AHP-Based Decision Support System for Elevators Selection

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Abstract
This paper presents an accurate managerial way of elevators selection at buildings. It dives deeply into 25 different objectives and explore their assertiveness on the decision while selecting elevators from a list of commercial proposals. That 25 objectives come from two main criteria, which are contact competence and technical wise. A structural model has been made to show the hierarchy of these objectives. Alfaisal University has been chosen to apply the said method on replacing some of elevators at two colleges. Three proposals were received from different well-known factories (A, B, and C) and by implementing the study, it has been found that Factory A is the most suitable provider to replace the elevators in discussion.

Keywords
Analytic Hierarchy Process (AHP), Decision-Making, Elevators, Buildings and Selection.

1. Introduction
In Facility management or even in the construction side, a lot of decision situations for building operation may require decision-maker(s)/ leaders to do trades among a complicated set of competing objectives and to do so, there are several multi-criteria decision-making techniques implemented in this regard (Chan, 2011). One of that structured techniques is Analytic Hierarchy Process (AHP), which is using to give the users/ stakeholders a good a view while deciding on pairwise comparison. It shows a sensitive approach for determining the quantitative weights of decision criteria (Li *et al*, 2019).

AHP was used in many applications, for instance, it was used for selecting a suitable enterprise resource planning (ERP) system which meets all the business strategies and the goals of a textile manufacturing company by studying three main criteria, which are investment factor, system characteristics and vendor criteria (Cebeci, 2009). AHP was also used to show a framework for the selection of tower cranes types and locations at construction sites (Marzouk & Abubakr, 2016). The said framework considered three main models, the first one is decision making model to select the tower crane type, the second model is optimization model for the selection of the ideal number and location of tower cranes, and last one is 4D simulation model to simulate tower crane operations. Another research was used AHP for selecting a supplier for an automotive industry in Pakistan (Dweiri *et al*, 2016). Four criteria were studied for that research: 1) Price, 2) Quality, 3) Delivery, and 4) Services with their sub-criteria such as unit price, compatibility, rejection rate, lead time, warranty, and geographical location. The authors found suppliers are selected and ranked based on sub criteria and a sensitivity analysis suggested the effects of changes to be in the main criteria on the suppliers ranking specially to cover the maintenance expenses. Having said maintenance and as it is playing a significant role in the sustainable development on buildings including safety, technical, economic, and environmental parts, a fuzzy AHP was used to determine the most cost-effective and efficient maintenance strategy in facility management (Pun *et al,* 2017). It had been found that, through formulating the most suitable strategy, the work efficiency can be improved, and the maintenance costs can be minimized. Moreover, machine tool selection is an important decision-making process for many manufacturing companies, a research was done for a flexible manufacturing cell to select the machine toll using AHP (Taha & Rostam, 2011). The researchers had done an innovative approach by making neural net simulation and combining artificial neural network with the used AHP model and got a powerful tool to select the most suitable alternative machines to form the structure of a flexible manufacturing cell. As safety aspect is concerned in all buildings, one of the studies proposed a decision support model to effectively concretize experts' and practitioners' subjectivities and to quantify the failure risk of evacuation work and the model is fundamentally constructed on fuzzy AHP, which weights the environmental influences that can derive a failure (Kim *et al*, 2014). The outcomes of this study are used as an input for fuzzy comprehensive operations to compute the quantitative failure risk. A different research presented a framework based on AHP methodology to select the most appropriate set of Knowledge Management (KM) tools to support the innovation processes in organizations (Grimaldi & Rippa, 2011). This framework built on the theoretical foundations underlying organizational KM to identify key KM processes enabling innovation. Having said management, AHP were also used to select the best equipment for construction projects by studying four managerial criteria. These criteria are addressing the previous experience with equipment, the dependance on outsourcing, the compilation, and the work on night shifts (Shapira & Goldenberg, 2005). Also, in project management, AHP has been joint with International Project Management Association (IPMA) competence baseline (ICB); to be a tool for decision making process of selecting the most suitable managers for projects (Varajao & Cruz-Cunha, 2013).

Elevator planning is based on up peak and calculation of handling capacity to meet the building traffic flow demand (Sorsa *et al*, 2005), and this was a successful study with regards to KONE brand by addressing destination operation panels at different floors like lobby. Another study was conducted for elevator selection using AHP (Drake & Lee, 2009). They had highlighted only four general criteria, which are quality, availability, cost, and time. In this research, AHP is used to select the best elevator option by comparing different commercial proposals/ quotations. A twenty-five objectives were studied to give the user a clear and accurate image about elevator selection.

2. Methodology

To get the benefit from AHP study for selecting elevators either as a replacement or as a new ones at the construction time, it is recommended to start identifying several criteria and objectives, which are related to the subject in debate and need to be evaluated. These alternatives could be the different criteria that solutions must be evaluated against different proposals. This paper tries to show and describe the most objectives may include in companies/ factories proposals. These objectives have been divided into two main groups, contract competence and technical wise. The contract competence contains six objectives, 1) purchasing cost excluding civil works, 2) civil works cost (Order of Magnitude), which may be needed to make the site ready to install each elevator, 3) payment terms, which are usually mentioned in the quotation like advance payment, 4) installation period, 5) delivery period of the requested elevators to be on site, and 6) after sale service, which may includes in the quotation like the number of free charge visits/ checks after awarding the contract. The technical wise contains nineteenth objectives, 1) model, 2) type; like passenger or freight 3) capacity, which is the number of passengers/ weights the elevator can handle, 4) speed, which is normally given in meter per seconds, 5) waiting time, which is the time a passenger has to wait in seconds, 6) number of stops, which reflects the number of floors an elevator travels, 7) weight of elevator, which is normally given in kilograms 8) number of starts per hour, which shows the elevator ability to respond, 9) shaft dimensions where elevator runs/ travels, 10) car size, which is the size of the elevator in terms of meter, 11) door opening, like one side or double sides, 12) pit depth, which is the space below the bottom floor of the elevator shaft, 13) headroom height, which is the space between the top of the elevator at the last stop, 14) country of origin, 15) certification, which shows the standard of elevator manufacturing, 16) need of machine room if the elevator requires a separate room for machinery or it is built in, 17) interior decoration, which may include marble, mirrors, etc, 18) safety features such as telephone device, and 19) ability of CCTV connections.

The next step is to model the problem or the desired goal. According to AHP methodology, a goal is a related set of sub objectives. The AHP method therefore relies on connecting the goal into a hierarchy of related objectives. In the process of breaking down the objectives, criteria to evaluate the solutions emerge. However, like root cause analysis, the user can go on and on to deeper levels within the required goal of this research. This will help the user to have a clear view of all related evaluation tools. A special structural model is made for this purpose (Figure 1).

Then, establishing priority amongst criteria using pairwise comparison is totally required. For each objective, AHP generates a weight. By convention, the weights are always chosen so that they sum to one. To obtain the weights for the various objectives, the user should begin by forming a matrix, known as the pairwise comparison matrix. One matrix should be formulated among all objectives (Table 1) and one matrix among factories on each objective (Table 2). Then a normalized matrix should be formulated for each previous pairwise comparison to get the related weights. The main part of building these matrices is to determine the importance for one objective against other one. Suggestive interpretation of values in the pairwise comparison between any two objectives is shown in Table 3 (S. Powell & K. Baker, 2010). Using Spreadsheet will help much in getting an accurate and swift results as shown in the application section of this paper. The consistency is recommended to be checked for each comparison to confirm the satisfactory.

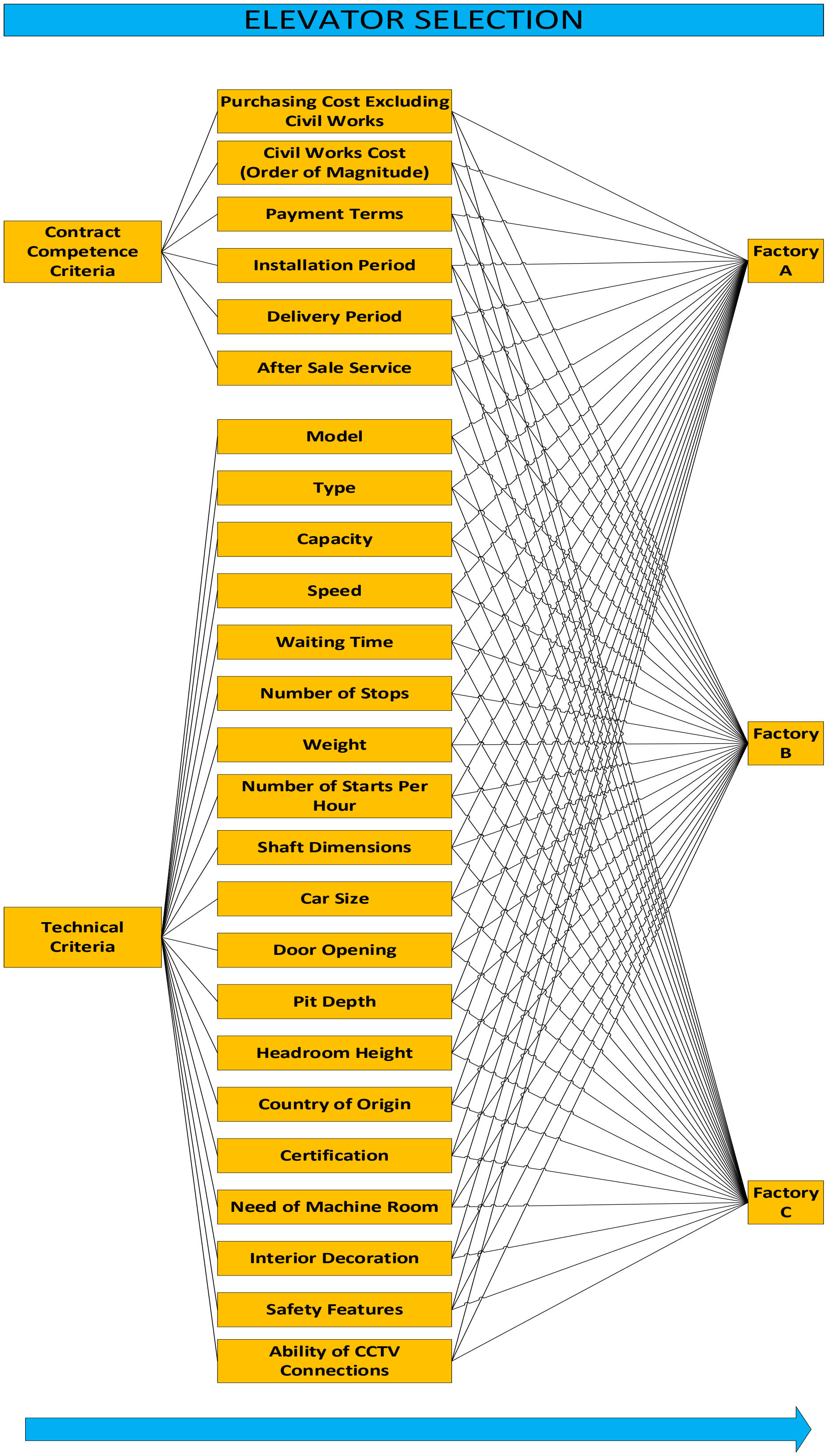

Fig. 1: AHP Structural Model for Elevator Selection

Table 1: Format for pairwise comparison among objectives

	Objective 1	Objective 2	. . . .	Objective n
Objective 1	1	x	. . . .	y
Objective 2	1/x	1	. . . .	z
. . . .	. . . .	. . . .	1	. . . .
Objective n	1/y	1/z	. . . .	1

Where:
x: The importance score rate for objective 1 against objective 2.
y: The importance score rate for objective 1 against objective n.
z: The importance score rate for objective 2 against objective n.
n: Number of objectives.

Table 2: Format for pairwise comparison among elevators on objective n

	Factory 1	Factory 2	. . . .	Factory m
Factory 1	1	x	. . . .	y
Factory 2	1/x	1	. . . .	z
. . . .	. . . .	. . . .	1	. . . .
Factory m	1/y	1/z	. . . .	1

Where:
x, y, and z follow the same concept as previous table.
m: Number of factories/ companies.

Table 3: Interpretation of values in the pairwise comparison

Score Value	Interpretation
1	First and second objectives are equally important
3	First objective is slightly more important than second one
5	First objective is strongly more important than second one
7	First objective is very strongly more important than second one
9	First objective is absolutely more important than second one
Remark: 2, 4, 6 and 8 are intermediate values	

3. Application & Results

Alfaisal University is planning to replace some elevators for two buildings as part of the improvement plan with new and advanced ones. Facility department has initiated the procurement process by calling sealed bids from well-known factories. Three bids were received to be evaluated (Factories A, B, and C) and accordingly, to select one. Therefore, AHP is used to do so by completing the required information by approaching the related stakeholders, who are members from Maintenance, Procurement, Finance, Student Affairs, and Senior Management with the needed questionnaire. The two tabulated formats have been filled with the rates mentioned in table 3 and then to build a normalized matrix, the value of each cell is the associated number divided by the sum of its column in the associated pairwise matrix. After that, to get the weight of each objective or factory, each row of the associated normalized matrix should be averaged. As recommended in methodology part, consistency ratio for each matrix has calculated by dividing the consistency index (CI) by the randomized index (RI) based on the number of objectives as well as factories, the value should be less than 0.10 to be satisfied (Saaty, 1990). For instance, CI can be gotten by considering the average of each matrix row as well as number of objectives/ factories and the inverse of the same number. For RI, it is random number based on eigenvalue (λ_{max}) and the simplicity of the criterion and can be gotten from the tabulated results (Alonso & Lamata, 2006). EXCEL is used to do all these calculations and from the following snapshots (Figures 2, 3, and 4), it shows that Factory A has the highest score weight (0.3873) while Factory B has 0.2860 and Factory C has 0.2965. This is supported by the consistency ratio being less than 0.1 for each wights score resulted from the associated matrix and therefore, university is going to award the contract to them.

1 Elevator selection using analytical hierarchy process

2

3 Pairwise comparisons among objectives

4		Purchasing Cost Excluding Civil Works	Civil Works Cost (Order of Magnitude)	Payment Terms	Installation Period	Delivery Period	After Sale Service	Model	Type	Capacity	Speed	Waiting Time	Number of Stops	Weight	Number of Starts Per Hour	Shaft Dimensions	Car Size	Door Opening	Pit Depth	Headroom Height	Country of Origin	Certificatio
5	Purchasing Cost Excluding Civil Works	1	5	3	3	7	9	7	3	3	3	3	5	7	5	5	5	9	7	7	9	
6	Civil Works Cost (Order of Magnitude)	1/5	1	3	3	5	9	7	3	5	5	5	7	9	7	7	7	9	9	9	9	9
7	Payment Terms	1/3	1/3	1	1	1	3	7	7	1/5	1/5	1/5	1/5	1/5	1/3	1/5	1/7	1/9	1/9	1/9	1/9	1,
8	Installation Period	1/3	1/3	1	1	1	3	3	3	1/9	1/9	1/9	1/9	1/9	1/9	1/9	1/9	1/9	1/9	1/9	1/9	1,
9	Delivery Period	1/7	1/5	1	1	1	1	3	3	1/9	1/9	1/9	1/9	1/9	1/9	1/9	1/9	1/9	1/9	1/9	1/9	1,
10	After Sale Service	1/9	1/9	1/3	1/3	1	1	5	5	1/3	3	1/3	3	5	3	3	3	7	3	3	7	
11	Model	1/7	1/7	1/7	1/3	1/3	1/5	1	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1,
12	Type	1/3	1/3	1/7	1/3	1/3	1/5	5	1	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1,
13	Capacity	1/3	1/5	5	9	9	3	5	5	1	1	1	5	1	3	3	1	7	3	3	7	
14	Speed	1/3	1/5	5	9	9	1/3	5	5	1	1	1/3	3	3	3	5	1	5	5	5	5	
15	Waiting Time	1/3	1/5	5	9	9	3	5	5	1	3	1	1	3	3	3	3	3	3	3	3	

Model

Fig. 2: Matrix snapshot for elevator selection pairwise comparison between objectives

Pairwise comparisons among Factories on Model

	Factory A	Factory B	Factory C
Factory A	1	1/3	1/3
Factory B	3	1	3
Factory C	3	1/3	1

Pairwise comparisons among Factories on Type

	Factory A	Factory B	Factory C
Factory A	1	1/7	1/5
Factory B	7	1	3
Factory C	5	1/3	1

Pairwise comparisons among Factories on Capacity

	Factory A	Factory B	Factory C
Factory A	1	5	3
Factory B	1/5	1	1/3
Factory C	1/3	3	1

Fig. 3: Some matrices snapshot for pairwise comparison among factories on some objectives

Normalized matrix

0.2500	0.2500	0.2500
0.2500	0.2500	0.2500
0.5000	0.5000	0.5000

Normalized matrix

0.5000	0.4000	0.5714
0.2500	0.2000	0.1429
0.2500	0.4000	0.2857

Safety Features	Ability of CCTV Connections	Weighted scores	
0.250	0.490	**0.3873**	Factory A has the highest
0.250	0.198	0.2860	
0.500	0.312	0.2965	

Fig. 4: Snapshot of the result

4. Conclusion

AHP is well used in this paper and gave the leadership a strong decision tool to select one out of three elevators factories have provided replacement quotations. This research explored the most possible terms, which are normally included in the commercial quotation. It gives the user an idea that cost objectives are not necessarily affect the decision whereas there are other objectives may have more priority or must be addressed more than the purchasing cost and it depends on the site situation as well as the occupant satisfaction. Factory A has the highest weighted score, which is resulted from all the matrices, which are done using spreadsheet. In future research, it is planned to extend the study with other decision-making tools.

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Biographies

Malek Almobarek is a Saudi national. He was born on April 1983 in Kuwait City. He took his primary and secondary education at AlMawardi School where he was a consistent honor student. He graduated in Industrial Engineering from King Saud University in the year 2009. He did assistance to his professors at the same university with tutorial & site visits for the students before starting his experience journey by taking up a job as Plants Equipment Specialist in O&M department at GASCO, Riyadh. He worked there from May 2009 to Sep 2011. He then moved to Dallah Hospital, Dallah Health Co., Riyadh to work as Engineering Department Manager from Sep 2011 to Nov 2013. Thereafter, He joined Alfaisal University as Facility manager in Dec 2013 and currently discharging his duties as Senior Facility Manager. The areas of responsibility in his current job include Buildings and grounds maintenance; Projects; Cleaning; Catering and Leasing; Health and Safety; Procurement and Contract management; Security; Space management; Waste disposal; Mails, Housing and Transportation; Utilities and Campus infrastructure. It is here that he decided to further his studies while continuing to work and joined in Master of Engineering Management (MEM) program that Alfaisal University was offering. He scored GPA 4.0/4.0 and completed a research thesis on Water Budget Control Framework Using DMAIC Approach for Commercial Buildings. He graduated in April 2020 with a first honor and now is a full time PhD student in Design, Manufacturing and Engineering Management at University of Strathclyde, UK. Eng. Malek is a result oriented, Innovative, resilient, and collaborative. He is not only very good in academics, but also, he is an expert in Facility and Project Management; Procurement and Inventory Management; Supply Chain Management; Emergency Response; Environmental Control; Security Control; Contractor Oversight; Resource Allocation; Building Regulations; Building Systems; Fire Safety; Scheduling; Processes and Procedures; Hazardous Waste, etc. He is a member of Saudi Council of Engineering in the capacity of Professional Engineer and loves travelling, reading, bowling, and watching debates on TV.

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