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Using Analytic Hierarchy Process as a Decision-Making Tool in Project Portfolio Management

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***Abstract*—**Project Portfolio Management (PPM) is an essential component of an organisation's strategic procedures, which requires attention of several factors to envisage a range of long-term outcomes to support strategic project portfolio decisions. To evaluate overall efficiency at the portfolio level, it is essential to identify the functionality of specific projects as well as to aggregate those findings in a mathematically meaningful manner that indicates the strategic significance of the associated projects at a number of levels of abstraction. PPM success is directly associated with the quality of decisions made and poor judgment increases portfolio costs. Hence, various Multi-Criteria Decision Making (MCDM) techniques have been designed and employed to support the decision-making functions. This paper reviews possible options to enhance the decision-making outcomes in organisational portfolio management processes using the Analytic Hierarchy Process (AHP) both from academic and practical perspectives and will examine the usability, certainty and quality of the technique. The results of the study will also provide insight into the technical risk associated with current decision-making model to underpin initiative tracking and strategic portfolio management.

***Keywords*—**Analytic hierarchy process, decision support systems, multi-criteria decision-making, project portfolio management.

I. Introduction

As organisations progressively transform into project forms, projects tend to be the key delivery tool for organisational strategy [1]-[5]. These projects are influenced by several drivers, such as competitive demands, greater complexity of organisational plans, along with the increasing accessibility of resources and software products [6], [7]. Generally, the role of Project Portfolio Management (PPM) is to evaluate, select, and prioritise new projects, as well as to revise priority, and possibly eliminate and reduce projects in progress [8]. By managing and analysing all projects and their interrelationships from a portfolio level, the goal of PPM is to enhance the overall efficiency of the project portfolio. Project investments decisions play an essential strategic role in the majority of businesses, particularly project-based businesses [9].

PPM is an essential portion of strategic management practice since it involves decisions concerning which actions a business needs to undertake to best achieve strategic targets. In other words, PPM is an organisational functionality of increasing value in a growing challenging project concept [10]-[12]. The literature emphasises that PPM is basically a strategic decision-making method that engages determining, reducing, as well as diversifying risk; identifying and addressing variations; along with recognising and accepting together with making trade-offs [12], [13]. The importance of the position of the project portfolio with the public as well as private sector strategy has been introduced more frequently as an essential activity for organisations, leading PPM to assume a significant role in competitive strategy as well as, to present itself as an impacting element in the long-term outcomes of the business [14]. An essential factor in PPM would be to assess which is the group of projects that maximises the success and achievement of strategic targets. PPM is then an active decision practice where an amount of new analysis items and improvement is constantly updated.

Although PPM is not directly focused on assuring good results in obtaining strategic goals and objectives, an effective PPM practice will be able to improve the probabilities of choosing and then completing the assignments that best achieve organisational goals and promote accomplishing the organisation's perspective. Fundamental aspects in obtaining such targets are (1) choosing the projects that best promote strategic targets, (2) analysing efficiency throughout execution to make sure the portfolio continues to be on target to provide strategic advantages as well as (3) modifying strategy along with the portfolio whenever adjustments in strategy or functionality require. To examine efficiency at the portfolio level, it is essential to identify the capability of single projects and combine the findings in a mathematically meaningful process which displays the strategic significance of the associate projects.

This paper proposes a practical study that aims to determine the inhibitors for decision-making when managing a complex portfolio and to provide an examination of the Analytic Hierarchy Process (AHP) method to indicate the characteristics of the approach in dealing with the MCDM problem. This paper also aims to improve organisations' knowledge of MCDM methods and the interdependencies within a project portfolio, thereby improving their capability to take strategic portfolio decisions.

In this paper, the academic perspective of the AHP technique is introduced through a literature review and the

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works according to this methodology is reviewed. The shortcomings of AHP and issues in using this method when exclusively used to deal with the MCDM problems is also explained accompanied by a practical case study of the way this process works. This study will describe the experiences of an organisation in implementing the proposed method of visually identifying and demonstrating information to assist strategic decision-making; and will examine the usability, certainty and quality of the technique in a real portfolio life cycle.

II. Literature Review

A. Project Portfolio Management (PPM) and Challenges

There are various methodologies for portfolio management. The best-suited models indicate an activity of regular selection of available project proposals, along with the re-evaluation of existing projects which are in implementation stage, therefore, enabling the compliance with the strategic targets of the organisation without exceeding available resources, nor violating business constraints, and responding to the minimal requests of the organisation in accordance with the different requirements [15]. A few of such requests might be: possible potential revenue, potential acceptance, and quantity of assets.

Recently, PPM has received interest as a means of aligning projects with strategy in addition to ensuring sufficient resourcing for projects, prompting businesses in different sectors to improve their PPM abilities [16], [17]. PPM procedures assist organisations to control their projects using a variety of tools or methods built to produce and evaluate project information as well as to drive decision-making to manage a well-balanced portfolio which is in parallel with key objectives [12]-[14]. The publications signifies that the effective management of project portfolios transcends the techniques employed, realising that the business framework, individuals together with tradition are likewise essential elements of an organisation's total ability to handle its project portfolio [18]. Studies frequently implies that PPM requires to be developed over time [14], [19] and different procedures and tools are designed for PPM which require to customised and specified for optimum outcomes [20]. The remarkable increase of best practice researches and growth techniques emphasises the existing link within PPM and final results improvement [21]-[24]. The remarkable increase of best practice researches and strong focus on PPM processes and techniques emphasises the existing link between growth and outcomes of PPM; and likewise, the ability to improve PPM outcomes as reported in different studies. A number of researches suggested the need for a mutual link between projects and strategic levels of the organisations instead of one way relationship from strategic level to projects level, as PPM procedures obtain from both strategic and Projects levels [3]-[5], [25]-[27]. PPM functions are proven to enable the mixture of top-down strategic objective with bottom-up strategy progress in a number of different scientific experiments [28]-[30]. Such research has revealed that PPM is a critical strategic functionality responsible for delivering and shaping strategy. This responsibility assists to describe the level of executive as well as scientific desire for comprehending and strengthening PPM decision-making abilities.

Portfolio decisions are in charge of guaranteeing resource adequacy and agility, and also to better implementing adjustment at the portfolio level rather than the project level [31], [32]. Having said that, PPM decisions depend on limitations in human intellectual ability to assess a number of different data in restricted time. PPM techniques and procedures are created to support these types of decision-making by offering a pure perspective of the project portfolio, making sure that information are obtainable and providing representation strategies and resources to simplify examination of project details [13], [14], [33]. Classic metrics and strategies emphasise efficiency and performance driven by cost, schedule, quality, or scope [34] while they do not examine, monitor, or track portfolios/projects to provide the strategic benefit.

The challenges of the execution and delivery of PPM are related to the uncertainties established by turbulences in the industry, sudden technological variations, and utilisation of uncommon resources shared among the many areas of the organisation [35], [36]. To be able to confirm the possible implementation of the portfolio, PPM needs to visualise options and potential outcomes of project decisions across a portfolio. Decision-making quality is a key element of a successful project portfolio [37]. Organisational achievement relies on proper PPM strategies techniques and tools that enhance the quality associated with these portfolio-level decisions. Projects interconnections together with the activities relations elevate the complexity of PPM decision-making and needs to be regarded alongside financial, strategic, risk, resource and other elements. Portfolios of complex and interdependent projects are significantly common and there is certainly an identified requirement for advanced methods to recognise and handle the associations between projects. Research in portfolio management identifies that decisions are depending on various criteria like product, market, and financial, knowing that over-emphasising a single measure is linked to poorer performance [38], [39].

B. Portfolio Decision-Making Tools

Dealing with a complex portfolio of projects with uncertainty is much more complicated when compared to the classic project management [40] especially throughout the control of project interconnectivities [41], [42] that could be one of the PPM’s shortcomings [43].

Different systems, applications, or methods are frequently presented and analysed in PPM research [15], [44]-[46]. Nevertheless, assessing the impact of a different application or technique is complicated since every single organisational nature is unique and there might be other aspects that affect project efficiency. Despite several studies in organisational environment, a reliable environment within which results can be generalised has not yet been provided.

Several studies indicate that strategic PPM decisions are consumed in group sessions applying graphical applications, however, these tools must to be specially developed or modified according to individual organisations needs or desires for highly valuable decisions [14], [47]-[52]. For example, portfolio maps provide projects and their options on two axes, supported by extra information such as variations and risk [14], [50], [51]. Although these mapping tools offering a portfolio level perspective, they are generally looking at projects independently. On the other hand, project interconnectivities might result in unexpected responses in the procedures [40]-[42], indicates the importance of the projects dependencies to make effective decisions [53], [54]. The use of classic PPM tools is no longer accepted as project portfolio complexity is increasing dramatically and most of projects are no longer considered independently or, if there are independent projects, their independencies should be fully understood for successful decisions [53], [54]. There is a variety of organisations that collect project interconnectivities data, however there is limited ability to use or apply this information or identify multistage dependencies [45], [55]. To meet these challenges, particularly as complexity rises, experts participated in developing different decision-making systems [40]. This research also employs controlled experimentation to test the ability of a decision-making model (AHP) to improve project portfolio decision-making knowledge among PPM decision makers.

C. Multi-Criteria Decision Making (MCDM) Overview

Decision-makers are no longer considering just one single criterion to make a decision. To develop ongoing communication and come up with viable choices, organisations consider multiple criteria in their decision practice. Decision difficulties such as ranking, selection and sorting challenges are sometimes complicated since they often consist of various criteria.

MCDM is a structure for analysing decision issues indicated by complex multiple targets [56], [57]. MCDM also can handle long-term time options, unknown aspects, risks, and complicated value concerns. The MCDM practice generally defines targets, selects the requirements to determine the targets, specifies options, modifies the measure values, assigns weights to the requirements, uses a mathematical algorithm to score options, and selects an option [58]-[61]. MCDM has been employed in different fields such as policy examination [62], [63], food security [64], policy examination [65], resource management [66]-[68], portfolio and financial assets management [69], location selection [70], procurement and best supplier selection [71], forest management [72], evaluation of business units performances [73], health care system [74], finance [75], energy [76], and environmental risk assessment [77].

Currently, there are more than 100 MCDM techniques and methodologies that are used to support decision-making. Each method has its own advantages and disadvantages, and its fitness depends on the situation. Usually portfolios with complex independencies and a large number of criteria or alternatives are managed in a hierarchical format and for the same reason a preferred method requires to support a hierarchical structure. As a result, those MCDM techniques that assume a single level of attributes and not support a hierarchical structure have been omitted.

D. Analytic Hierarchy Process (AHP)

According to [78]: "the human mind uses hierarchies as the prevailing method for classifying what we observe". The AHP method is one such approach that presents a solution to shape key decisions into hierarchies of targets, in addition to evaluate those to support difficult choices, like selection of project portfolios for an organisation. AHP seems to be one of the most popular and appropriate among the remaining MCDM techniques for solving the portfolio decision problems because of its simplicity and applicability to multilevel hierarchies.

AHP, developed in the 1980 [79], is among the most common MCDM methods and is well suited to modelling quantitative considerations and has discovered extensive purposes in so many different fields like preference, assessment, designing as well as improvement and decision-making, etc. [80]. AHP presents the relative priority of particular indicators [81]-[83].

AHP employs hierarchical (or network) system to indicate a decision problem [79]. The system is designed in such a manner that the total goal is at the top level, requirements at the center level(s), and alternatives decisions at the bottom. The AHP approach presents an organised structure for arranging preferences at each level of the hierarchy employing pairwise analysis [84]. The feature vector that is obtained is then compared by determining the matrix elements to find the relative value of the same unit on the different levels and then rank the value of each option [79], [85]. The hierarchical equation first introduced by [86] and practised in [87], [88]. The 1-9 ratios are based on Stevens and Fechner studies [89], [90] which the value of objects in each level is simulated by [91].

TABLE I
COMPARATIVE JUDGMENT TABLE

	Intensity Scale	
Less important than	Extremely less important	1/9
		1/8
	Very strong less important	1/7
		1/6
	Strongly less important	1/5
		1/4
	Moderately less important	1/3
		1/2
	Equal Importance	1
More important than		2
	Moderately more important	3
		4
	Strongly more important	5
		6
	Very strong more important	7
		8
	Extremely more important	9

The AHP method has been widely applied for performance evaluation and used by various researchers to solve different decision-making problems and the growth in AHP-related publications is enormous [80], [92]-[99]. AHP has been employed in many areas like designing, preferencing, optimisation, resource delegation, problem solution, etc. [100].

E. AHP Mathematical Logic and Processes

AHP incorporates decision-makers' inputs and defines a process for decision-making. The AHP method procedure contains the following steps [79]:

a) Decomposition (structuring or construction) of the decision problem into factors in accordance with their characteristics along with the development of a hierarchical model having different levels. The structuring step breaks down a situation into related clusters.
b) Making comparative judgments (measuring or priority analysis). The measuring step compares the relative importance of each factor in a group to each of the other factors of the cluster 'with regard to the parent of the cluster' [101] to obtain the preferences of those aspects.
c) Combining (synthesising or consistency verification): The synthesising step is an AHP advantage and incorporates the measuring step results into a group of mathematically result. AHP combines such outcomes applying accurate mathematical techniques for calculating eigenvectors [102]. In this step, the AHP method receives the priority weights of factors by calculating the eigenvector of matrix A, $w = (w_1, w_2, ..., w_s)^T$, which is related to the largest eigenvalue, $\lambda_{\max}$.

$$Aw = \lambda_{\max} w \tag{1}$$

A is an $n \times n$ pairwise comparison matrix, where n is the number of factors considered for examination. Likewise, matrix B for the priority weights of sub-factors,

$$e_h = (e_{h1}, e_{h2}, ..., e_{hs'})^T .$$

B is an $m \times m$ pairwise comparison matrix, where m is the number of options evaluated.

$$Be_h = \lambda_{\max} e_h \tag{2}$$

Saaty, T. L. [79] described a statistical equation to examine the consistency of the respondent (Consistency index - *CI*):

$$CI = \mu = \frac{\lambda_{\max} - n}{n - 1} \tag{3}$$

where n is the dimension of the matrix and $\lambda_{\max}$ is the maximal eigenvalue.

The Random Index (or Random Indices) (*RI*) is the average of the *CI* for a large number of randomly generated matrices. The values of *RI* for small problems ($n \leq 10$) can be found in Table II, developed by [103].

The Consistency Ratio (*CR*) is a critical function of the AHP which aims to avoid the potential for inconsistency in the criteria weights. To decide if the inconsistency in a comparison matrix is practical the CR is determined by:

$$CR = \frac{\lambda_{\max} - N}{(N-1)RI} \tag{4}$$

The *CR* of less than 0.1 or even slightly above 0.1 is regarded as sufficient [79]. Values greater than 0.1 are found unreliable and in these situations, the comparison scores need to be reconsidered.

TABLE II
RANDOM INDEX FORM

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

III. CASE STUDY

This study used an actual example of the PPM process to investigate the usability, reliability and characteristic of the AHP method in a real portfolio life cycle, and then used it as a baseline in the evaluation process for this research. The selected organisation was working in engineering management industry and dealing with complex construction projects in Australia. The experiment aimed to select the project that would best support portfolio objectives by determining the efficiency of individual projects and combining the measurements which displayed the strategic significance of the member projects. AHP adopted to assess which project would maximise the success and achievement of strategic targets in the organisations portfolio.

We have collected the historical information of five projects decision making time, cost, quality, risk and work health and safety (WH&S) factors. Also, the decisions made by executives on those requirements are studied and utilised to establish a framework of portfolio. Five evaluation criteria (n = 5) and five alternatives (to evaluate) have been considered as input for the AHP evaluation process to describe the AHP mechanism. If more criteria are required to be considered, then this example can be expanded accordingly. The AHP model for our study is illustrated in Fig. 1.

A. Pairwise Comparison

The decision-maker first built the pairwise comparison matrix for the five factors (n=5) and five alternatives to be evaluated (m=5) using the intensity scales presented in Table I comparison judgment table.

$$Aw = \begin{bmatrix} 1 & 3 & 3 & 5 & 2 \\ 1/3 & 1 & 1 & 1 & 1 \\ 1/3 & 1 & 1 & 1 & 2 \\ 1/5 & 1 & 1 & 1 & 1 \\ 1/2 & 1 & 1/2 & 1 & 1 \end{bmatrix} \tag{5}$$

The weight vector $w = (0.431, 0.138, 0.167, 0.127, 0.137)^T$

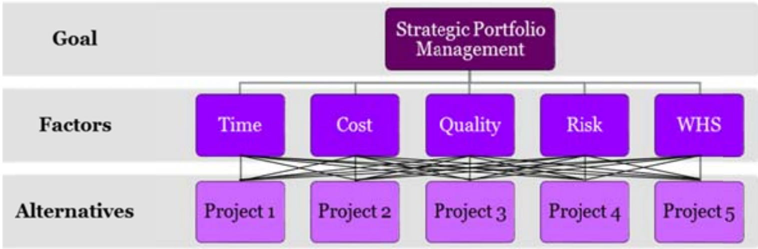

Fig. 1 AHP model

TABLE III
PAIRWISE COMPARISON MATRIX (FACTORS)

Factor	Time	Cost	Quality	Risk	WHS
Time	1	3	3	5	2
Cost	1/3	1	1	1	1
Quality	1/3	1	1	1	2
Risk	1/5	1	1	1	1
WHS	1/2	1	1/2	1	1
Total	**2.367**	**7.000**	**6.500**	**9.000**	**7.000**

B. Normalisation

From the comparison matrix, the priority or weights of each parameter has been calculated (Table IV (A)) by totaling values in each column. Each value is then divided by the total value of the column. For example, considering 'Time' factor, 'Time' value (1) divided by total value of 'Time' column (2.367) gives the value of 0.423; or in the case of 'Cost' factor, 3 / 7= 0.429 and so on.

TABLE IV (A)
PARAMETER WEIGHTS

Factor	Time	Cost	Quality	Risk	WHS
Time	**0.423**	0.429	0.462	0.556	0.286
Cost	0.141	**0.143**	0.154	0.111	0.143
Quality	0.141	0.143	**0.154**	0.111	0.286
Risk	0.085	0.143	0.154	**0.111**	0.143
WHS	0.211	0.143	0.077	0.111	**0.143**
Total	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

TABLE IV (B)
PARAMETER WEIGHTS

Factor	Total (Factors)	Weight Vector	%
Time	2.154	0.431	**43.08%**
Cost	0.692	0.138	**13.83%**
Quality	0.834	0.167	**16.69%**
Risk	0.635	0.127	**12.70%**
WHS	0.685	0.137	**13.70%**

'Total (Factors)' is the total and 'Weight Vector' is the average of all factors in each raw. The total of each column in Table IV (A) must be equal to one (1) otherwise the calculation is not correct. As indicated in Table IV (B), the highest weight vector is 0.431 which is related to the 'Time' factor of projects.

C. Consistency Analysis

Consistency index (*CI*) is calculated through multiplying each pairwise comparison column by the associated weight. The total value of each row is then divided by the identical weight, and by averaging them the $\lambda_{\max}$ value is identified in Table V. The Random Index is selected from Table II (*n*=5, so, *RI*=1.12).

TABLE V
CONSISTENCY MEASURE (FACTORS)

Consistency Measure	
Time	5.236
Cost	5.154
Quality	5.093
Risk	5.159
WHS	5.118
$\lambda_{\max}$	**5.152**

$$\lambda_{\max} = 5.152 \tag{6}$$

$$CR = \frac{\lambda_{\max} - N}{(N-1)RI} = \frac{5.152 - 5}{(5-1)1.12} = 0.034 \tag{7}$$

$$\text{CR} = 3\% \tag{8}$$

$$\text{Consistency} = \text{OK} \tag{9}$$

Priority vectors also applied to each sub-factors (Projects) which are on their own a composite amount of other factors. For instance – in Fig. 1, all factors are composite parameters (Time, Cost, Quality, Risk and WHS). Thus, priority vectors have to be created for all five factors. An example of 'Time' factor is shown in Table VI:

TABLE VI
PAIRWISE COMPARISON MATRIX FOR 'TIME' FACTOR

Time	Project 1	Project 2	Project 3	Project 4	Project 5
Project 1	1	3	1	2	1
Project 2	1/3	1	1	1	1
Project 3	1	1	1	1	1
Project 4	1/2	1	1	1	1
Project 5	1	1	1	1	1
Total	**3.833**	**7.000**	**5.000**	**6.000**	**5.000**

$$Be_{Time} = \begin{bmatrix} 1 & 3 & 1 & 2 & 1 \\ 1/3 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1/2 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix} \tag{10}$$

TABLE VII
CONSISTENCY MEASURE (SUB-FACTORS)

Consistency Measure	
Project 1	5.224
Project 2	5.087
Project 3	5.153
Project 4	5.106
Project 5	5.153
$\lambda_{\max}$	**5.144**

$$\lambda_{\max} = 5.144 \quad (11)$$

$$CR = \frac{\lambda_{\max} - N}{(N-1)RI} = \frac{5.144-5}{(5-1)1.12} = 0.032 \quad (12)$$

$$CR = 3\% \quad (13)$$

$$\text{Consistency= OK} \quad (14)$$

D. Portfolio Summary

Five projects have been scored on the five factors described in Fig. 1. Assigning accurate weight to each element is a key factor that impacts the outcome of this experiment. Table VIII indicates weights and scores of the portfolio in summary.

TABLE VIII
PORTFOLIO SUMMARY

Summary	Time		Cost		Quality		Risk		WHS		Final Score	Final Score
	Weight (w_{Time})	Score (Be_{Time})	Weight (w_{Cost})	Score (Be_{Cost})	Weight ($w_{Quality}$)	Score ($Be_{Quality}$)	Weight (w_{Risk})	Score (Be_{Risk})	Weight (w_{WHS})	Score (Be_{WHS})	**(Be_{Total})**	**(%)**
Project 1	0.431	0.285	0.138	0.337	0.167	0.299	0.127	0.236	0.137	0.191	0.2752	27.52%
Project 2	0.431	0.159	0.138	0.252	0.167	0.199	0.127	0.275	0.137	0.228	0.2029	20.29%
Project 3	0.431	0.194	0.138	0.185	0.167	0.245	0.127	0.179	0.137	0.191	0.1989	19.89%
Project 4	0.431	0.168	0.138	0.114	0.167	0.130	0.127	0.119	0.137	0.225	0.1558	15.58%
Project 5	0.431	0.194	0.138	0.112	0.167	0.127	0.127	0.191	0.137	0.166	0.1672	16.72%

The score matrix B is:

$$Be_{Total} = (Be_{Time}, Be_{Cost}, Be_{Quality}, Be_{Risk}, Be_{WHS}) = \\ = \begin{bmatrix} 0.285 & 0.337 & 0.299 & 0.236 & 0.191 \\ 0.159 & 0.252 & 0.199 & 0.275 & 0.228 \\ 0.194 & 0.185 & 0.245 & 0.179 & 0.191 \\ 0.168 & 0.114 & 0.130 & 0.119 & 0.225 \\ 0.194 & 0.112 & 0.127 & 0.191 & 0.166 \end{bmatrix} \quad (15)$$

As mentioned in Section A (pairwise comparison) and shown in Table VIII, the priority weights of factors have been identified:

$$w = (0.431, 0.138, 0.167, 0.127, 0.137)^T \quad (16)$$

Hence, the final score vector is:

$$v = w.\, e_{Total} = (0.2752, 0.2029, 0.1989, 0.1558, 0.1672)^T \quad (17)$$

As a result, ‘Project 1’ with a total score of 27.52% (as shown in Table IX and Fig. 2) is the project that maximises our portfolio’s strategic targets success.

TABLE IX
PROJECTS RANKING

Projects	%	Rank
Project 1	27.52%	**1**
Project 2	20.29%	**2**
Project 3	19.89%	**3**
Project 4	15.58%	**5**
Project 5	16.72%	**4**

IV. RESULT AND DISCUSSION

A. Identified Advantages

The main function of the AHP method is the utilisation of pairwise comparisons that help decision-makers to weight coefficients and simply examine choices with ideal [104]. It is scalable, which enables it to simply modify in dimension to support decision-making issues as a result of its hierarchical format. AHP can be applied for dealing with decision-making issues in almost any kind of issue. Given that AHP is amongst the very first techniques employed in multi-criteria decision examination, there are a number of tools which make full use of this approach. An additional advantage is the fact that inconsistency in decisions is permitted and is allowed to be assessed [105]. In the event that consistency fails, the eigenvector continues to create a number of priorities which are all acceptable approximation, allowing 10% error [102]. Utilising a Consistence Index, unreasonable results can be eliminated, allowing weights to be identified [106]. Other advantage of AHP is its convenience, flexibility and the capability to verify inconsistencies and analyse a problem where sub-problems are hierarchised applying different factors and making the qualitative index into quantitative index. Therefore, significant and complicated problems with contentious requirements and factors can be considerably simplified. Where quantitative data are restricted, the experts’ decisions to define the weights of the factors as well as the scores of the options could be greatly valuable. AHP is a reliable method for decision procedures and help decision-makers to assess the criteria’s weights and chosen the best alternative [107].

The consistency verification in AHP, allows decision-makers to stay away from unreliable decisions as a consequence of personal judgments. AHP presents a precise and effective strategy for determining the aspect weights which also considers the characteristics of human decision-making. So, inputs from customers and other professionals with regards to the related advantages of the individual factors is employed in the development of the comparison matrix which eventually produced the factor weights. The end result of AHP is weights in the ratio basis that is much more usable and accurate compared to ordinal scales generated by some other methodologies. It is actually less difficult to evaluate the variables/factors two simultaneously and determine their relative benefits (that is just what exactly is conducted in AHP) instead of to evaluate several criteria as well as sub-criteria all together and seek to precisely determine their weight values. AHP is truly very simple to apply and has a consistency checking function included in the method designed to omit the potential inconsistencies discovered in the factors weight.

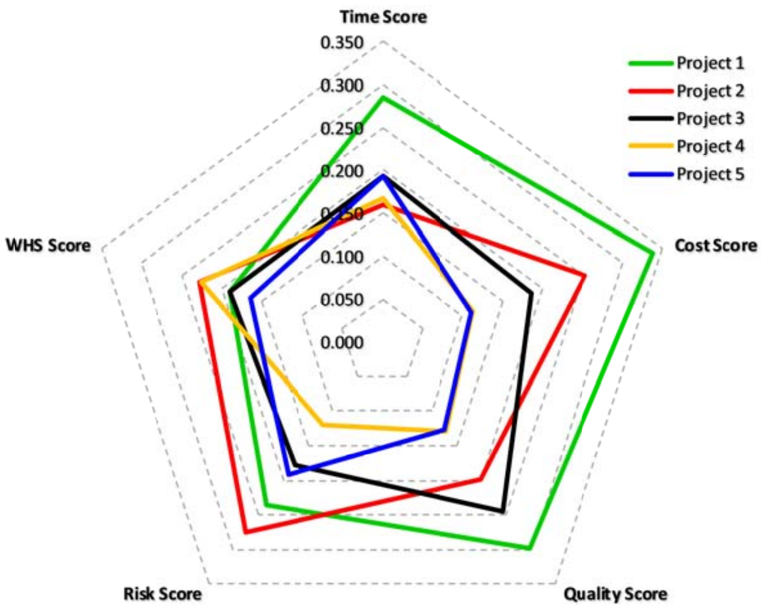

Fig. 2 Projects Ranking Diagram

The broad applicability of AHP results from its functionality, simplicity, and great flexibility, and more importantly it is capable of be incorporated with methods such as mathematical programming to have the ability to evaluate both qualitative and quantitative aspects [98]. Individual acceptability and assurance in the examination offered by AHP is much higher than other decision methods [108]. Apart from being applied as a standalone application, AHP has been combined with several other methods and techniques for many practical functions such as by [109] which investigated a problem employing binary non-linear programming approach.

B. Identified Problems

Even though the AHP is a well-known technique, it possesses a number of disadvantages, and a number of changes have been recommended for improvement. AHP is a subjective method as it depends on the opinions of experts [106]. In addition, its approach has issues associated with the interdependency between criteria and alternatives. Given that the AHP technique depends on setting up priorities between criteria and alternatives employing pairwise reviews, it just facilitates quantitative values as input values to matrices (i.e. qualitative values, and missing data are not verified using this method). The downside of employing AHP might also be the ability to employ a restricted number of criteria. As it is crucial to perform $n\times(n-1)/2$ analysis it is recommended not to use more than 10 criteria.

One of AHP's biggest criticisms is that the method suffers from the rank-reversal problem. As a consequence of the comparisons of ratings, adding up options towards the end of the practice may result in the finalised ratings to reverse. There are some publications in the area of project management, [110]-[112] that criticise AHP model as not following rank-reversal scenarios, in which the ranking of options identified by AHP might possibly be modified by the adding up of a different option for evaluation. Ranks could potentially be reversed when an irrelevant alternative is added to the existing alternatives. Even so, several researchers state that the rank reversal issue can be resolved without making an adjustment to the scores of the current options [113]-[115]. Moreover, one other criticism is the fact that AHP is not an axiomatic structure and the large number of pairwise reviews of the options could make the application of AHP a lengthy task. In the AHP approach, an aspect is compared against the best factor so the finalised selections will only be evaluated.

There are a number of researchers who presented a variety of ways to advance the flexibility of the AHP technique. Boender et al. [116] and Chen et al. [117] added the fuzzy method into AHP. Sugihara and Tanaka [118] as well presented a fuzzy AHP by modifying the simple AHP matrix values into a fuzzy amount to manage the risk in human's decision as well as a number of limited data. Nevertheless, none at all had given a manageable parameter to make the selection of the weightings variable. Generally, the pairwise matrix is not totally consistent due to an excessive number of redundancies in the pairwise reviews. However, as a result of the redundancy in the pairwise reviews, the method is unsupportive to judgmental issues [119].

V. Conclusion and Future Works

To perform PPM effectively, organisations should revise their strategy and prioritise the targets in the strategic plan for effective portfolio decisions. They should map their candidate projects to the objective(s) in addition to prioritise them against all other projects.

Portfolio decisions are complicated [120] and usually require multiple criteria or targets with a great number of requirements as well as capabilities, many of them intangible or involving some level of risk, in an area that may include contradictory goals and contains both quantitative and qualitative factors. The accuracy in estimation of the relevant data through the decision-making practice is essential for the success of the portfolio. Some methods are not able to provide this function where extracting qualitative data from the decision-maker is required. It is desirable that techniques have the capability of handling uncertain, imprecise, or missing information. They need to apply different qualitative and quantitative variables to the portfolio decision-making process.

Yeh [121] stated that AHP technique is very useful once an element hierarchy carries above the three levels. This indicates that, the total aim and target of the problem at the top level, a number of factors which explain options at the center point, and then competing solutions in the end. However, since the portfolio decision-making process may have more than 10 alternatives and criteria, AHP method is not recommended tool to be used alone. AHP do not support missing values and presents consistency in decision given that the consistency index is measured before developing pairwise assessment matrices. Probably the most important steps in decision-making techniques are the precise valuation of the relevant information. This issue is specifically critical in techniques which have to elicit qualitative data from the decision-maker. AHP cannot fulfil this requirement and can only support the values that are quantified. AHP is clearly inferior to other MCDM methods in terms of issue framework since AHP cannot be utilised once several requirements and options are required.

This study has determined that AHP cannot individually support the strategic decision-making for a complex PPM. This review concluded that engaging utilisation of the techniques significantly increases the performance of the planning procedure, considering that it would be better to apply more than only one MCDM technique or even a hybrid method. In particular, a combination of other MCDM methods with AHP appears to be useful; one using quantitative data and the other using qualitative data. Further study can be based on methods that are able to support both quantitative and qualitative information and perhaps an AHP integrated method. However, there are still many questions and limitations which need further investigation. Other requirements like feedback about the quality prediction or reliability/accuracy of the solution also requires further investigations. In order to overcome this problem, future attempts will apply or combine different MCDM theories with AHP to score projects properly. This research can be extended in different ways and the following summarises some of the future directions:

- Applying implemented mixed models,
- Developing a hierarchy profiling model which can combine two models,
- Profiling an integrated model due to extra conformity of such models to the reality.

Then, an executive dashboard of indicators can be proposed as an alternate decision-support tool for decision-makers to measure and track portfolio activities and assess portfolio's performance, risks, inputs, and outputs generated from the proposed model.

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