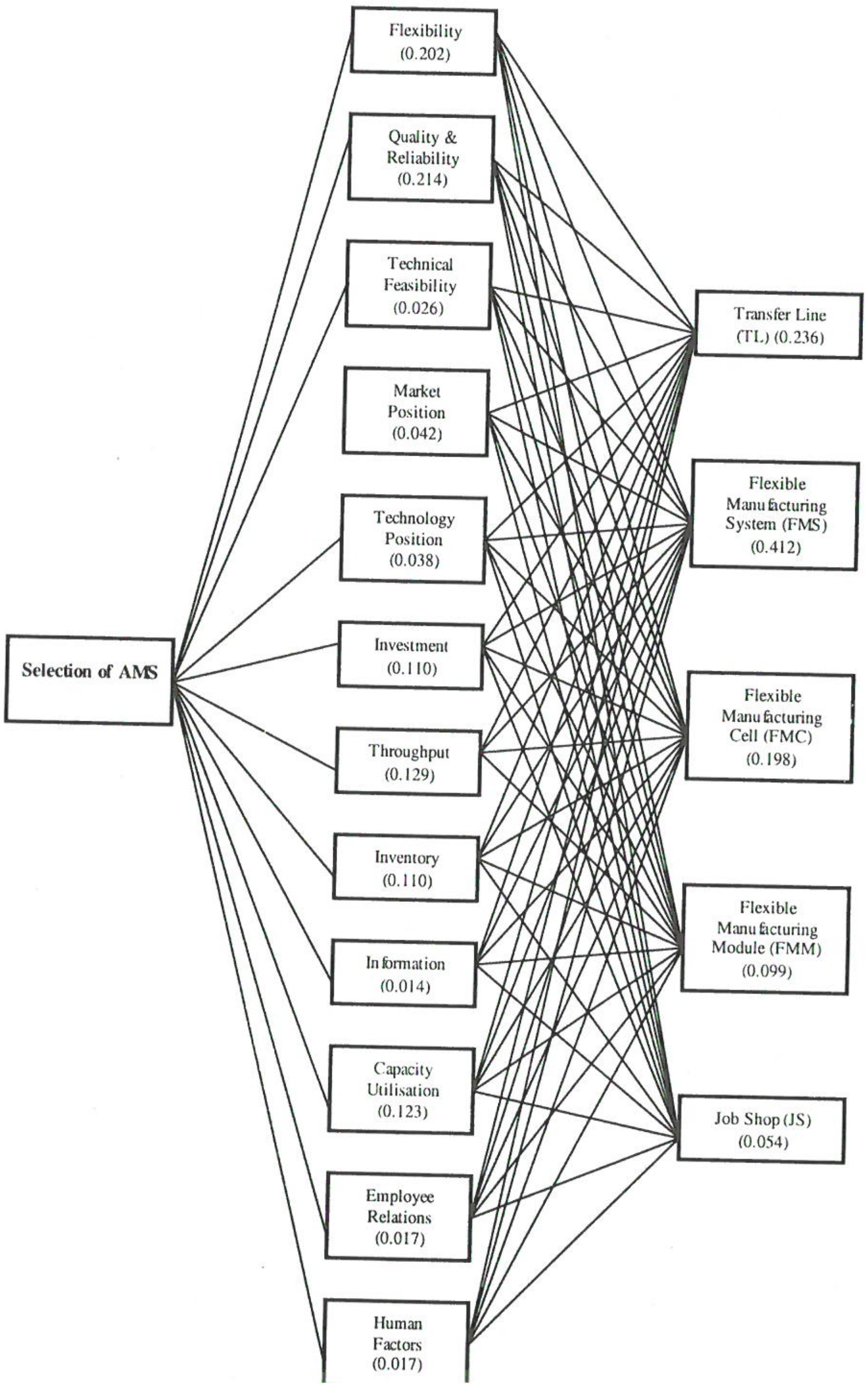
Selection of AMS
Flexibility (0.202)
Quality & Reliability (0.214)
Technical Feasibility (0.026)
Market Position (0.042)
Technology Position (0.038)
Investment (0.110)
Throughput (0.129)
Inventory (0.110)
Information (0.014)
Capacity Utilisation (0.123)
Employee Relations (0.017)
Human Factors (0.017)
Transfer Line (TL) (0.236)
Flexible Manufacturing System (FMS) (0.412)
Flexible Manufacturing Cell (FMC) (0.198)
Flexible Manufacturing Module (FMM) (0.099)
Job Shop (JS) (0.054)