ANP-GP Approach for Selection of Software Architecture Styles

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Abstract

Selection of Software Architecture for any system is a difficult task as many different stake holders are involved in the selection process. Stakeholders view on quality requirements is different and at times they may also be conflicting in nature. Also selecting appropriate styles for the software architecture is important as styles impact characteristics of software (e.g. reliability, performance). Moreover, styles influence how software is built as they determine architectural elements (e.g. components, connectors) and rules on how to integrate these elements in the architecture. Selecting the best style is difficult because there are multiple factors such as project risk, corporate goals, limited availability of resources, etc. Therefore this study presents a method, called SSAS, for the selection of software architecture styles. Moreover, this selection is a multi-criteria decision-making problem in which different goals and objectives must be taken into consideration. In this paper, we suggest an improved selection methodology, which reflects interdependencies among evaluation criteria and alternatives using analytic network process (ANP) within a zero-one goal programming (ZOGP) model.

Keywords: Software Architecture; Selection of Software Architecture Styles; Multi-Criteria Decision Making; Interdependence; Analytic Network Process (ANP); Zero-One Goal Programming (ZOGP)

1. INTRODUCTION

Software architectures significantly impact software project success [1]. However, creating architectures is one of the most complex activities during software development [2]. When creating architectures, architecture styles narrow the solution space: First, styles define what elements can exist in architecture (e.g. components, connectors). Second, they define rules on how to integrate these elements in the architecture. Moreover, styles address non-functional issues (e.g. performance) [3]. Selecting the best style is difficult because there are multiple criteria and factors such as project risk, budget, limited availability of resources, etc. Moreover, this selection is a multi-criteria decision-making problem in which different goals and objectives must be taken into consideration. When we evaluate, we need to collect group opinion in order to know the interdependence relationship among criteria.

The contributions of this paper are as follows:

1. This paper presents a method called SSAS (Selection of Software Architecture Styles).
2. It uses analytic network process (ANP) to determine the degree of interdependence relationship among the alternatives and criteria.
3. It provides a way of collecting expert group opinion along with stakeholders interests (e.g. reliability, performance)
4. It uses a systematic procedure to determine the following factors in constructing the GP model through a group discussion: (i) objectives, (ii) desired level of attainment for each objective, (iii) a degree of interdependence relationship, and (iv) penalty weights for over or under achievement of each goal [4]

Therefore, the information obtained from ANP is then used to formulate zero-one goal programming (ZOGP) model [5]. The objective of this paper is to describe an integrated approach of style selection using ANP and GP. Thus, in this paper, we suggest an improved selection methodology, which reflects interdependencies among evaluation criteria using analytic network process within a zero-one goal programming model. Thus a systematic approach is adopted to set priorities among multi-criteria and also among alternatives.

2. ANP-GP APPROACH FOR SSAS

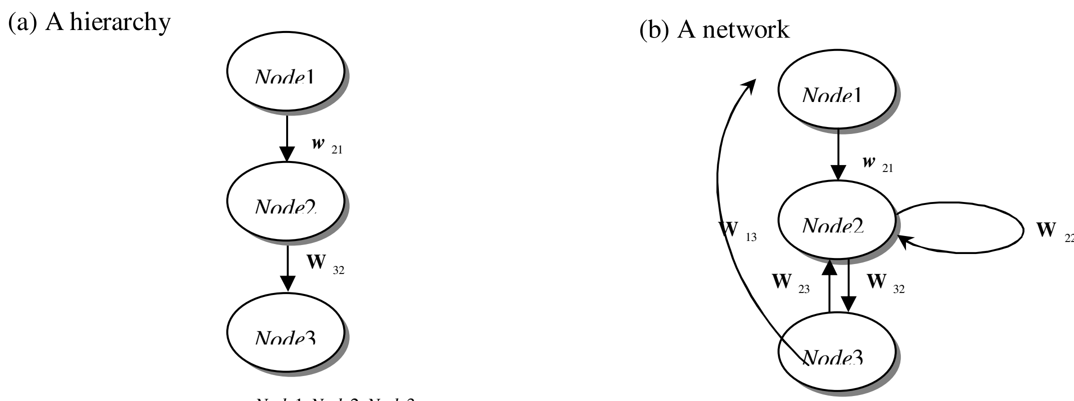
2.1. Analytic Network Process

The initial study identified the multi-criteria decision technique known as the Analytic Hierarchy Process (AHP) to be the most appropriate for solving complicated problems. Many decision problems cannot be structured hierarchically because they involve the interaction and dependence of higher-level elements on a lower-level element [6]. Also he suggested the use of AHP to solve the problem of independence on alternatives or criteria and the use of ANP to solve the problem of dependence among alternatives or criteria [7].
The ANP addresses how to determine the relative importance of a set of activities in a multi-criteria decision problem. The process utilizes pairwise comparisons of the style alternatives as well as pairwise comparisons of the multiple criteria [8]. Figure 1 is a standard form of a 'supermatrix' introduced by Saaty to deal with the interdependence characteristics among elements and components. He suggested Supermatrix for solving network structure [7]. The supermatrix is column stochastic as all its columns sum to unity [9]. This matrix means that any column of the limiting power $\lim_{k \to \infty} A^{2k+1}$ gives the outcome of the cyclic interaction of the alternatives and the criteria.

$$
\mathbf{W} = \begin{array}{cc}
 & \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \\ e_{11}\; e_{12} \cdots e_{1m_1} & e_{21}\; e_{22} \cdots e_{2m_1} & \cdots & e_{n1}\; e_{n2} \cdots e_{nm_1} \end{array} \\
\begin{array}{cc} C_1 & \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1m_1} \end{array} \\ C_2 & \begin{array}{c} e_{21} \\ e_{22} \\ \vdots \\ e_{2m_2} \end{array} \\ \vdots & \vdots \\ C_n & \begin{array}{c} e_{n1} \\ e_{n2} \\ \vdots \\ e_{nm_n} \end{array} \end{array} &
\begin{bmatrix}
\mathbf{W}_{11} & \mathbf{W}_{12} & \cdots & \mathbf{W}_{1n} \\
\mathbf{W}_{21} & \mathbf{W}_{22} & \cdots & \mathbf{W}_{2n} \\
\vdots & \vdots & \vdots & \vdots \\
\mathbf{W}_{n1} & \mathbf{W}_{n2} & \cdots & \mathbf{W}_{nn}
\end{bmatrix}
\end{array}
$$

Figure 1. Supermatrix

Figure 2 depicts the difference of structures and corresponding supermatrix between a hierarchy and a network. A node represents a component with elements inside it; a straight line/or an arc denotes the interactions between two components; and a loop indicates the inner dependence of elements within a component. When the elements of a component *Node*1 depend on another component *Node2*, we represent this relation with an arrow from component *Node*1 to *Node*2. The corresponding supermatrix of the hierarchy with three levels of clusters is also shown: where ***w***21 is a vector that represents the impact of the *Node*1 on the *Node*2; **W**32 is a matrix that represents the impact of the *Node*2 on each element of the *Node*3; and **I** is the identity matrix. It is observed that a hierarchy is a simple and special case of a network.



$$W_h = \begin{array}{c} Node\ 1 \\ Node\ 2 \\ Node\ 3 \end{array} \overset{\begin{array}{ccc} Node1 & Node2 & Node3 \end{array}}{\begin{bmatrix} 0 & 0 & 0 \\ w_{21} & 0 & 0 \\ 0 & W_{32} & I \end{bmatrix}} \qquad W_n = \begin{array}{c} Node\ 1 \\ Node\ 2 \\ Node\ 3 \end{array} \overset{\begin{array}{ccc} Node1 & Node2 & Node3 \end{array}}{\begin{bmatrix} 0 & 0 & W_{13} \\ w_{21} & W_{22} & W_{23} \\ 0 & W_{32} & I \end{bmatrix}}$$

FIGURE 2: (a) Linear hierarchy and (b) Nonlinear network

The process of solving interdependence problem is summarized as follows: In order to consider interdependence, the first step is to identify the multiple criteria of merit consideration and then draw a relationship between the criteria that show the degree of interdependence among the criteria. Next step is determining the degree of impact or influence between the criteria or alternatives. When comparing the alternatives for each criterion, the decision maker will respond to questions such as: “In comparing style 1 and style2, on the basis of performance, which style is preferred?” When there is interdependence, the same decision maker answers the following kind of question (pairwise comparisons): “Given an alternative and an attribute, which of the two alternatives influences the given alternatives more with respect to the attribute? and how much more than the other alternative?” The responses are presented numerically, scaled on the basis of Saaty's proposed 1-9 scale with reciprocals, in a style comparison matrix. The final step is to determine the overall prioritization.

2.2. Goal programming

The information obtained from the ANP is then used to formulate a zero-one goal programming (ZOGP) model as a weight. The solution to ZOGP will provide a pattern by which weights will be allocated among architecture styles [10, 11].

The ZOGP model for architecture style selection can be stated as follows:

Minimize $Z = P_K(w_j d_i^+, w_j d_i^-)$ (1)

Subject to $a_{ij}x_j + d_i^- - d_i^+ \le b_i$

for $i = 1, 2, \ldots, m$, $j = 1, 2, \ldots, n$ (2)

$$x_j + d_i^- = 1$$

for $i = m+1, m+2, \ldots m+n$, $j = 1, 2, \ldots, n$ (3)

$x_j = 0$ or 1

for $\forall j$ (4)

where m = the number of goals to be considered in the model, n = the pool of architecture styles from which the optimal set will be selected, w_j = the ANP mathematical weight on the j =1, 2,…, n architecture style, P_K = some k priority preemptive priority $(P_1 > P_2 > \cdots > P_k)$, for i =1, 2,…, m goals, d_i^+, d_i^- = the ith positive and negative deviation variables for i = 1, 2,…, m goals, x_j = a zero-one variable, where j = 1, 2,…, n possible projects to choose from and where x_j = 1, then select the jth architecture style or when x_j =0, then do not select the jth architecture style, a_{ij} = the jth parameter of the ith resources, and b_i = the ith available resource or limitation factors that must be considered in the selection decision.

The ZOGP model selects the best architectural style x_j for which the weight w_j is derived from ANP which has maximum value and minimum deviation d_j.

3. A CASE-STUDY FOR SELECTION OF SOFTWARE ARCHITECTURE STYLE

A case study to illustrate the advantages of the integrated ANP and ZOGP based on the expert opinion of an organization is taken [10, 11]. The problem consisted of prioritizing three architectures styles [1] on the basis of seven criteria deemed to be important for an organization. The criteria used are (1) Efficiency (E), (2) Scalability (S), (3) Evolvability (Ev), (4) Portability (P), (5) Reliability (R), (6) Performance (Pe) and (7) Configurability (C). It should be noted that, the traditional AHP is applied to the problem without considering interdependence property among the criteria.

However, we are of the opinion that there is an existence of interdependence relationship among these seven criteria. The attribute of criteria P influence criteria C, the attribute of criteria Ev influence criteria R, E, S, Pe, C and P, and criteria R influence criteria C, Pe, Ev, E and S and so on. In order to check network structure or relationship of criteria or alternative, we need to have group discussion because the type of network or relationship depends on the stakeholders' judgment. The relationship having interdependence among the criteria is shown in Figure 3.

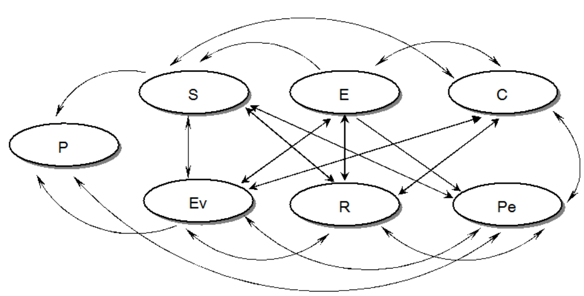


FIGURE 3: Interdependent relationship among the criteria.

In order to find the weight of the degree of influence among the criteria, we will show the procedure using the matrix manipulation based on Saaty's supermatrix. The procedure is shown as follows:

Step 1: Compare the criteria, through the question: "Which criteria should be emphasized, and how much more?". Then by pairwise comparison of all pairs with respect to the three architecture styles (LS, PF, BB) [16], we will get the following data via AHP method (E, S, Ev, P, R, Pe, C) = (0.383, 0.163, 0.098, 0.022, 0.223, 0.072, 0.040). Assume that there is no interdependence among criteria and architecture styles [15]. The weight matrix criteria W_1 = (E, S, Ev, P, R, Pe, C) = (0.383, 0.163, 0.098, 0.022, 0.223, 0.072, 0.040).

Step 2: Again assume that there is no interdependence among the three architecture styles with respect to each criterion yielding the each column normalized to one, as shown in Table 1.

Table 1. Data of three architecture styles to seven criteria (E, S, Ev, P, R, Pe, C)

W_2	*E*	*S*	*Ev*	*P*	*R*	*Pe*	*C*
LS	7	7	7	5	9	7	9
PF	7	9	5	7	7	9	7
BB	5	7	9	3	5	7	5
LS	0.368	0.304	0.333	0.333	0.429	0.304	0.429
PF	0.368	0.391	0.238	0.467	0.333	0.391	0.333
BB	0.263	0.304	0.429	0.200	0.238	0.304	0.238
	W_{21}	W_{22}	W_{23}	W_{24}	W_{25}	W_{26}	W_{27}

The second row of data in Table 1 gives the degree of relative importance for each criterion, and the data of third row sum is normalized to one, for each criteria. We defined the weight matrix of three styles for criteria E as

$$w_{21} = \begin{bmatrix} 0.368 \\ 0.368 \\ 0.263 \end{bmatrix}$$

Step 3: Next, we considered the interdependence among the criteria. When we select the architecture style, we cannot concentrate only on one criterion, but we must consider the other criteria also. Therefore, we need to examine the impact of one criterion on all other criteria by using pairwise comparisons and so on [12]. In Table 2, we obtain the seven sets of weights through expert opinion. The data of Table 2 shows seven criteria's degree of relative impact for each seven criteria. For example, the E's degree of relative impact for Ev is 0.291, the Ev's degree of relative impact for C is 0.059, and the R's degree of relative impact for Pe is 0.168.

Table 2. Data among seven criteria

W_3	E	S	Ev	P	R	Pe	C
E	0.564	0.093	0.291	0	0.093	0.256	0.022
S	0	0.422	0.085	0.118	0.268	0.053	0.156
Ev	0.055	0.047	0.402	0.263	0.025	0.090	0.059
P	0	0	0	0.564	0	0	0.270
R	0.118	0.244	0.049	0	0.398	0.168	0.037
Pe	0.263	0.169	0.146	0	0.047	0.402	0.088
C	0	0.025	0.027	0.055	0.169	0.033	0.369

We defined the interdependence weight matrix of criteria as

$$W_3 = \begin{bmatrix} 0.564 & 0.093 & 0.291 & 0 & 0.093 & 0.256 & 0.022 \\ 0 & 0.422 & 0.085 & 0.118 & 0.268 & 0.053 & 0.156 \\ 0.055 & 0.047 & 0.402 & 0.263 & 0.025 & 0.090 & 0.059 \\ 0 & 0 & 0 & 0.564 & 0 & 0 & 0.270 \\ 0.118 & 0.244 & 0.049 & 0 & 0.398 & 0.168 & 0.037 \\ 0.263 & 0.169 & 0.146 & 0 & 0.047 & 0.402 & 0.088 \\ 0 & 0.025 & 0.027 & 0.055 & 0.169 & 0.033 & 0.369 \end{bmatrix}$$

Table 3 to Table 9 shows the data interdependence among criteria's degree of relative impact for each criteria individually.

Table 3. Data among four interdependent criteria's degree of relative impact for criteria 1 (E)

W_{31}	*E*	*P*	*R*	*Pe*
E	1	7	5	3
P	1/7	1	1/3	1/5
R	1/5	3	1	1/3
Pe	1/3	5	3	1

The interdependence weight of the criteria W_{31} = (0.564, 0.055, 0.118, 0.263).

Table 4. Data among six interdependent criteria's degree of relative impact for criteria 2 (S)

W_{32}	*E*	*S*	*Ev*	*R*	*Pe*	*C*
E	1	1/5	3	1/3	1/3	5
S	5	1	7	3	3	9
Ev	1/3	1/7	1	1/5	1/5	3
R	3	1/3	5	1	3	7
Pe	3	1/3	5	1/3	1	7
C	1/5	1/9	1/3	1/7	1/7	1

The interdependence weight of the criteria W_{32} = (0.093, 0.422, 0.047, 0.244, 0.169, 0.025).

Table 5. Data among six interdependent criteria's degree of relative impact for criteria 3 (Ev)

W_{33}	*E*	*S*	*Ev*	*R*	*Pe*	*C*
E	1	5	1/3	7	3	9
S	1/5	1	1/5	3	1/3	5
Ev	3	5	1	7	3	7
R	1/7	1/3	1/7	1	1/3	3
Pe	1/3	3	1/3	3	1	5
C	1/9	1/5	1/7	1/3	1/5	1

The interdependence weight of the criteria W_{33} = (0.291, 0.085, 0.402, 0.049, 0.146, 0.027).

Table 6. Data among four interdependent criteria's degree of relative impact for criteria 4 (P)

W_{34}	*S*	*Ev*	*P*	*C*
S	1	1/3	1/5	3
Ev	3	1	1/3	5
P	5	3	1	7
C	1/3	1/5	1/7	1

The interdependence weight of the criteria W_{34} = (0.118, 0.263, 0.564, 0.055).

Table 7. Data among six interdependent criteria's degree of relative impact for criteria 5 (R)

W_{35}	*E*	*S*	*Ev*	*R*	*Pe*	*C*
E	1	1/3	5	1/5	3	1/3
S	3	1	9	1/3	7	3
Ev	1/5	1/9	1	1/9	1/3	1/7
R	5	3	9	1	5	3
Pe	1/3	1/7	3	1/5	1	1/5
C	3	1/3	7	1/3	5	1

The interdependence weight of the criteria W_{35} = (0.093, 0.268, 0.025, 0.398, 0.047, 0.169).

Table 8. Data among six interdependent criteria's degree of relative impact for criteria 6 (Pe)

W_{36}	*E*	*S*	*Ev*	*R*	*Pe*	*C*
E	1	5	3	3	1/3	7
S	1/5	1	1/3	1/5	1/5	3
Ev	1/3	3	1	1/3	1/5	3
R	1/3	5	3	1	1/3	5
Pe	3	5	5	3	1	7
C	1/7	1/3	1/3	1/5	1/7	1

The interdependence weight of the criteria W_{36} = (0.256, 0.053, 0.090, 0.168, 0.402, 0.033).

Table 9. Data among seven interdependent criteria's degree of relative impact for criteria 7 (C)

W_{37}	*E*	*S*	*Ev*	*P*	*R*	*Pe*	*C*
E	1	1/7	1/3	1/9	1/3	1/5	1/9
S	7	1	3	1/3	5	3	1/3
Ev	3	1/3	1	1/5	3	1/3	1/5
P	9	3	5	1	7	5	1/3
R	3	1/5	1/3	1/7	1	1/3	1/7
Pe	5	1/3	3	1/5	3	1	1/5
C	9	3	5	3	7	5	1

The interdependence weight of the criteria W_{37} = (0.022, 0.156, 0.059, 0.270, 0.037, 0.088, 0.369).

Step 4: Next, we dealt with the interdependence among the architecture styles with respect to each criterion [14]. To satisfy the criteria, “which style contributes more and how much more?” The stake holder response for each criterion is tabulated as shown from Table 10 to Table 16.

Table 10. Data among three architecture styles for criteria 1 (E)

W_{41}	*LS*	*PF*	*BB*
LS	1	1/3	5
PF	3	1	5
BB	1/5	1/5	1
LS	0.238	0.217	0.455
PF	0.714	0.652	0.455
BB	0.048	0.130	0.091

In Table 10, the data of second row is obtained from stake holders (Saaty's nine scale), which shows the degree of interdependence among the alternatives with respect to each style and the column sum is normalized to one. The project interdependence weight matrix for criteria E is W_{41}.

Table 11. Data among three architecture styles for criteria 2 (S)

W_{42}	*LS*	*PF*	*BB*
LS	1	1/5	1/3
PF	5	1	3
BB	3	1/3	1
LS	0.111	0.130	0.077
PF	0.556	0.652	0.692
BB	0.333	0.217	0.231

Table 12. Data among three architecture styles for criteria 3 (Ev)

W_{43}	*LS*	*PF*	*BB*
LS	1	7	3
PF	1/7	1	1/5
BB	1/3	5	1
LS	0.678	0.538	0.714
PF	0.097	0.077	0.048
BB	0.226	0.385	0.238

Table 13. Data among three architecture styles for criteria 4 (P)

W_{44}	*LS*	*PF*	*BB*
LS	1	1/3	5
PF	3	1	5
BB	1/5	1/5	1
LS	0.238	0.217	0.455
PF	0.714	0.652	0.455
BB	0.048	0.130	0.091

Table 14. Data among three architecture styles for criteria 5 (R)

W_{45}	*LS*	*PF*	*BB*
LS	1	3	5
PF	1/3	1	3
BB	1/5	1/3	1
LS	0.652	0.692	0.556
PF	0.217	0.231	0.333
BB	0.130	0.077	0.111

Table 15. Data among three architecture styles for criteria 6 (Pe)

W_{46}	*LS*	*PF*	*BB*
LS	1	1/7	1/7
PF	7	1	3
BB	7	1/3	1
LS	0.067	0.097	0.035
PF	0.467	0.678	0.724
BB	0.467	0.226	0.241

Table 16. Data among three architecture styles for criteria 7 (C)

W_{47}	*LS*	*PF*	*BB*
LS	1	3	5
PF	1/3	1	5
BB	1/5	1/5	1
LS	0.652	0.714	0.455
PF	0.217	0.238	0.455
BB	0.130	0.048	0.091

Step 5: The interdependence priorities of the criteria by synthesizing the results from Step 1 to Step 3 as:

$$W_c = W_3 \times W_1 = \begin{bmatrix} 0.564 & 0.093 & 0.291 & 0 & 0.093 & 0.256 & 0.022 \\ 0 & 0.422 & 0.085 & 0.118 & 0.268 & 0.053 & 0.156 \\ 0.055 & 0.047 & 0.402 & 0.263 & 0.025 & 0.090 & 0.059 \\ 0 & 0 & 0 & 0.564 & 0 & 0 & 0.270 \\ 0.118 & 0.244 & 0.049 & 0 & 0.398 & 0.168 & 0.037 \\ 0.263 & 0.169 & 0.146 & 0 & 0.047 & 0.402 & 0.088 \\ 0 & 0.025 & 0.027 & 0.055 & 0.169 & 0.033 & 0.369 \end{bmatrix} \times \begin{bmatrix} 0.383 \\ 0.163 \\ 0.098 \\ 0.022 \\ 0.223 \\ 0.072 \\ 0.040 \end{bmatrix} = \begin{bmatrix} 0.300 \\ 0.150 \\ 0.088 \\ 0.023 \\ 0.192 \\ 0.186 \\ 0.063 \end{bmatrix}$$

W_c = (E, S, Ev, P, R, Pe, C) = (0.300, 0.150, 0.088, 0.023, 0.192, 0.186, 0.063).

Step 6: The priorities of the architecture styles W_p with respect to each of the seven criteria are given by synthesizing the results from Step 2 to Step 4 as follows:

$$W_{P1} = W_{41} \times W_{21} = \begin{bmatrix} 0.238 & 0.217 & 0.455 \\ 0.714 & 0.652 & 0.455 \\ 0.048 & 0.130 & 0.091 \end{bmatrix} \times \begin{bmatrix} 0.368 \\ 0.368 \\ 0.263 \end{bmatrix} = \begin{bmatrix} 0.287 \\ 0.622 \\ 0.089 \end{bmatrix}$$

$$W_{P2} = W_{42} \times W_{22} = \begin{bmatrix} 0.111 & 0.130 & 0.077 \\ 0.556 & 0.652 & 0.692 \\ 0.333 & 0.217 & 0.231 \end{bmatrix} \times \begin{bmatrix} 0.304 \\ 0.391 \\ 0.304 \end{bmatrix} = \begin{bmatrix} 0.108 \\ 0.634 \\ 0.256 \end{bmatrix}$$

$$W_{P3} = W_{43} \times W_{23} = \begin{bmatrix} 0.678 & 0.538 & 0.714 \\ 0.097 & 0.077 & 0.048 \\ 0.226 & 0.385 & 0.238 \end{bmatrix} \times \begin{bmatrix} 0.333 \\ 0.238 \\ 0.429 \end{bmatrix} = \begin{bmatrix} 0.660 \\ 0.071 \\ 0.269 \end{bmatrix}$$

$$W_{P4} = W_{44} \times W_{24} = \begin{bmatrix} 0.238 & 0.217 & 0.455 \\ 0.714 & 0.652 & 0.455 \\ 0.048 & 0.130 & 0.091 \end{bmatrix} \times \begin{bmatrix} 0.333 \\ 0.467 \\ 0.200 \end{bmatrix} = \begin{bmatrix} 0.272 \\ 0.633 \\ 0.095 \end{bmatrix}$$

$$W_{P5} = W_{45} \times W_{25} = \begin{bmatrix} 0.652 & 0.692 & 0.556 \\ 0.217 & 0.231 & 0.333 \\ 0.130 & 0.077 & 0.111 \end{bmatrix} \times \begin{bmatrix} 0.429 \\ 0.333 \\ 0.238 \end{bmatrix} = \begin{bmatrix} 0.642 \\ 0.249 \\ 0.108 \end{bmatrix}$$

$$W_{P6} = W_{46} \times W_{26} = \begin{bmatrix} 0.067 & 0.097 & 0.035 \\ 0.467 & 0.678 & 0.724 \\ 0.467 & 0.226 & 0.241 \end{bmatrix} \times \begin{bmatrix} 0.304 \\ 0.391 \\ 0.304 \end{bmatrix} = \begin{bmatrix} 0.069 \\ 0.627 \\ 0.304 \end{bmatrix}$$

$$W_{P7} = W_{47} \times W_{27} = \begin{bmatrix} 0.652 & 0.714 & 0.455 \\ 0.217 & 0.238 & 0.445 \\ 0.130 & 0.048 & 0.091 \end{bmatrix} \times \begin{bmatrix} 0.429 \\ 0.333 \\ 0.238 \end{bmatrix} = \begin{bmatrix} 0.626 \\ 0.281 \\ 0.093 \end{bmatrix}$$

The matrix W_p by grouping all the seven columns:

$$W_p = (W_{p1}, W_{p2}, W_{p3}, W_{p4}, W_{p5}, W_{p6}, W_{p7}) .$$

$$W_p = \begin{bmatrix} 0.287 & 0.108 & 0.660 & 0.272 & 0.642 & 0.069 & 0.626 \\ 0.622 & 0.634 & 0.071 & 0.633 & 0.249 & 0.627 & 0.281 \\ 0.089 & 0.256 & 0.269 & 0.095 & 0.108 & 0.304 & 0.093 \end{bmatrix}$$

Step 7: Finally, the overall priorities for the architecture styles W_A are calculated by multiplying W_p by W_c.

$$W_A = W_p \times W_c = \begin{bmatrix} 0.287 & 0.108 & 0.660 & 0.272 & 0.642 & 0.069 & 0.626 \\ 0.622 & 0.634 & 0.071 & 0.633 & 0.249 & 0.627 & 0.281 \\ 0.089 & 0.256 & 0.269 & 0.095 & 0.108 & 0.304 & 0.093 \end{bmatrix} \times \begin{bmatrix} 0.300 \\ 0.150 \\ 0.088 \\ 0.023 \\ 0.192 \\ 0.186 \\ 0.063 \end{bmatrix} = \begin{bmatrix} 0.342 \\ 0.484 \\ 0.174 \end{bmatrix}$$

The final results in the ANP Phase are (LS, PF, BB) = (0.342, 0.484, 0.174). These weights are used as priorities in goal programming formulation. That is (LS, PF, BB) = (w_1, w_2, w_3) = (0.342, 0.484, 0.174), w_j are the values of the three architecture styles.

The weight vector obtained from the above ANP model is used to optimize the solution further by zero-one goal programming as follows: There exist several obligatory and flexible goals that must be considered in the selection from the available pool of three architecture styles. There are three obligatory goals: (1) a maximum time of 24 working days is required to select the best architecture style, (2) a maximum duration of 35 months is required to complete the software project and (3) a maximum budget of $ 30,000 is allocated to develop the project.

In addition to the obligatory goals of selecting the best architecture style, there are two other flexible goals, stated in order of importance: (1) allocation of budget is set at $30,000 and (2) allocation of miscellaneous fees is set at $4200, deviation from this allocation is not allowed. In Table 17, the cost and resource usage information for each of the three styles is presented.

Table 17.Cost and resources usage information

	Project resource usage (a_{ij})			
	x_1	x_2	x_3	b_i
Planning and design days	10	24	18	24 days
Construction months	32	34	30	35 months
Budgeted cost (00)	$150	$300	$280	$300
Misc cost (00)	$18	$24	$15	$42

Based on the weight vector computed using ANP, we can formulate the goal constraints in Table 18. This ZOGP model is solved using LINDO Ver 6.1. The results are summarized as follows:

Table 18. ZOGP model formulation

ZOGP model formulation	Goals
Minimize Z =	
$pl_1(d_1^+ + d_2^+ + d_3^+)$	Satisfy all obligatory goals
$pl_2(0.342d_5^- + 0.484d_6^- + 0.174d_7^-)$	Select highest ANP weighted architecture styles
$pl_3(d_8^- + d_8^+)$	Use $30,000 for all architecture styles selected
$pl_4(d_4^- + d_4^+)$	Use $4200for all architecture styles selected
Subject to	
$10X_1 + 24X_2 + 18X_3 + d_1^- - d_1^+ = 24$	Avoid over utilizing max. planning and design days
$32X_1 + 34X_2 + 30X_3 + d_2^- - d_2^+ = 35$	Avoid over utilizing max. construction months
$150X_1 + 300X_2 + 280X_3 + d_3^- - d_3^+ = 300$	Avoid over utilizing max. budgeted dollars
$X_1 + d_5^- = 1$	Select Layered Style (LS)
$X_2 + d_6^- = 1$	Select Pipe & Filter (PF)
$X_3 + d_7^- = 1$	Select Blackboard Style (BB)
$18X_1 + 24X_2 + 15X_3 + d_4^- - d_4^+ = 42$	Avoid over or under utilizing misc cost
$150X_1 + 300X_2 + 280X_3 + d_8^- - d_8^+ = 300$	Avoid over or under utilizing expected budget
$Xj = 0 \text{ or } \forall \text{j} = 1,2,3$	

$$x_1 = 0 \; x_2 = 1, \quad x_3 = 0$$

$$d_1^- = 0,\; d_1^+ = 0,\; d_2^- = 1,\; d_2^+ = 0,\; d_3^- = 0,\; d_3^+ = 0,\; d_4^- = 18,\; d_4^+ = 0, d_5^- = 1,\; d_6^- = 0,\; d_7^- = 1,\; d_8^- = 0,\; d_8^+ = 0.$$

Architecture Style 2 is chosen as it is consumes the total budgeted cost of $30,000 and use 14 days of time for decision. Also, the selected style will save one month construction time (total time is 35 months) as $d_2^- = 1$.

4. DISCUSSION

Several methods have been proposed to help organizations for solving problems related to interdependence among criteria. The existing methodologies range from single-criteria cost/benefit analysis to multiple criteria scoring models, ranking methods and AHP. However they did not consider interdependence property. But they have addressed consider independence property among alternatives or criteria. Also Ranking, Scoring, AHP methods are not applicable to problems having resource feasibility, optimization requirements. In spite of this limitation, the ranking and scoring method and AHP method have been used with real problems because they are simple and easy to understand. In order to solve optimization problems, researchers have used mathematical methods such as goal programming, dynamic programming, etc. [25, 30]. Many real-world problems are related to interdependence among alternatives and/or criteria (multiple criteria) and these problems are need to apply resource feasibility, optimization and so on. Table 15 shows the list of methods for various problem characteristics.

Table 19. List of methods for various problem characteristics

Method	Multiple Criteria	Resource Feasibility	Interdependence	Optimization required
Ranking [16]	Yes	No	No	No
Scoring [17]	Yes	No	No	No
AHP [18]	Yes	No	No	No
Goal Programming [20]	Yes	Yes	No	Yes
Dynamic Programming[19]	No	Yes	Yes	Yes
AHP-GP [13]	Yes	Yes	No	Yes
ANP-GP (This paper)	Yes	Yes	Yes	Yes

According to experts, in selecting a style there is no single decision involved but in the decisions consideration may be better or worse but still significant. For example, a style with a low weight might be selected over a style with a high weight if developers are more familiar with the style which has a lower score. The weight vector obtained using AHP for the above example is (0.371, 0.474, 0.154) [18]. AHP and ANP approaches have no much difference in solving the example given, but there are some differences with respect to decision variables. It is evident that resource feasibility, optimization requirements cannot be fulfilled with AHP method. But it is simple and easy to understand and so the method more frequently used [21, 22, 24]. Table 18 shows the comparison among the AHP and ANP approaches.

Table 20. Comparison of AHP and ANP approaches

Method	Resources Used			
	Planning and design days	Construction months	Budgeted cost (00)	Misc cost (00)
AHP	24	35	300	42
ANP	24	34*	300	18**

* We will save one month construction time (total time is 35 months) as $d_2^- = 1$

** We will use only Misc cost $1800 (<$4200) more than the initial Budgeted cost as $d_4^- = 18$.

The proposed model, ANP is to demonstrate the procedure of finding weight that considers interdependence among criteria or alternatives [23] which has highest weight wj. The ZOGP model selects the best architectural style for which the weight wj is derived from ANP which has maximum value and minimum deviation dj. Finally, architecture Style 2 is chosen which is optimum as it is consumes the total budget cost of $30,000 and use exactly 24 days of time for decision. The selected style will save one month construction time (total time is 35 months) as $d_2^- = 1$.

In literature, all techniques mainly focused on problems related to independence among criteria. Also recent survey indicates that the use of mathematical models is becoming prevalent for solving this kind of problems [25, 26]. This paper shows an example solving interdependence problem using the integrated approach ANP and ZOGP by using group expert interview. Using this approach we conclude that we can select suitable architecture style having multiple criteria, interdependence and resource feasibility.

5. CONCLUSIONS

There are mainly two inadequacies in the traditional approaches for selection of architecture styles. First, they focused on relative importance among criteria to minimize the cost. However, the interests of stakeholders and experts opinion were neglected. Second they considered only quantitative factors.

To overcome the above drawbacks, this paper presented a method for a selecting the best architecture style. In this method, ANP is used to determine the interdependency among the alternatives and criteria. The priority vector obtained from **Analytic Network Process** is used to formulate **Zero-One Goal Programming** model. For some scenarios, it might be obvious if all architecture element types and all architecture properties are taken into consideration. So in this paper three architecture styles and seven criteria are used in the case study. The major advantage of this integrated approach is both the interests of stakeholder and expert opinion are focused. Qualitative factors are also considered. Therefore, it is believed that this approach is much more practical and the results obtained in this approach are better than earlier approaches like Fuzzy Logic, AHP, ANP for selecting the best architecture style.

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