DECISION MAKING IN SURVEYING AND GEOINFORMATICS

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ABSTRACT

One of the most important decisions that a surveyor has to make before embarking on a given surveying project is the selection of the instrument. Where there are number of choices, a decision by way of selection has to be made. The selection can be based on a number of criteria, for instance, accuracy, cost, user friendly, size of project, user knowledge and experience, project type and duration. The need to have the best equipment for the right job cannot be overemphasized. This requires that the surveyor should select the equipment to be used in an objective way, taking into cognizance all factors and their priorities. The aim of this paper is to demonstrate the use of the Analytical Hierarchy Process (AHP) as a form of decision-making methodology in the selection of equipment for a surveying project. Priority weights for each factor controlling the choice are also determined. 3 instruments were considered for selection – Total station, DGPS and theodolite and 7 elements used in the instrument selection - accuracy, cost, user friendly, size of project, experience/ knowledge, project type and duration. The accuracy of the equipment appears to be the element with the highest importance. While experience and knowledge accounted for the next element on the level of importance. The element with the least importance user friendly element.

Keywords: Analytical Hierarchy Process, Decision Making, Multi-criteria, Priority Weight, Surveying.

1.0 INTRODUCTION

Decision-making is one of the key exercise performed by a surveyor. Surveying is defined as the art and science of measuring, determining, depicting, or representing the dimensions, extent, features or relative positions of portions of the earth's surface (SURCON, 2002). The fundamental purpose of surveying therefore is that any portion on the earth's surface must be determined, known, and represented correctly. Surveyors are saddled with these responsibilities using surveying instrument and equipment. One of the most important decisions that a surveyor has to make before embarking on a given surveying project is the selection of the instrument. Where there are number of choices, a decision by way of selection has to be made regarding the instrument to be used to execute a project. Most recently, especially with the dawn of new millennium technology, there has been tremendous improved surveying equipment thus simplifying the surveying work. However, the basis for the selection of instrument needs to be well defined in such a way the most important factors are used. This paper therefore focuses on demonstrating the use of the Analytical Hierarchy Process (AHP) as a form of decision-making tool in the selection of equipment for a surveying project.

2.0 BRIEF LITERATURE

Selection problem is not a new concept. For instance, Piantanakulchai, 2005 used the concept to address facilities location strategically, Highway corridor planning (Ramanathan, 2006), Project selection (Cheng, and Li, 2005), Selection of logistics (Kayastha et al, 2013,), Selection of alternative fuels for residential heating (Erdogmus etal, 2006), Waste disposal Site selection problem (Babalola and Busu 2011), (Wolfslehner et al, 2005), (Chen and Kao 1997), (Baheeci and Topkaya 2008) and Facility selection (Jharkaria and Shankar 2007) and Project selection and ranking (Brans et al, 1986). The application of AHP as a decision making tool is also not new as it has found usefulness in software selection (Partovi 2006), Data envelopment analysis for weight derivation (Surveyor Council of Nigeria (SURCON, 2012) and (Ertay et al, 2006), Landslide susceptibility mapping (Lai et al, 1999), and Power plants evaluation (Chatzimouratidis and Pilavachi 2009). The AHP is used by decision makers to breakdown decision-making problem into criteria and alternatives. Within the AHP structure, quantitative and qualitative decision-making criteria are easily manipulated.

2.1 STUDY OBJECTIVES

In the literature review, no research was identified in Surveying that has used Multi-Criteria Decision Making (MCDM) for the selection of instrument or equipment for surveying project. Therefore, the aim of this study is to present a structure of the multi-criteria decision making using the analytical hierarchy process to assist surveyors and engineers in the selection of equipment for surveying projects. The major objectives of this study can be stated thus:

a) To analyse factors for the selection of the equipment
b) To develop a model to select the best equipment for the project, and
c) To check the model with real data as presented by the participants

3.0 METHODOLOGY

This study commenced with the formulation of the factors to be considered and thereafter the demonstration process. The selection problem was formed taking into cognizance a multi-criteria decision making process. The demonstration process was carried out with a group of national diploma (ND) students of Surveying and Geoinformatics.

The students were requested to itemize all possible factors they thought should be considered before selecting a surveying instrument for a project. Thirty students took part in this study but only twenty-five responded. This gave rise to ten factors however, some were later merged which resulted in seven factors presented here. The selection problem was formulated using the seven factors, which serve as the criteria (Table 1). The developed process was implemented using the MATLAB software.

Table 1: Elements used in the Instrument Selection

Elements	Description
1. Accuracy (AC)	The accuracy of the instrument
2. Cost (CS)	Cost of hiring or acquiring the instrument
3. User Friendly (UF)	Is the Instrument easy to use?
4. Size of Project (SP)	Extent of the project
5. Experience/Knowledge (EK)	Experience and Knowledge of the Surveyor
6. Project Type (PT)	The type of Surveying project
7. Project Duration (PD)	Time allocated for the project

Having identified the elements in the table above, we identified the method to adopt in order to ascertain the relative importance of the elements for each instrument. Thus, we need to assign importance weight in an objective way to the elements in Table 1. The method proposed here is the Analytic Hierarchy Process (AHP). The AHP was originally developed by (Sumathi et al 2007); this method allows selection and priority ordering of alternatives based on multiple criteria. The fundamentals will be summarized for the purpose of this work. The modelling process can be divided into six as follows:

1. Defined the unstructured problem, stating clearly its objectives and outcomes.
2. Decompose the complex problem into decision elements (detailed criteria and alternatives)
3. Employ pairwise comparisons among decision elements to form comparison matrices.
4. Use the eigenvalue method (or some other method) to estimate the relative weights of the decision elements.
5. Calculate the consistency properties of the matrices to ensure that the judgments of decision-makers are consistent.
6. Aggregate the weighted decision elements to obtain an overall rating for the alternatives.

The pairwise comparison or preference judgments can be carried out applying any rating scale. (Sumathi et al 2007) applied the scale in Table 2.

Table 2: The Pairwise comparison

Scale value	Explanation
1	Equally preferred (or important)
3	Slightly more preferred (or Important)
5	Strongly more preferred (or important)
7	Very strongly more preferred (or important)
9	Extremely more preferred (or important)
2,4,6,8	Used to reflect compromise between scale values

Since there are seven objectives, weight is assigned to each objective and the AHP determines the weight using a pairwise comparison matrix thus:

$$A=\begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \frac{w_2}{w_n} \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \frac{w_n}{w_n} \end{bmatrix} \qquad \textbf{[3.1]}$$

The reciprocals of these numbers are used to express the inverse relationship.
To compute the principal eigenvector (Sumathi et al 2007);

$$\theta V = \lambda_{max} V \qquad \textbf{[3.2]}$$

V= vector of relative values (weights) and λ_{max} = maximum eigenvalue
The consistency index (CI) can be obtained thus:

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad \textbf{[3.3]}$$

as a rule, the consistency ratio (CR) ≤ 0.10, is an acceptable level of inconsistency in decision situations.
The consistency index of a randomly generated reciprocal matrix is known as the random index (RI). The RI values have been derived experimentally as shown in Table 3

Table 3: Values of Random Index (RI)

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	01.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

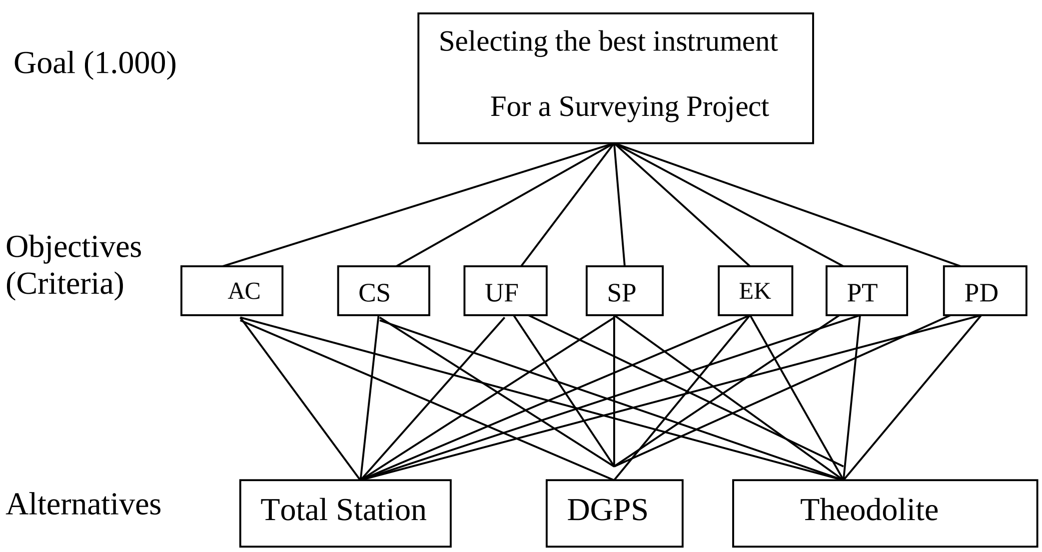

Fig. 1: The hierarchal structure for Instrument selection (Decision problem)

Figure 1 is the decision problem as formulated using the Analytic hierarchy process. The top level of the hierarchy represents the goal of the decision problem, that is, Instrument selection. The next level of the hierarchy represents the objectives (Criteria) that should be satisfied. The alternatives are the choices from which the selection will be made. In this case three alternatives instrument are presented namely; Total station, Dual frequency global positioning system (DGPS), and Theodolite. The decision here is based on relative importance of the elements as generated by the Students and the level by which each instrument fulfils the requirement of the elements. Through a process known as Synthesis the instrument with the highest total rating is selected.

4.0 RESULTS AND DISCUSSION

Pairwise comparison matrix of the Objectives

A =

1.0000	3.0000	7.0000	5.0000	1.0000	7.0000	1.0000
0.3333	1.0000	9.0000	1.0000	1.0000	5.0000	1.0000
0.1429	0.1111	1.0000	0.1429	0.2000	0.5000	0.2500
0.2000	1.0000	7.0000	1.0000	0.2500	7.0000	0.3333
1.0000	1.0000	5.0000	4.0000	1.0000	5.0000	3.0000
0.1429	0.2000	2.0000	0.1429	0.2000	1.0000	0.1667
1.0000	1.0000	4.0000	3.0000	0.3333	6.0000	1.0000

[3.5]

STEP 1: Yields a new matrix called $A_{norm,}$ for normalized.

<u>NORMALIZED MATRIX</u>

0.2618	0.4103	0.2000	0.3500	0.2510	0.2222	0.1481
0.0873	0.1368	0.2571	0.0700	0.2510	0.1587	0.1481
0.0374	0.0152	0.0286	0.0100	0.0502	0.0159	0.0370
0.0524	0.1368	0.2000	0.0700	0.0628	0.2222	0.0494
0.2618	0.1368	0.1429	0.2800	0.2510	0.1587	0.4444
0.0374	0.0274	0.0571	0.0100	0.0502	0.0317	0.0247
0.2618	0.1368	0.1143	0.2100	0.0837	0.1905	0.1481

[3.6]

STEP 2: To determine an approximation to W_{max} (to be used to estimate W)

WEIGHT MATRIX

$$W = \begin{bmatrix} 0.2634 \\ 0.1584 \\ 0.0278 \\ 0.1134 \\ 0.2394 \\ 0.0341 \\ 0.1636 \end{bmatrix}$$

[3.7]

That is; W1 = 0.2634, W2 = 0.1584, W3 = 0.0278, W4 = 0.1134, W5 = 0.2394, W6 = 0.0341 and W7 = 0.1636

CHECKING FOR CONSISTENCY

Step 1:
WEIGHT MATRIX [A*W]

$$AW^T = \begin{bmatrix} 2.1413 \\ 1.1828 \\ 0.2050 \\ 0.8717 \\ 1.9146 \\ 0.2502 \\ 1.3208 \end{bmatrix}$$ **[3.8]**

Step 2: $AW^T/W^T = 7.7264$ **[3.9]**

Step 3: Computing the Consistency index (CI)

CI = 0.1211,   RI = 1.3200

Comparing CI to the random index (RI) for the appropriate value of consistency ratio, n, shown in Table 3 above.

Step 4: n = CI/RI = 0.0917 < 0.10, **[3.10]**

Thus, the student's pairwise comparison matrix is consistent.

Determining the Score of each Alternative for each objective

AC =

$$\begin{bmatrix} 1.0000 & 9.0000 & 3.0000 \\ 0.1111 & 1.0000 & 0.2000 \\ 0.3333 & 5.0000 & 1.0000 \end{bmatrix}$$

CS =

$$\begin{bmatrix} 1.0000 & 7.0000 & 4.0000 \\ 0.1429 & 1.0000 & 0.3333 \\ 0.2500 & 3.0000 & 1.0000 \end{bmatrix}$$

UF =

1.0000	0.2000	0.3333
5.0000	6.0000	2.0000
3.0000	0.5000	1.0000

PT =

1.0000	0.1429	0.2500
7.0000	1.0000	3.0000
3.0000	0.3333	1.0000

SP =

1.0000	6.0000	3.0000
0.1667	1.0000	0.5000
0.3333	2.0000	1.0000

PD =

1.0000	0.1429	0.3333
7.0000	1.0000	3.0000
3.0000	0.3333	1.0000

EK =

1.0000	0.1111	0.2000
9.0000	0.5000	4.0000
5.0000	0.2500	1.0000

[3.11]

n = CI/ RI = 0.0917 **[3.12]**

0.2222	0.2222	0.2222

<u>FACTORS NORMALIZED</u>

ACnorm =

0.6923	0.6000	0.7143
0.0769	0.0667	0.0476
0.2308	0.3333	0.2381

EKnorm =

0.0667	0.1290	0.0385
0.6000	0.5806	0.7692
0.3333	0.2903	0.1923

CSnorm =

0.7179	0.6364	0.7500
0.1026	0.0909	0.0625
0.1795	0.2727	0.1875

PTnorm =

0.0909	0.0968	0.0588
0.6364	0.6774	0.7059
0.2727	0.2258	0.2353

UFnorm =

0.1111	0.0299	0.1000
0.5556	0.8955	0.6000
0.3333	0.0746	0.3000

PDnorm =

0.0909	0.0968	0.0769
0.6364	0.6774	0.6923
0.2727	0.2258	0.2308

SPnorm =

0.6667	0.6667	0.6667
0.1111	0.1111	0.1111

[3.13]

ACweight =

$$\begin{bmatrix} 0.6689 \\ 0.0637 \\ 0.2674 \end{bmatrix}$$

CSweight =

$$\begin{bmatrix} 0.7014 \\ 0.0853 \\ 0.2132 \end{bmatrix}$$

UFweight =

$$\begin{bmatrix} 0.0803 \\ 0.6837 \\ 0.2360 \end{bmatrix}$$

SPweight =

$$\begin{bmatrix} 0.1111 \\ 0.2222 \\ \end{bmatrix}$$

EKweight =

$$\begin{bmatrix} 0.0781 \\ 0.6500 \\ 0.2720 \end{bmatrix}$$

0.6667

PTweight =

$$\begin{bmatrix} 0.0822 \\ 0.6732 \\ 0.2446 \end{bmatrix}$$

PDweight =

$$\begin{bmatrix} 0.0882 \\ 0.6687 \\ 0.2431 \end{bmatrix}$$

[3.14]

SYNTHESIZING THE MATRIX FOR EACH OBJECTIVE

S =

$$\begin{bmatrix} 0.6689 & 0.0637 & 0.2674 \\ 0.7014 & 0.0853 & 0.2132 \\ 0.0803 & 0.6837 & 0.2360 \\ 0.6667 & 0.1111 & 0.2222 \\ 0.0781 & 0.6500 & 0.2720 \\ 0.0822 & 0.6732 & 0.2446 \\ 0.0882 & 0.6687 & 0.2431 \end{bmatrix}$$

[3.15]

TOTAL STATION score = 0.4010 **[3.16]**

DGPS score = 0.3498 **[3.17]**

THEODOLITE score = 0.2492 **[3.18]**

Table 4: ND Student's Score for each Instrument and Objective

Objective	Total Station	DGPS	Theodolite
AC	0.6689	0.0637	0.2674
CS	0.7014	0.0853	0.2132
UF	0.0803	0.6837	0.2360
SP	0.6667	0.1111	0.2222
EK	0.0781	0.6500	0.2720
PT	0.0822	0.6732	0.2446
PD	0.0882	0.6687	0.2431

From the analysis presented, the objective of this paper has been met. The importance attached to each objective or elements in the selection of instrument has emerged. The analysis also put forth the difference in the assigned priorities. The accuracy of the equipment appears to be the element
with the highest importance. While experience and knowledge accounted for the next element on the level of importance. The students simply believed that the accuracy of the instrument is the most significant attribute they would look out for when selecting an instrument for a surveying job. The element with the least importance as presented by the students is user friendly. They felt the element is of a lesser consequence to the choice of an instrument.

In this study three alternatives were presented considering three instruments namely; Total station, Theodolite and DGPS. The Instruments were ranked by a method of synthesis (3.15). Each element was considered and compared taking into consideration the three instruments thus giving rise to the score of alternative for each objective (3.16, 3.17, 3.18). The score for each instrument is obtained as 0.4010, 0.2492 and 0.3498 for Total station, Theodolite and DGPS respectively. The students at the end of the exercise selected the instrument with highest score of 0.4010 which is the Total station.

4.1 LIMITATIONS

Some assumptions were made in the course of this study and in the methodology applied. First and foremost, the ND students were aware of the choices and the pairwise comparison as well as correct priorities. Secondly, the students even though at the level of a National Diploma will be able to do a fair and objective comparison among the three instruments, taking into cognizance the seven criteria. Advanced participants or professional surveyors may provide additional criteria, objective judgments and better pairwise comparison. However, this will provide an avenue for further study to re-evaluate the criteria, their relevance, and of course their relative importance for the selection of surveying instrument.

5.0 CONCLUSION

The choice of a surveying instrument for a surveying work is an important step in order to get the job done and on schedule. It is therefore imperative that a sound judgment and decision be made. In this paper, a methodology known as the Analytic Hierarchy Process (AHP) has been proposed using a practical approach. The method demonstrated how surveying instrument can be selected for the purpose of carryout a surveying project. It allowed the students to make an informed decision with objectivity. AHP is an excellent modelling structure for decision making which has found usefulness in many fields such as; marketing, planning, facility management and medicine.

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