QUANTIFICATION OF RISKS: COMPARISON BASED ON AHP/ ANP –SIMULATION TEQNIQUES

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ABSTRCT

Cost saving and time performance are usually essential to all parties who are involved in a construction project, i.e. owner, contractor, subcontractor, etc. The main causes of disputes in construction projects involve delay and failure to complete the work in the specified cost and period. An effective risk management process encourages the construction companies to identify and quantify risks. Construction companies that manage risk effectively and efficiently realizes financial stability, greater productivity and higher performance rates. This work aims at comparing two decision-supporting systems for quantifying the risk especially for construction projects in Egypt.

Keywords: Risk assessment; cost overrun; probability; AHP; ANP

INTRODUCTION

In this paper, a comparative study was carried out between using of analytical hierarchy process AHP and using of analytical network process, ANP. The priorities for sub-criterions and the attributes were analyzed using both techniques; the cost overrun was estimated depending on the probabilities and the impacts either for sub-criterions or for the attributes, *El.Nawawy, 2015.*
The AHP is a specific mechanism which takes the relation between the attributes with respect to one factor which mentioned previously as the cost overrun, this process doesn't take the mutual relation between the sub-criterions/attributes themselves, see Fig1.

Therefore, the analysis was repeated to reflect the internal relations either between the sub-criterions or between the attributes themselves. The attributes are dependent and the entire network was built in order to reflect these relations.

Fig.2 shows the model built through ANP, the initial target is calculating the impact weights for the sub-criterions and the attributes, these weights were used for estimating the cost overrun by applying the attributes likelihood. The model consists of four criteria; site conditions, resources, project parties and project features. Each criterion consists of some sub-criterions; first group includes environmental, sub-surface and site location. Second group includes labor, equipment and material. Third group includes owner, engineering, contractor and project management. The fourth group includes financial, political and schedule. The model consists of 13 sub-criterions in addition to 59 attributes, *El.Nawawy, 2015.*

LIMITATION OF ANALYTICAL HIERARCHY

In the AHP, the problem was structured as a hierarchy, and then a process of prioritization was required. Prioritization entails seeking judgments in the form of experts' response to questions about the dominance of one element of the hierarchy over another when compared with respect to a specific criterion. A judgment was developed through numerical comparisons between two elements of the model with respect to a common criterion. In the AHP, a nine-point evaluation scale for relative pair wise comparison was used. The judgments can be represented in a square matrix in which the set of elements was compared with itself. Where, each judgment reflects the dominance of an element in the criterion list relative to another element in the same list. The pair wise comparisons, which were carried out, resulted in conditional importance weights. Hence, the derived value for each risk factor is dependent on other compared factors' values.

With different comparison, a risk factor can obtain different importance weight*, Saaty and Niemira, 2006; Dikmen and Birgonul, 2006.*

By using the AHP, it is unnecessary to define a subjective scale and utility curves that reflect preferences of decision maker. However, ratio scales, proportionality, and normalized ratio scales are central requirements for comparison needed to determine and synthesize priorities.

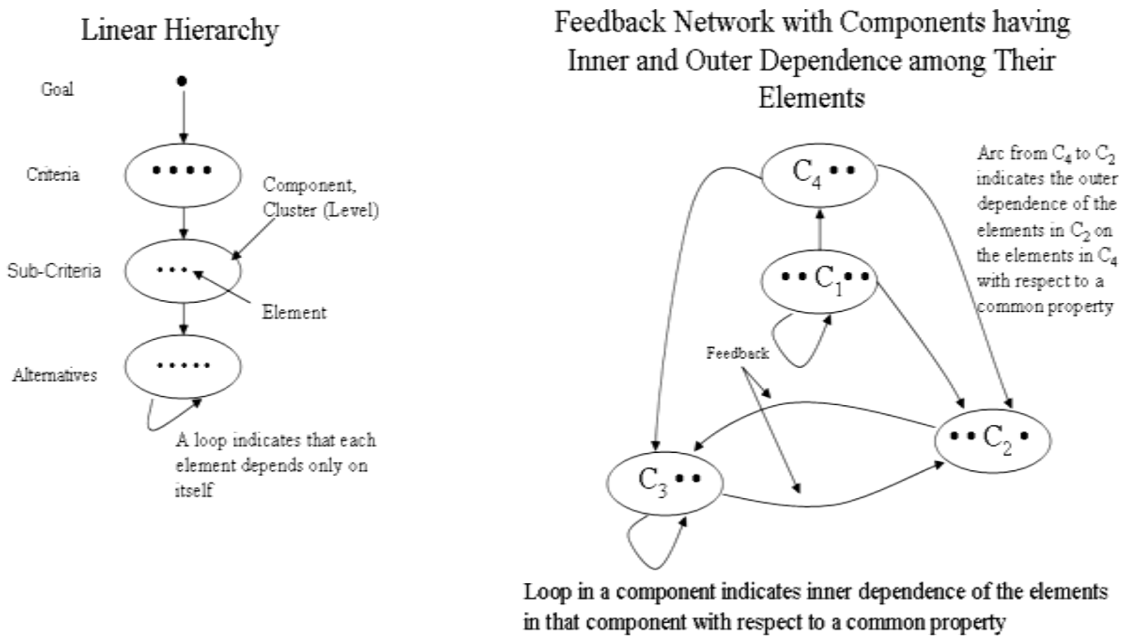

Fig. 1: How a Hierarchy Compares to a Network (Saaty, 2005)

Development of AHP Model using SUPERDECISIONS Software

The first step in building the AHP model is to decide on the logical groupings of the nodes and clusters that structure the problem. Fig. 2, represents the basis for the AHP model, thus, the general control criterion according to which the clusters are compared is the "Construction project risks priorities". The clusters that build the model are the thirteen sub-criterions mentioned in item 1.0 and Fig. 2.

Fig. 3 shows a snapshot of the AHP Model which the SUPERDECISIONS software developed. The purpose of this model is to estimate the priorities of risk factors associated with construction projects. The model consists of a single network that has all clusters and their nodes in one window. Thus, there are no sub-networks.

Therefore, all the comparison questions were asked from the perspective of what is more important with respect to the goal “Construction project risks priorities”. Taking into consideration that each node will illustrate one attribute, therefore there will be 60 nodes (59 attributes in addition to the goal “Construction project risks priorities” node).

There will be 14 clusters (13 for sub-criterions and one for the goal “Construction project risks priorities”), when the user choose the comparison matrices between attributes weight with respect to Construction project risks priorities node; it will describe the same weights mentioned in the previous AHP model discussed in another paper and developed by MS-Excel spreadsheets.

In addition, the comparison matrices between clusters with respect to Construction project risks priorities cluster will describe the same weights mentioned in the previous AHP model discussed in another paper and developed by MS-Excel spreadsheets.

That means the AHP analysis is a specific mechanism that takes the weight of attributes/sub-criterion with respect to the goal, on the other hand, the ANP is a generic mechanism, which takes into consideration the weight of attributes/sub-criterions with respect of each attribute and each sub- criterions, and this reflects the dependent nature between factors.

Development of ANP Model using SUPERDECISIONS Software

The ANP is implemented in the software SUPERDECISIONS. The ANP is a compound of two essential parts. The first consists of a control hierarchy or network of criteria and sub-criteria that control the interactions in the considered system. The second component of the ANP is a network of influences among the elements and clusters. The network is dependent on the criterion, as for each criterion the network of influence is different, and a super matrix of limiting influence is computed for each control criterion.
Then, each of these super matrices was weighted by the priority of its control criterion and the results are synthesized through addition of all the control criteria, *Saaty, 2003*.

Goal	Construction Project Risks Priorities												
Criteria	A) Site conditions			B) Resources			C) Project parties				D) Project features		
Sub-criterion	1.Environmental	2.Sub-surface	3.Site location	4.Labor	5.Equipment	6.Material	7.Owner	8.Engineering	9.Contractor	10.Project management	11.Financial	12.Political	13.Schedule
Attributes/Risk factors	1.1.Earthquake	2.1.Unexpected Surface conditions	3.1.Construction area (rural/urban)	4.1.Labor skills level	5.1.Equipment quality	6.1.Material delivery	7.1.Owner type	8.1.Team experience	9.1.Contractor pre-qualified	10.1 Management experience	11.1.Type of Funds	12.1 Bribery and Corruption	13.1 Fast track schedule
	1.2.Unpredicted Weather conditions	2.2.Archeological survey done	3.2.Access conditions	4.2.Labor availability	5.2.Equipment breakdown	6.2.Material storage	7.2.Management strategy	8.2.Complexity of design	9.2.New technology	10.2.Scope definition	11.2.Fluctuation in prices	12.2 Wars and revolutions	13.2 Project duration
	1.3.Pollution	2.3.Geo-technical investigation	3.3.Delay in permits and licenses	4.3.Drop in productivity	5.3.Equipment transportation	6.3.Material theft & damage	7.3.Organization structure	8.3.Ad-hoc consultants	9.3.Rework	10.3.Quality control process	11.3.Invoices delay	12.3 Changes in laws and regulations	13.3 Resource oriented schedule
			3.4.Security requirements	4.4.Labor accidents		6.4.Non-conforming material	7.4.Work/labour permits	8.4.Design changes	9.4.Nominated sub-contractors	10.4.Type of contract	11.4.Change in currency rate	12.4 Puplic objections	
			3.5.Safety regulation	4.5.Human resource planning		6.5.Material monopoly	7.5.Level of expertise		9.5.Staff turnover	10.5.Availability of variations	11.5.Interest rate &Tax rate	12.5 Stability of government	
				4.6.Wage rates		6.6.Nominated vendors	7.6.Owner quality assurance						

Fig. 2: Proposed Analytical network process - Model

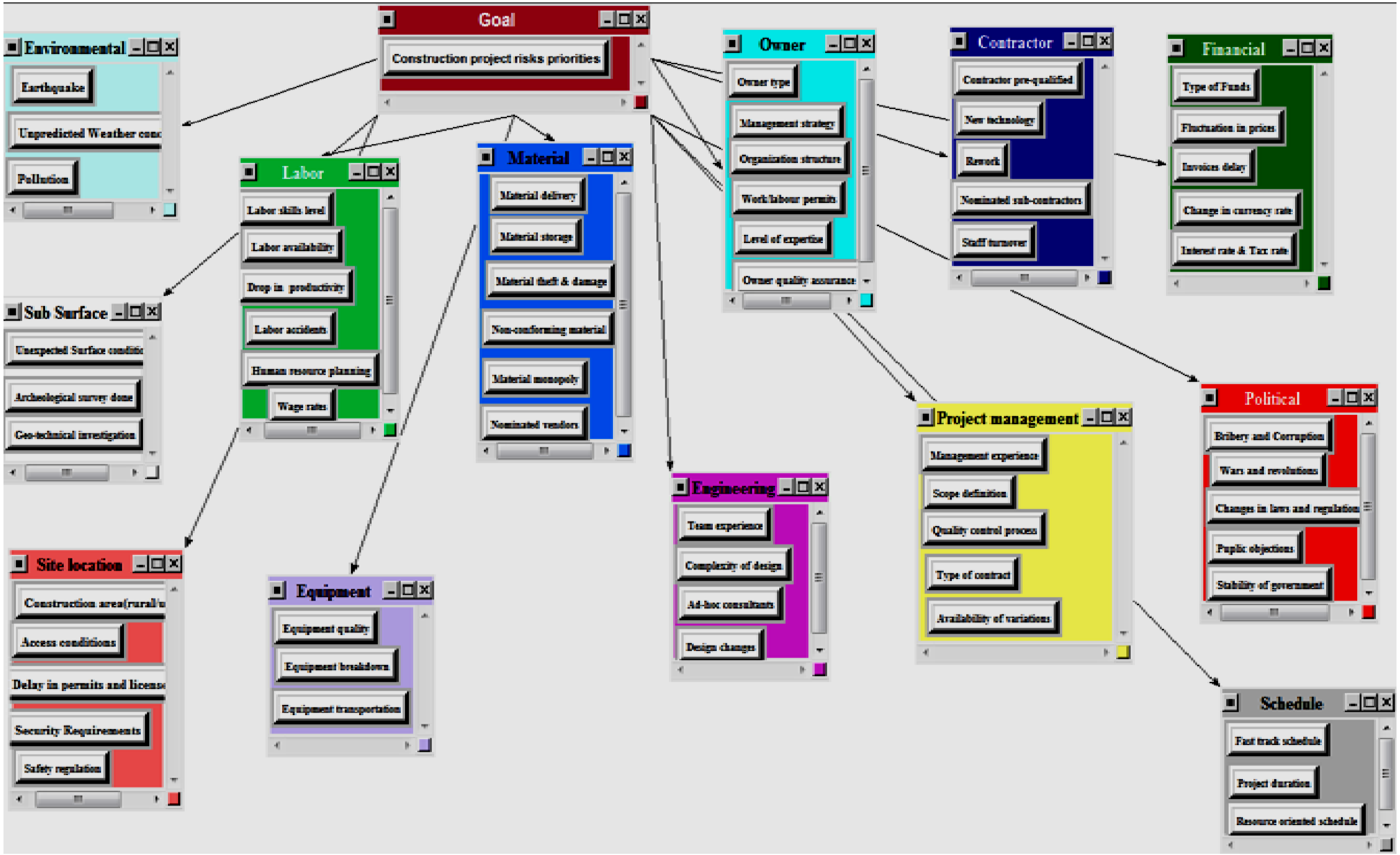

Fig. 3: Snapshot of the proposed AHP model

Demonstration of Building the Model

In Fig.5, the loops indicate inner dependence among the elements in the same cluster. Pair wise comparisons for the nodes in each cluster that belong to a parent node should be conducted for all the parent nodes in the model.

The comparison was carried out by selecting the Assess/Compare command, then selecting cluster and the node to serve as the parent node.
To build the dependent groups which have mutual effects, the node should be selected then right click to choose “Node connexions from” and select the attributes that affect on the selected node as illustrated in figure 4 below.

To start comparisons with respect to a selected node, first the Node Comparisons command from the drop-down menu should be selected. Then the cluster is selected, which has the nodes compared with respect to the parent node. This process will introduce the comparisons screen in the questionnaire mode as shown in Fig. 6.

The user of the SUPERDECISIONS software can select from several ways to do comparisons, the available ways are: graphic, verbal, matrix, and questionnaire. To switch to the matrix mode from the questionnaire mode one should click on the matrix tab in the comparison window. The matrix mode for the previous comparison questionnaire is shown in Fig. 7.

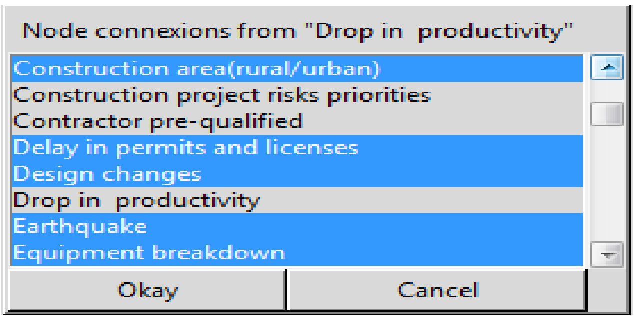

Fig.4: Development of nodes mutual connections

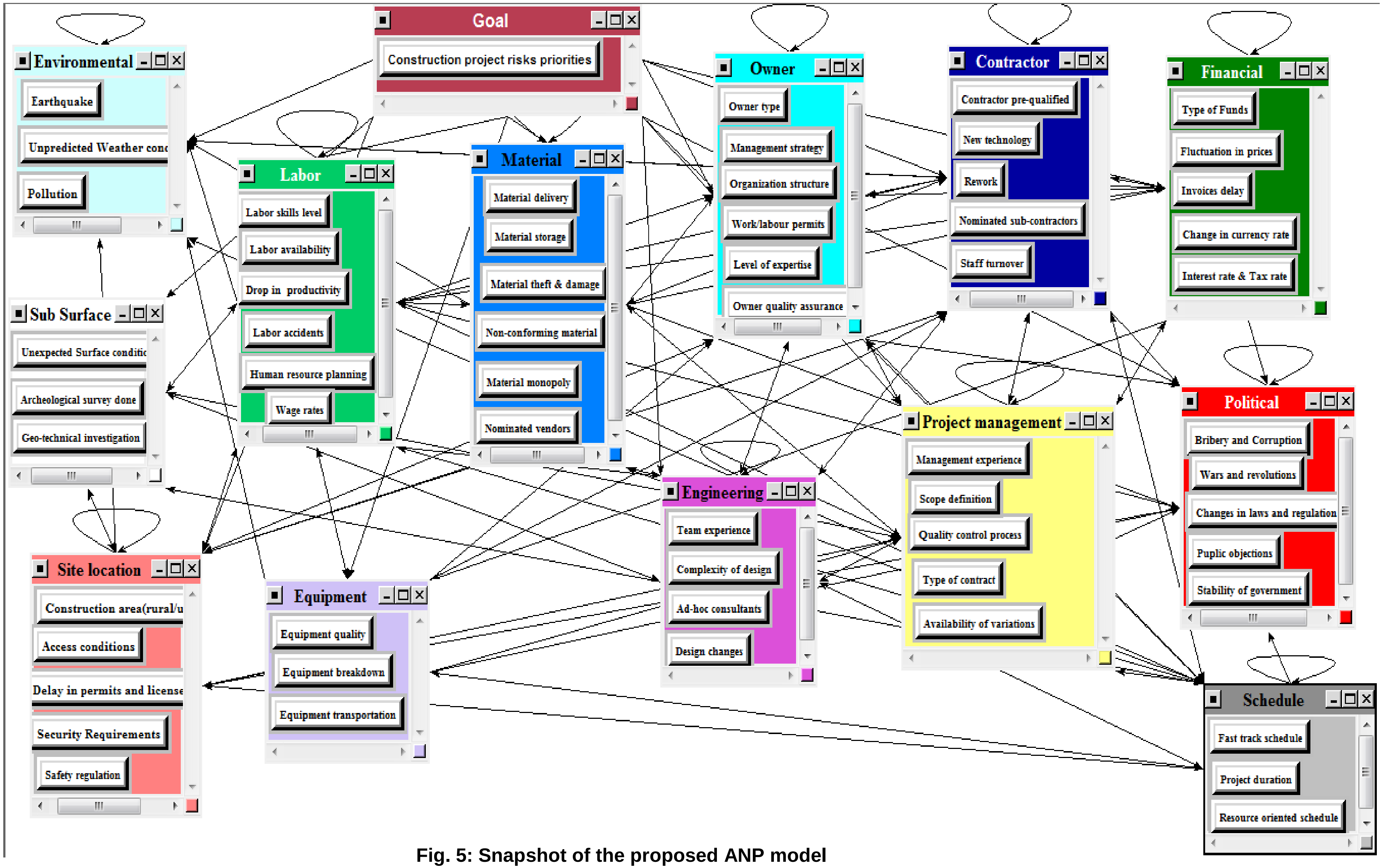

Fig. 5: Snapshot of the proposed ANP model

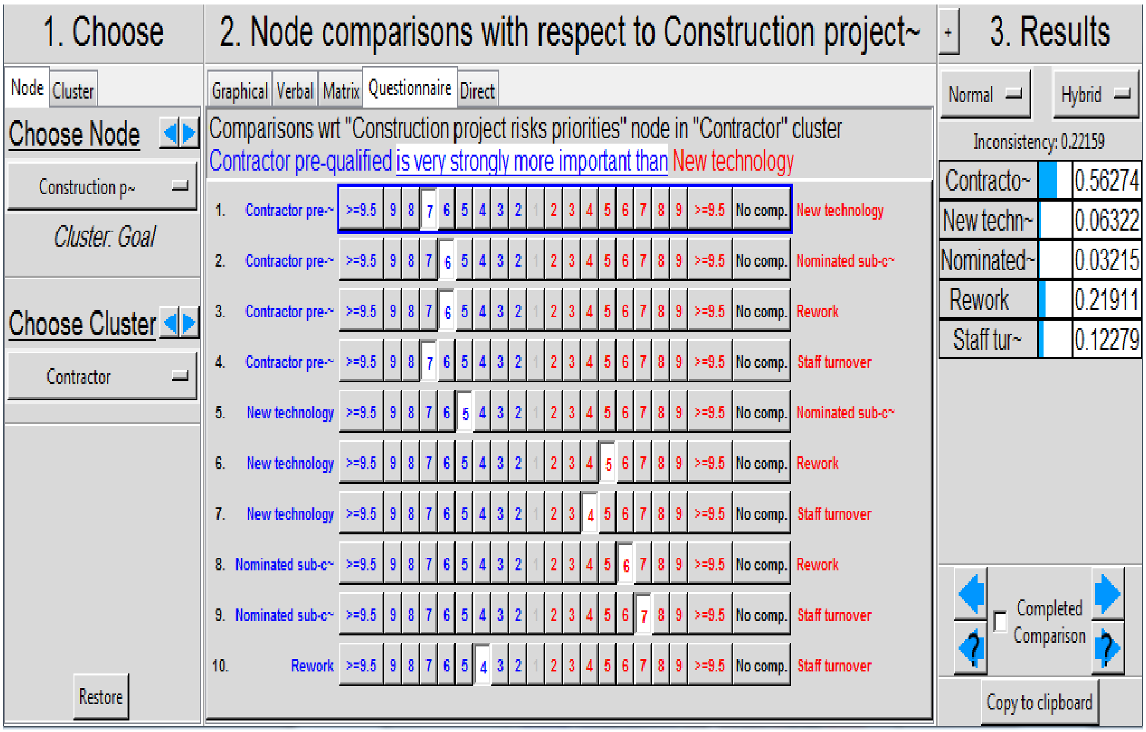

Fig. 6: The Questionnaire Mode for Comparisons

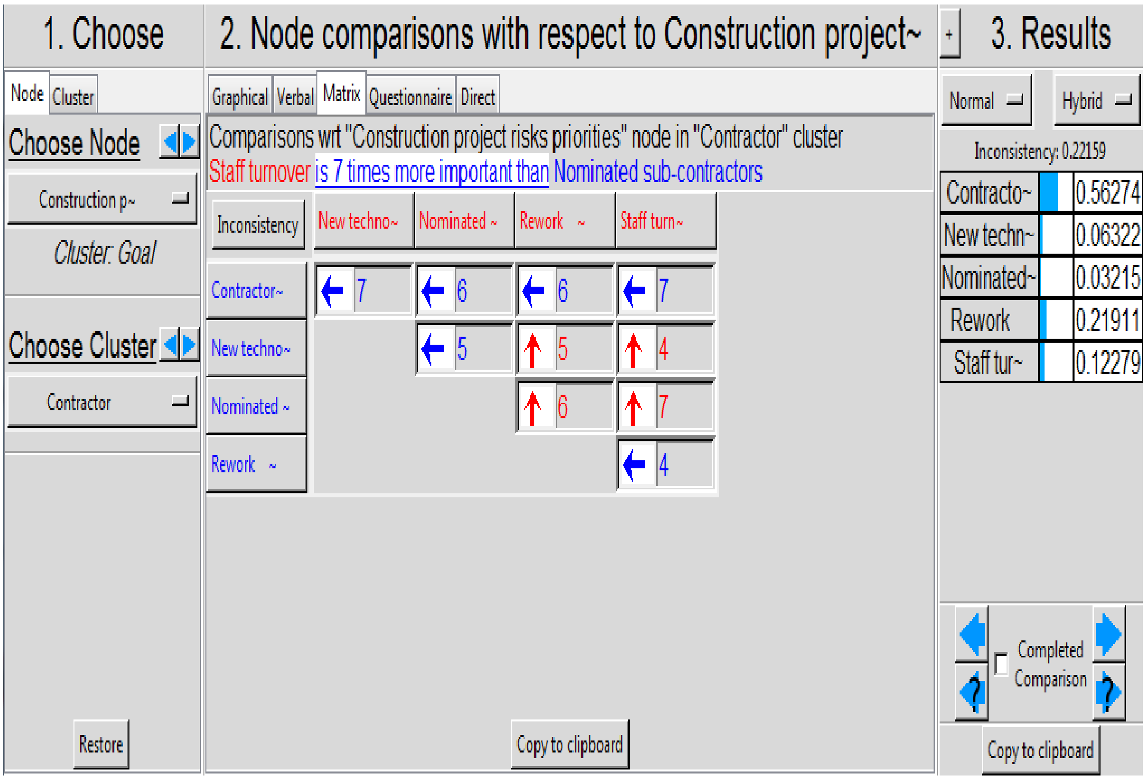

Fig .7: The Matrix Mode for Comparisons

A judgment was entered in each cell. A cell contains the comparison for the pair listed at the top and at the side. The arrows in the matrix mode point toward the preferred node of the pair. Hence, the top node is preferred when the arrow is red and directed to the top, while the side node is preferred when the arrow is blue and directed to the left. After each comparison matrix is filled, local priorities associated with the assigned judgments can be calculated, to compute these local priorities, one should select the Computations, Show New Priorities command. Thus, the priorities of the nodes in the contractor cluster with respect to the goal node will have the form as shown Figure 8. Consistency for each comparison matrix is directly listed with in the local priorities screen, the software also assists in improving the consistency.

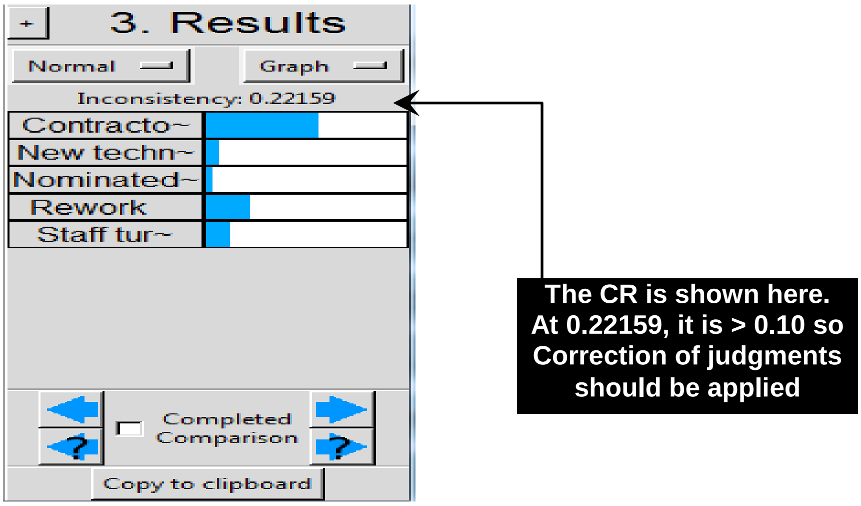

Fig.8: Consistency of comparison matrix

To improve the matrix consistency; the software can correct the judgments scale without changing in the local priorities, figure 9. illustrates the ability of matrix best fitting by pressing invert box then remove the right sign.

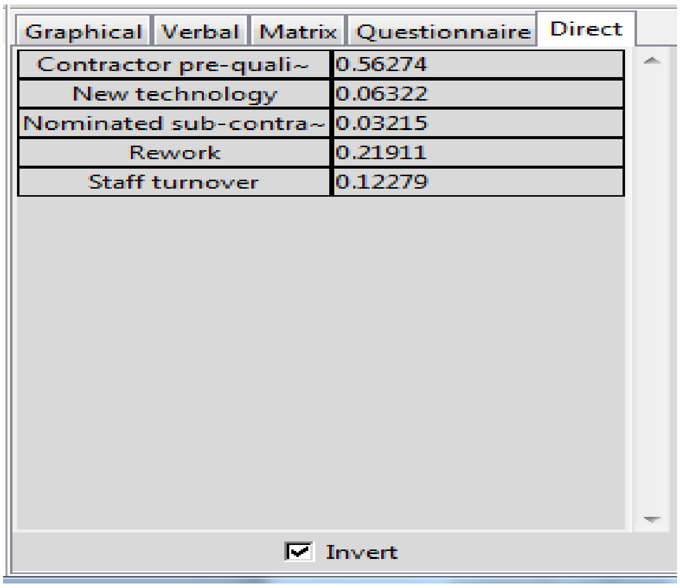

Fig. 9: Best fitting of matrix consistency

Design of Questionnaire

While filling in the comparison matrices experts' judgments were called for, thus discussion sessions were held with five experts in the area of international construction. The comparison matrices resulted from constructing the model were prepared in tabulated forms and grouped into several sets according to the governing parent nodes. A questionnaire was set from the prepared matrices and a brief description of the problem was given at the outset to focus attention on the desired objective of the research.

The experts were also asked to check the proposed relationships between the elements by giving their comments on the prepared questionnaire; the model was intended to be modified accordingly. Then, several discussion sessions were conducted together with the five experts in the area of international construction. The average total experience of the experts was 20 years in international construction. Due to the great amount of concentration and focused discussion required, it was agreed on to limit each session to a maximum of two hours to maintain efficiency and avoid inconsistency. Four discussion sessions were conducted. The total number of matrices, which were filled by the experts, was **218** matrices for node comparisons and **13** for cluster comparisons. This is after several modifications, which have, took place to the model because of the experts' suggestions. All the comparison matrices have been best fitted to reach the optimum consistency, CR have been within ranges and less than the maximum consistency.

The Super matrix

While using the software there are various computations involved with the super matrix. To show the different super matrices, the Computations command should be selected. There are three super matrices associated with each network: the un-weighted super matrix, the weighted super matrix, and the limit super matrix. The un-weighted super matrix contains the local priorities derived from the pair wise comparisons throughout the network. Hence, the results of all the pair wise comparison are entered in the un-weighted super matrix. Figure 10 shows part of the un-weighted super matrix of the goal. (Saaty, 2003) has defined a component in a super matrix, it is the block defined by a cluster name at the left and a cluster name at the top of the super matrix.

Cluster Node Labels		Contractor					Engineering		
		Contractor pre-qualified	New technology	Nominated sub-contractors	Rework	Staff turnover	Ad-hoc consultants	Complexity of design	Design changes
Contractor	Contractor pre-qualified	0.000000	0.000000	0.125000	0.250000	0.111111	0.000000	0.000000	0.000000
	New technology	0.000000	0.000000	0.875000	0.750000	0.000000	0.000000	0.000000	0.000000
	Nominated sub-contractors	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	Rework	0.000000	0.000000	0.000000	0.000000	0.888889	0.000000	0.000000	0.000000
	Staff turnover	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Engineering	Ad-hoc consultants	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.059887
	Complexity of design	0.250000	0.000000	0.833333	0.111111	0.000000	0.800000	0.000000	0.690974
	Design changes	0.750000	0.000000	0.000000	0.888889	0.000000	0.000000	0.000000	0.000000

Done

Fig. 10: Part of the Un-weighted Super matrix for the goal

The weighted super matrix derived by multiplying all the elements in a component of the un-weighted super matrix by the corresponding cluster weight. Segment of the weighted super matrix for the goal is shown in Figure 11.

Super Decisions Main Window: ANP Rev6 overall network without best fitting.sdmod: formulaic: Weighted Super Matrix

Cluster Node Labels		Contractor					Engineering		
		Contractor pre-qualified	New technology	Nominated sub-contractors	Rework	Staff turnover	Ad-hoc consultants	Complexity of design	Design changes
Contractor	Contractor pre-qualified	0.000000	0.000000	0.004878	0.006594	0.003320	0.000000	0.000000	0.000000
	New technology	0.000000	0.000000	0.034143	0.019783	0.000000	0.000000	0.000000	0.000000
	Nominated sub-contractors	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	Rework	0.000000	0.000000	0.000000	0.000000	0.026557	0.000000	0.000000	0.000000
	Staff turnover	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Engineering	Ad-hoc consultants	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.010798
	Complexity of design	0.063359	0.000000	0.070843	0.006385	0.000000	0.205605	0.000000	0.124587
	Design changes	0.190077	0.000000	0.000000	0.051083	0.000000	0.000000	0.000000	0.000000

Done

Fig. 11: Part of the Weighted Super matrix for the goal

The Limit super matrix derived by raising the weighted super matrix to powers by multiplying it times itself. When the columns of numbers become identical, it was said that the limit matrix has been reached. Consequently, the matrix multiplication process was stopped. Figure 12 shows a section of the limit super matrix for the goal.

Super Decisions Main Window: ANP Rev6 overall network without best fitting.sdmod: formulaic: Limit Matrix

Cluster Node Labels		Contractor					Engineering		
		Contractor pre-qualified	New technology	Nominated sub-contractors	Rework	Staff turnover	Ad-hoc consultants	Complexity of design	Design changes
Contractor	Contractor pre-qualified	0.000710	0.000710	0.000710	0.000710	0.000710	0.000710	0.000710	0.000710
	New technology	0.007029	0.007029	0.007029	0.007029	0.007029	0.007029	0.007029	0.007029
	Nominated sub-contractors	0.000021	0.000021	0.000021	0.000021	0.000021	0.000021	0.000021	0.000021
	Rework	0.000393	0.000393	0.000393	0.000393	0.000393	0.000393	0.000393	0.000393
	Staff turnover	0.001348	0.001348	0.001348	0.001348	0.001348	0.001348	0.001348	0.001348
Engineering	Ad-hoc consultants	0.000172	0.000172	0.000172	0.000172	0.000172	0.000172	0.000172	0.000172
	Complexity of design	0.001909	0.001909	0.001909	0.001909	0.001909	0.001909	0.001909	0.001909
	Design changes	0.001262	0.001262	0.001262	0.001262	0.001262	0.001262	0.001262	0.001262

Done

Fig.12: Section of the Limit Super matrix for the goal

The key importance of the limit super matrix is that it provides the priorities for the different factors that structure the problem. Since the columns of the limit super matrix are all identical, the priorities for all the elements in any cluster can be read directly from any column. Moreover, the Computations Priorities command on the menu displays the priorities in two different ways, both as they appear in the limit super matrix, and with the priorities normalized by cluster. Figures 13a, 13b and 13c display the Priorities as obtained from limit super matrix. When alternatives are included in the model, the software can synthesize them to give the best available alternative according to the provided judgments.

Here are the priorities.

Icon	Name	Normalized by Cluster	Limiting
No Icon	Contractor pre-qualified	0.07473	0.000710
No Icon	New technology	0.73982	0.007029
No Icon	Nominated sub-contractors	0.00221	0.000021
No Icon	Rework	0.04136	0.000393
No Icon	Staff turnover	0.14188	0.001348
No Icon	Ad-hoc consultants	0.03538	0.000172
No Icon	Complexity of design	0.39264	0.001909
No Icon	Design changes	0.25956	0.001262
No Icon	Team experience	0.31242	0.001519
No Icon	Earthquake	0.76604	0.054585
No Icon	Pollution	0.07508	0.005350
No Icon	Unpredicted Weather conditions	0.15888	0.011321
No Icon	Equipment breakdown	0.88027	0.002963
No Icon	Equipment quality	0.11408	0.000384
No Icon	Equipment transportation	0.00564	0.000019
No Icon	Change in currency rate	0.01838	0.000044
No Icon	Fluctuation in prices	0.22306	0.000534
No Icon	Interest rate & Tax rate	0.11362	0.000272
No Icon	Invoices delay	0.03049	0.000073
No Icon	Type of Funds	0.61445	0.001471

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Fig 13.a: The Priorities from the Limit Super matrix "part-1"

Here are the priorities.

No Icon	Construction project risks priorities	0.00000	0.000000
No Icon	Drop in productivity	0.00117	0.000030
No Icon	Human resource planning	0.00276	0.000071
No Icon	Labor accidents	0.36928	0.009505
No Icon	Labor availability	0.13757	0.003541
No Icon	Labor skills level	0.12584	0.003239
No Icon	Wage rates	0.36338	0.009353
No Icon	Material delivery	0.11940	0.000168
No Icon	Material monopoly	0.05970	0.000084
No Icon	Material storage	0.00000	0.000000
No Icon	Material theft & damage	0.36887	0.000519
No Icon	Nominated vendors	0.05615	0.000079
No Icon	Non-conforming material	0.39588	0.000557
No Icon	Level of expertise	0.68668	0.034503
No Icon	Management strategy	0.00042	0.000021
No Icon	Organization structure	0.00444	0.000223
No Icon	Owner quality assurance	0.08072	0.004056
No Icon	Owner type	0.18768	0.009430
No Icon	Work/labour permits	0.04006	0.002013
No Icon	Bribery and Corruption	0.02619	0.020989

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Fig.13.b: The Priorities from the Limit Super matrix "part-2"

Here are the priorities.

No Icon	Changes in laws and regulations	0.12999	0.104160
No Icon	Puplic objections	0.07623	0.061083
No Icon	Stability of government	0.08947	0.071691
No Icon	Wars and revolutions	0.67811	0.543361
No Icon	Availability of variations	0.09944	0.001005
No Icon	Management experience	0.64846	0.006554
No Icon	Quality control process	0.02018	0.000204
No Icon	Scope definition	0.14752	0.001491
No Icon	Type of contract	0.08440	0.000853
No Icon	Fast track schedule	0.83178	0.001879
No Icon	Project duration	0.10934	0.000247
No Icon	Resource oriented schedule	0.05888	0.000133
No Icon	Access conditions	0.05559	0.000869
No Icon	Construction area(rural/ urban)	0.65268	0.010202
No Icon	Delay in permits and licenses	0.06596	0.001031
No Icon	Safety regulation	0.17638	0.002757
No Icon	Security Requirements	0.04939	0.000772
No Icon	Archeological survey done	0.01438	0.000028
No Icon	Geo-technical investigation	0.19312	0.000376
No Icon	Unexpected Surface conditions	0.79250	0.001543

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Fig.13.c: The Priorities from the Limit Super matrix "part-3"

Cluster Comparisons

It was pointed out earlier that the weighted super matrix is derived by multiplying all the elements in a component of the un-weighted super matrix by the corresponding cluster weight. Thus, to achieve the weighted super matrix clusters were needed to be compared. Clusters are compared by taking each cluster in turn, as the parent, and pair wise compare all the clusters it connects to for importance with respect to their influence on it. The output of this process is the creation of the cluster matrix, which is shown in Figure 14. It is essential to recall that the overall goal for the model is the level of Construction project risks priorities. In cluster comparisons, the comparison process is used to pair wise compare the clusters for influence to which the parent cluster connects.
The concept of comparing the clusters is fundamental in real life practice. One needs to identify the importance of the categories under which the elements were classified since the final priorities depend on that. The local priorities of the elements under each cluster are modified for the overall network according to the influence of the cluster within which the elements are contained on the main goal.

Super Decisions Main Window: ANP Rev6 overall network without best fitting.sdmod: ...

Cluster Node Labels	Contractor	Engineering	Environmental	Equipment	Financial	Goal	Labor	Material
Contractor	0.024091	0.021856	0.000000	0.059990	0.080620	0.049887	0.080810	0.027162
Engineering	0.052485	0.170150	0.000000	0.000000	0.000000	0.016034	0.007270	0.094117
Environmental	0.173970	0.000000	1.000000	0.231149	0.151557	0.154932	0.177293	0.054978
Equipment	0.000000	0.000000	0.000000	0.000000	0.053758	0.013770	0.065463	0.000000
Financial	0.000000	0.000000	0.000000	0.000000	0.129234	0.113464	0.000000	0.174468
Goal	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Labor	0.019226	0.000000	0.000000	0.099621	0.112283	0.055222	0.089181	0.000000
Material	0.108891	0.000000	0.000000	0.000000	0.000000	0.116604	0.110346	0.182347

Done

Fig.14: The Cluster Matrix for Construction Project Risks Priorities

Thus, the main objective from utilizing the ANP technique in this thesis, besides demonstrating its effective use in counting for dependence and feedback in a complex structure, was to derive relative priorities for the identified risk factors. That is why no alternatives were proposed, since the main objective was not to derive a case specific model that cannot be used practically, yet it was believed to be more meaningful to develop a general model, which forms a foundation for the aimed comprehensive methodology. Accordingly, the output of this ANP model is to be utilized to develop a decision support tool, which a decision maker can use to compare between any available international construction projects alternatives.

Conclusions

As illustrated in above, when the attributes/sub-criterions priorities are developed with respect to the goal “Construction Project Risks Priorities” by AHP technique; that results describe the attributes/sub-criterions impact global weights, the MS.Excel used to multiply the likelihood per each attribute by its impact to calculate the estimated cost overrun percentage, this percentage was ***38.57***%. The ranking of heights weighted attributes as follows:

1- Wars and revolutions "Political sub-criterion"
2- Bribery and Corruption "Political sub-criterion"
3- Construction area(rural/urban) "Site location sub-criterion"
4- Non-conforming material "Material sub-criterion"
5- Earthquake "Environmental sub-criterion"
6- Unexpected Surface conditions "Sub-surface sub-criterion"
7- Contractor pre-qualified "Contractor sub-criterion"
8- Interest rate & Tax rate "Financial sub-criterion"
9- Fluctuation in prices "Financial sub-criterion"
10- Level of expertise "Owner sub-criterion"

After implementation of ANP technique, the calculated cost overrun was ***37.68%.*** As indicated in figures15a and 15b below which illustrates the comparison between AHP technique outputs and ANP technique outputs. The ranking of heights weighted attributes as follows:

1- Wars and revolutions "Political sub-criterion"
2- Bribery and Corruption "Political sub-criterion"
3- Non-conforming material "Material sub-criterion"
4- Construction area(rural/urban) "Site location sub-criterion"
5- Unexpected Surface conditions "Sub-surface sub-criterion"
6- Stability of government "Political sub-criterion"
7- Changes in laws and regulations "Political sub-criterion"
8- Interest rate & Tax rate "Financial sub-criterion"
9- Fluctuation in prices "Financial sub-criterion"
10- Level of expertise "Owner sub-criterion"

That is mean the AHP technique is adequate for the required analysis, the ANP technique is more accurate and takes the mutual relations between attributes/sub-criterions into consideration. On the other hand ANP technique is complicated and needs extra effort and time specially for the models include high number of nodes and clusters.

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Table1.a: Comparison between AHP and ANP results “part1”

Comparison

between Priorities developed by AHP technique and ANP technique

Name	by AHP Normalized By Cluster	by ANP Normalized By Cluster	by AHP Limiting	by ANP Limiting	Attribute Likelihood	by AHP Cost overrun	by AHP Ranking	by ANP Cost overrun	by ANP Ranking
Earthquake	79%	76.60%	12%	5.46%	16.67%	2.03%	5	0.91%	
Unpredicted Weather conditions	17%	15.89%	3%	1.13%	29.39%	0.76%		0.88%	
Pollution	5%	7.51%	1%	0.54%	46.36%	0.33%		0.38%	
Unexpected Surface conditions	74%	79.25%	3%	0.15%	48.18%	1.56%	6	1.51%	5
Archeological survey done	5%	1.44%	0%	0.00%	27.58%	0.06%		0.07%	
Geo-technical investigation	21%	19.31%	1%	0.04%	40.91%	0.38%		0.43%	
Construction area(rural/urban)	56%	65.27%	4%	1.02%	57.27%	2.09%	3	1.91%	4
Access conditions	3%	5.56%	0%	0.09%	40.30%	0.09%		0.10%	
Delay in permits and licenses	5%	6.60%	0%	0.10%	42.12%	0.13%		0.16%	
Security Requirements	12%	4.94%	1%	0.08%	33.03%	0.26%		0.30%	
Safety regulation	25%	17.64%	2%	0.28%	50.00%	0.80%		0.79%	
Labor skills level	12%	12.58%	1%	0.32%	34.85%	0.24%		0.27%	
Labor availability	13%	13.76%	1%	0.35%	33.03%	0.24%		0.26%	
Drop in productivity	41%	0.12%	2%	0.00%	38.48%	0.88%		0.98%	
Labor accidents	8%	36.93%	0%	0.95%	34.85%	0.15%		0.18%	
Human resource planning	13%	0.28%	1%	0.01%	34.85%	0.24%		0.25%	
Wage rates	13%	36.34%	1%	0.94%	50.00%	0.36%		0.41%	
Equipment quality	19%	11.41%	0%	0.04%	34.85%	0.09%		0.14%	
Equipment breakdown	75%	88.03%	1%	0.30%	34.85%	0.36%		0.47%	
Equipment transportation	6%	0.56%	0%	0.00%	38.48%	0.03%		0.05%	
Material delivery	8%	11.94%	1%	0.02%	33.03%	0.30%		0.33%	
Material storage	2%		0%		29.39%	0.07%		0.08%	
Material theft & damage	35%	36.89%	4%	0.05%	29.39%	1.21%		1.10%	
Non-conforming material	41%	39.59%	5%	0.06%	43.94%	2.08%	4	2.01%	3
Material monopoly	7%	5.97%	1%	0.01%	29.39%	0.25%		0.24%	
Nominated vendors	7%	5.62%	1%	0.01%	31.21%	0.26%		0.28%	

Comparison

between Priorities developed by AHP technique and ANP technique

Name	by AHP Normalized By Cluster	by ANP Normalized By Cluster	by AHP Limiting	by ANP Limiting	Attribute Likelihood	by AHP Cost overrun	Ranking	by ANP Cost overrun	Ranking
Owner type	30%	18.77%	2%	0.94%	33.03%	0.66%		0.56%	
Management strategy	7%	0.04%	0%	0.00%	25.76%	0.12%		0.14%	
Organization structure	3%	0.44%	0%	0.02%	25.76%	0.05%		0.05%	
Work/labour permits	5%	4.01%	0%	0.20%	33.03%	0.11%		0.13%	
Level of expertise	43%	68.67%	3%	3.45%	46.36%	1.30%	10	1.20%	10
Owner quality assurance	11%	8.07%	1%	0.41%	51.82%	0.38%		0.39%	
Team experience	63%	31.24%	1%	0.15%	40.30%	0.41%		0.50%	
Complexity of design	13%	39.26%	0%	0.19%	36.67%	0.07%		0.10%	
Ad-hoc consultants	5%	3.54%	0%	0.02%	33.03%	0.03%		0.04%	
Design changes	19%	25.96%	0%	0.13%	29.39%	0.09%		0.13%	
Contractor pre-qualified	56%	7.47%	3%	0.07%	51.82%	1.45%	7	1.18%	
New technology	6%	73.98%	0%	0.70%	59.70%	0.19%		0.20%	
Rework	22%	4.14%	1%	0.04%	34.85%	0.38%		0.33%	
Nominated sub-contractors	3%	0.22%	0%	0.00%	25.76%	0.04%		0.04%	
Staff turnover	12%	14.19%	1%	0.13%	25.76%	0.16%		0.16%	
Management experience	25%	64.85%	1%	0.66%	40.30%	0.23%		0.26%	
Scope definition	10%	14.75%	0%	0.15%	46.36%	0.11%		0.13%	
Quality control process	4%	2.02%	0%	0.02%	46.36%	0.04%		0.05%	
Type of contract	52%	8.44%	1%	0.09%	46.36%	0.53%		0.59%	
Availability of variations	9%	9.94%	0%	0.10%	38.48%	0.07%		0.10%	
Type of Funds	33%	61.45%	4%	0.15%	29.39%	1.11%		1.10%	
Fluctuation in prices	25%	22.31%	3%	0.05%	48.18%	1.36%	9	1.29%	9
Invoices delay	5%	3.05%	1%	0.01%	50.00%	0.28%		0.30%	
Change in currency rate	3%	1.84%	0%	0.00%	51.82%	0.21%		0.20%	
Interest rate & Tax rate	33%	11.36%	4%	0.03%	36.67%	1.39%	8	1.34%	8
Bribery and Corruption	14%	2.62%	4%	2.10%	63.33%	2.42%	2	2.34%	2
Wars and revolutions	61%	67.81%	17%	54.34%	42.12%	7.07%	1	6.73%	1
Changes in laws and regulations	14%	13.00%	4%	10.42%	33.03%	1.26%		1.39%	7
Puplic objections	2%	7.62%	1%	6.11%	46.36%	0.27%		0.37%	
Stability of government	9%	8.95%	2%	7.17%	46.36%	1.15%		1.39%	6
Fast track schedule	78%	83.18%	1%	0.19%	51.82%	0.34%		0.40%	
Project duration	5%	10.93%	0%	0.02%	36.67%	0.02%		0.02%	
Resource oriented schedule	17%	5.89%	0%	0.01%	25.76%	0.04%		0.05%	
						38.57%		**37.68%**	