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FACTORS AFFECT PERFORMANCE MEASUREMENT IN CONSTRUCTION PROJECT PORTFOLIO

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ABSTRACT

Construction companies regularly perform multiple construction projects concurrently. Projects vary by complexity, duration, budget, variety of works, and the number of stakeholders. To determine and report the status of the ongoing portfolio of projects, methodical agreed-upon metrics should be set forth at both projects and portfolio level. The assessment of project indicators during implementation is not an easy task due to the lack of up-to-date data and factors measuring problems. The purpose of the research is to analyze common performance measurement factors, the contribution of those factors to the overall project portfolio performance, and to illustrate how to assess a projects' execution efficiency. A review for the earlier research and studies has been done to name the commonly used factors usually picked to measure the performance of portfolio and project management efficiency. A questionnaire survey conducted to project management professionals exploring their judgment in respect of relative weight contribution to each factor. AHP mathematical model used to analyses the survey responses.

Keywords: Construction Project portfolio, Performance measurement, AHP.

1. List of Abbreviations:

AHP: Analytic Hierarchy Process.
PPM: Project Portfolio Management
MEF: Management Efficiency Factor
RAF: Resource Allocation Factor
SAF: Strategic Alignment Factor

CR: Consistency Ratio
PPP: Project Portfolio Performance
PPW: Project Priority Weight
POP: Project Overall Performance
SD: Standard Deviation

2. Introduction

The term portfolio is associated with a collection of financial investment instruments, stocks, and bonds. However, this research does not try to address such types of portfolios. Instead, the area of concern encompasses project portfolio management and is hereafter referred to as PPM. Project Management is a tool for executing an overall organizational strategy. Therefore, it is inadequate to view project management only within the confines of the project. It must be considered within the context of the overall organization and its strategy. [1]. Included in this study is the positioning of project performance measurement of its (i) role in the management of project-related investments, as well as (ii) its role in contributing towards achieving the portfolio strategic objective. This research aims to analyze factors affecting the performance of construction projects.

3. Problem statement

It is shown from previous studies ([2] & [3] [4] [5] [6] [7] [8]) that the failure of any project is mainly related to the problems and failure in performance. Moreover, there are many reasons and factors which contribute to this problem. Many construction projects fail without an early alert to the stakeholders. Besides, performance measurement systems are not effective or efficient to overcome this problem. Construction projects performance problem appears in different directions. Many constructed projects fail in time performance, others fail in cost performance, and others fail in other performance indicators. Therefore, this research will evaluate the factors affecting the performance of construction projects to improve the performance measurement ability of organizations while managing their construction projects in the context of portfolio management.

4. Research Methodology

Research based primarily on a literature review of factors affects project portfolio performance measurement. A conceptual model is proposed (Figure 1) with a two-level measurement, the project management efficiency

performance level, and the project portfolio performance level. The contributions of each factor to the overall performance with each level will be evaluated. The hierarchy of project Portfolio performance factors shown in figure 1.

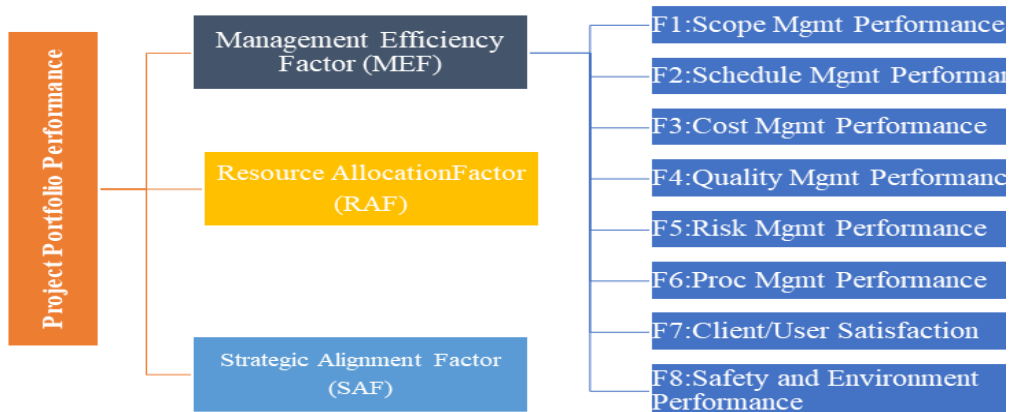


Figure 1: The proposed hierarchy of project Portfolio performance factors

The proposed model will assess the performance of the project portfolio using three performance factors; (1) Strategic Alignment Factor: measures to what extent the project still aligned with the business purpose that originally initiated., (2) Resource Allocation Factor: measures the organization's commitment to the allocation of project required resources. (3) Management Efficiency Factor; measure the overall performance of project management. At a project level, Management Efficiency Factor will be evaluated using eight performance factors: (1) Scope Management Performance, (2) Schedule Management Performance, (3) Cost Management Performance, (4) Quality Management Performance, (5) Risk Management Performance, (6) Procurement Management Performance, (7) Client/User Satisfaction, and (8) Safety and Environment Performance.

The survey questionnaire method used to produce a paired comparison for those factors. (Construction industry). The online survey conducted using an online surveying tool—the survey distributed in an online format through email to experts in the construction industry. Based on survey responses analysis, a comparison matrix constructed. Strategic Alignment Factor: measures to what extent still the project aligned with the business purpose that originally setup. It is determined through a survey of proper project management professionals, business unit managers, and executives. Resource Allocations' Factor: measure to what extent the organization committed to the

allocation of project required resources. Management Efficiency Factor; measure the overall performance of project management.

Table 1 A nine-point scale for AHP analysis Saaty (1994)

Ratings	Definition	Intensity of importance
1	Equal importance	Two criteria/alternatives contribute equally to the objective
2	Weak	Experience and judgment slightly favor one
3	Moderate importance	criterion/alternative over another
4	Moderate plus	Experience and judgment strongly favor one
5	Strong importance	criterion/alternative over another
6	Strong plus	A criterion/alternative is favored very strong over another
7	Very strong importance	
8	Very, very strong	The evidence favoring one criterion/alternative over another
9	Extreme importance	Is of the highest possible order of affirmation

5. Findings and analysis

The experiential study was based on a questionnaire survey targeting construction industry experts. The questionnaire was created by using Lime Survey. The questionnaire was initially sent to more than 30 groups that include thousands of project management professionals; 216 individuals' access to the survey out of this group (40%) fill in the complete survey—the survey organized into three parts. The first section was general questions regarding participants' experience and the environment of their respective organizations. In that part, three sets of questions were included to screen-and classify those interviewed based upon their role and work experience, the project for which they worked, and organization surroundings. Out of 80, the full response, representing the population, (62.77%) responded that they work in the construction industry. Those 62 answers only will be deemed as sample sizes for the subsequent analysis since research is focused on building firms. The respondents show a diversity of the roles they assigned in their organizations with several positions; Consultants (23%), Senior Project Managers/Project Manager/Director (19%), Head of Department (10%), PMO Manager (8%), Portfolio Manager/Director (8%), and other positions like (Business/Operations Manager, Program Manager/Director, Business Change Manager, and Business Unit Director.) (32%). Related to the project(s) durations, 48% of respondents are working on a project with an average duration of over two years, 31% managing projects in duration from

1 to 2 years, 13% are working on projects 3 to six-month average duration. Over half of those responding to the questionnaire (56%) demonstrates that they use General Individual Tools (i.e., Excel Spreadsheets, Word, Email.), and at the same time, managing their projects. Specialized Stand-alone Tools (i.e., Primavera P6 & Ms. Project Standard,) used by 39% of the organizations surveyed. While 40% of organizations use collaboration Tools (i.e., Web-based applications like Primavera P6 EPPM, MS Project Server, SharePoint server etc.., several of the organizations surveyed are using more than one type of tool; hence, the sum of the percentages to well over 100.

The following section examines the factor that is commonly used in organizations to measure Projects Management Efficiency per the respondents' company kind (i.e., the owner (or) owner representative, Architect/Engineer (Consultant), Contractor, Project Management). Figure 2 shows the percentage of surveyed firms in each role.

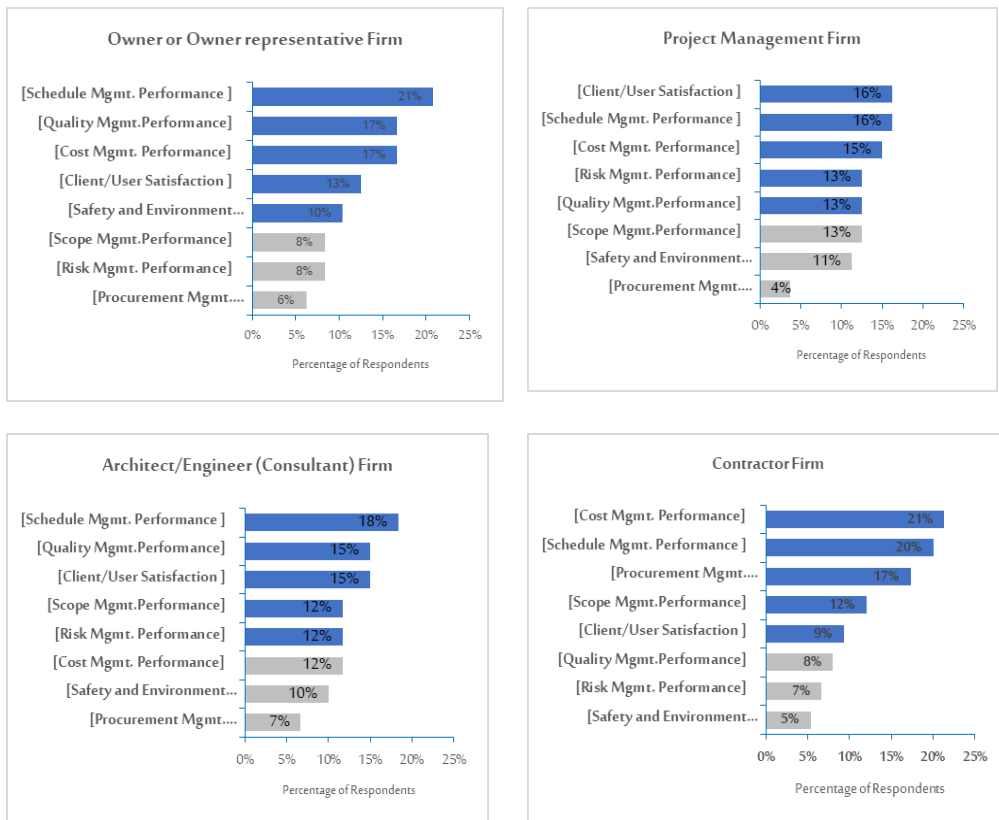


Figure 2: Factors routinely used in respondent's organization to measure Project Management Efficiency according to respondent's firm type

5.1. Calculating the eigenvectors and the consistency ratio (CR) for the Project Management Efficiency Factors

The second part of the questionnaire was to determine the attribution of each management performance factor to the Project Management Efficiency Factors. In AHP this step is the calculation of a list of the relative weights, importance, or value, of the factors, such as cost and operability, which are relevant to the problem in question (technically, this list is called an eigenvector). The final stage is to calculate a Consistency Ratio (CR) to measure how consistent the judgments have been relative to large samples of purely random judgments. As shown in (figure 3), the questionnaire surveys the participants' preferences regarding each factor by pairwise questions.

* With respect to evaluating **Project management efficiency** which of the two factors on each row below is more important, and how important is it?

	-9	-8	-7	-6	-5	-4	-3	-2	1	2	3	4	5	6	7	8	9	
Scope Mgmt Performance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Schedule Mgmt Performance
Scope Mgmt Performance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Cost Mgmt Performance
Scope Mgmt Performance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Quality Mgmt Performance
Scope Mgmt Performance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Risk Mgmt Performance
Scope Mgmt Performance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Procurement Mgmt Performance
Scope Mgmt Performance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Client/User Satisfaction
Scope Mgmt Performance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Safety and Environment Performance

Figure 3: Sample of questionnaires' pairwise questions.

The questionnaire participants (total of 62) respond (individual Pairwise comparison) considered in the analysis. After calculating the respondent with the consistency ratio, $CR < 0.15$ only taken into the aggregation. The rest of the calculations will consider only the 19 respondents ($CR < 0.15$).

Using R¹ and "ahpsurvey²" Package, the (ahp. aggjudge) function has been used to calculate Aggregate individual judgments from pairwise comparison matrices

¹ R is a programming language and free software environment for statistical computing and graphics supported by the R Foundation for Statistical Computing. ([https://en.wikipedia.org/wiki/R_\(programming_language\)](https://en.wikipedia.org/wiki/R_(programming_language)))

² <https://cran.r-project.org/web/packages/ahpsurvey/vignettes/my-vignette.html>

the aggregated (from 19 matrixes) comparison matrix the as displayed in (Table 2).

Table 2 Aggregated comparison matrices for the 19 respondent that has CR<0.15

	Scope Management Performance	Schedule Management Performance	Cost Management Performance	Quality Management Performance	Risk Management Performance	Procurement Management Performance	Client / User Satisfaction	Safety and Environment Performance
Scope Management Performance	1	0.8581695	0.6271082	0.7772655	1.4095902	1.459185	0.681978	1.0442996
Schedule Management Performance	1.165271	1	0.6923826	1.1490066	1.0333958	2.045837	0.6448965	1.0541216
Cost Management Performance	1.5946212	1.4442883	1	1.0579563	1.3904849	1.860183	0.880968	1.3952161
Quality Management Performance	1.2865616	0.870317	0.9452186	1	1.4582142	1.635915	0.7505327	1.0333958
Risk Management Performance	0.7094261	0.9676835	0.7191736	0.6857703	1	1.383942	0.6850265	0.9504747
Procurement Management Performance	0.6853139	0.4887974	0.5375814	0.6112788	0.7225735	1	0.5116322	0.7354836
Client / User Satisfaction	1.4663229	1.5506364	1.135115	1.3323869	1.4597975	1.954529	1	1.0298915
Safety and Environment Performance	0.9575796	0.9486572	0.7167349	0.9676835	1.0521059	1.35965	0.9709761	1

Aggregate priority weights (Compute and aggregate individual priority weights from pairwise comparison matrices). The individual preference weights are computed using the Dominant Eigenvalues method described in Saaty (2003) [9]

Table 3 Project Management Efficiency Factors aggregated contributions and stander deviation

Factor	Scope Management Performance	Schedule Management Performance	Cost Management Performance	Quality Management Performance	Risk Management Performance	Procurement Management Performance	Client / User Satisfaction	Safety and Environment Performance
Aggregated Preferences	0.120746 3 12.07%	0.124456 4 12.45%	0.153042 6 15.30%	0.123921 1 12.39%	0.105667 2 10.57%	0.077990 9 7.80%	0.158972 15.90%	0.135203 5 13.52%
SD	0.081044 4	0.077126 0	0.102975 8	0.056995 5	0.060373 6	0.04696	0.090757	0.104686 2

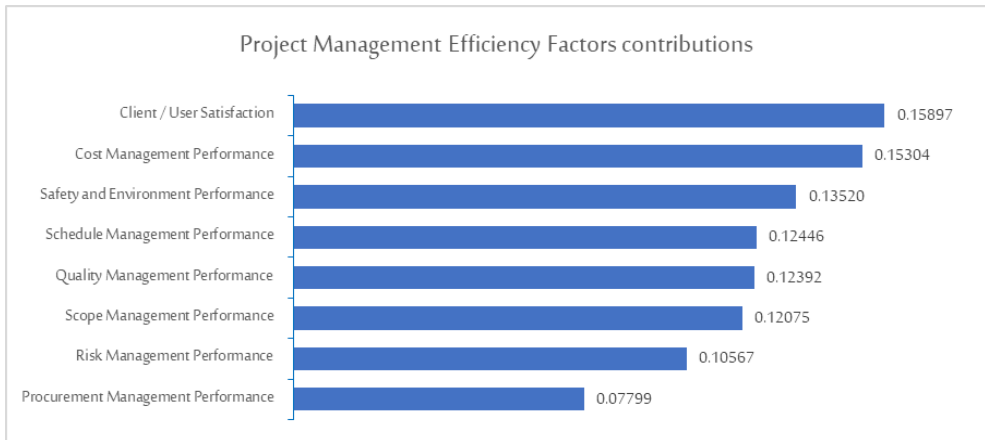


Figure 4 The contribution of each factor to the Project Management Efficiency.

5.2. Calculating the eigenvectors and the consistency ratio (CR) for the Project Portfolio Performance.

The last part of the questionnaire was to calculate the overall Project Portfolio Performance, and the following three factors have been considered.

- 1- Strategic Alignment Factor: measures to what extent the project still aligned with the business purpose that initially initiated.
- 2- Resource Allocation Factor: measures the organization's commitment to the allocation of project required resources.
- 3- Management Efficiency Factor; measure the overall performance of project management.

Part 3 of the questioner was to collect individuals' Pairwise comparison for these factors.

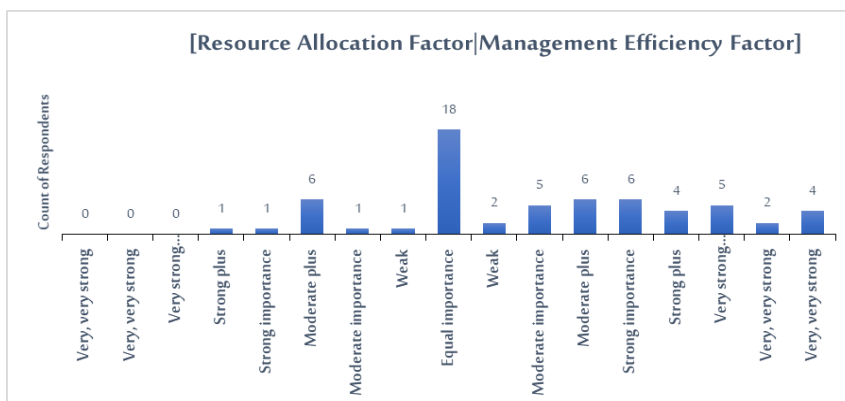


Figure 5 Respondent count for the comparison weight of Resource Allocation Factor and Management Efficiency Factor

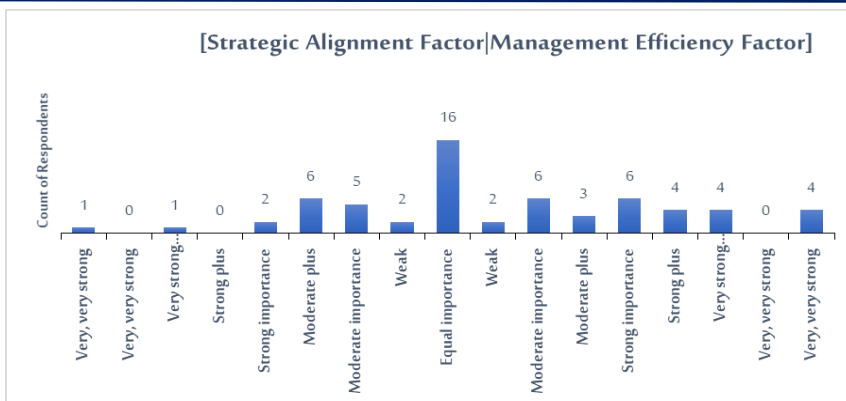


Figure 6: Respondent count for the comparison weight of [Strategic Alignment Factor and Management Efficiency Factor]

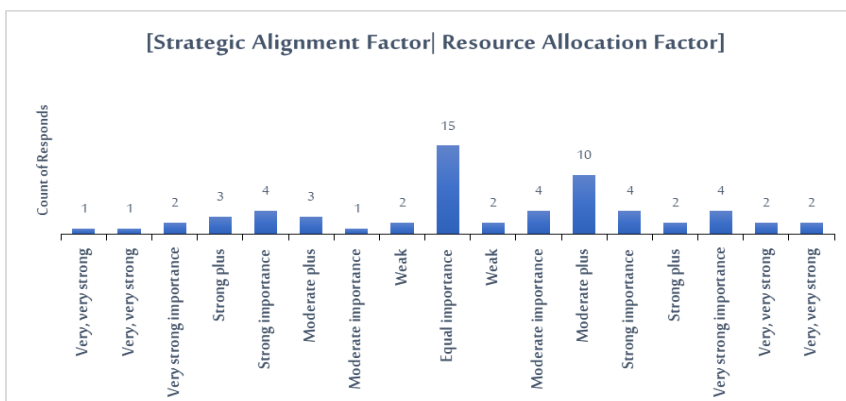


Figure 7: Respondent count for the comparison weight of Strategic Alignment Factor and Resource Allocation Factor

Based on it and using R, the Individual priority weights of the decision-makers have been calculated for each. Finally, the CR for each respondent calculated. Moreover, as per Saaty, all Respondent with $Cr > 0.1$ removed from the following calculation. Only 21 out of 62 responses have $Cr < 0.1$ and will be used for the rest of the analysis. Using R and "ahp survey" Package, the (ahp. aggjudge) function has been used to calculate Aggregate individual judgments from pairwise comparison matrices

Table 4 Aggregated comparison matrices for the 21 respondents with $CR < 0.1$

	Strategic Alignment	Resource Allocation	Management Efficiency
Strategic Alignment	1.00	1.385757	0.8642102
Resource Allocation	0.721627	1.00	0.5820066
Management Efficiency	1.157126	1.718194	1.00

Aggregate priority weights (Compute and aggregate individual priority weights from pairwise comparison matrices). The individual preference weights are computed using the Dominant Eigenvalues method described in Saaty (2003)

Table 5 Project Portfolio Performance factors aggregated contributions and stander deviation (SD)

Factor	Strategic Alignment	Resource Allocation	Management Efficiency
Aggregated Preferences	0.348418415 (34.84%)	0.245974109 (24.60%)	0.405607476 (40.56%)
SD (Aggregated Preferences)	0.172259257	0.118605593	0.178519659

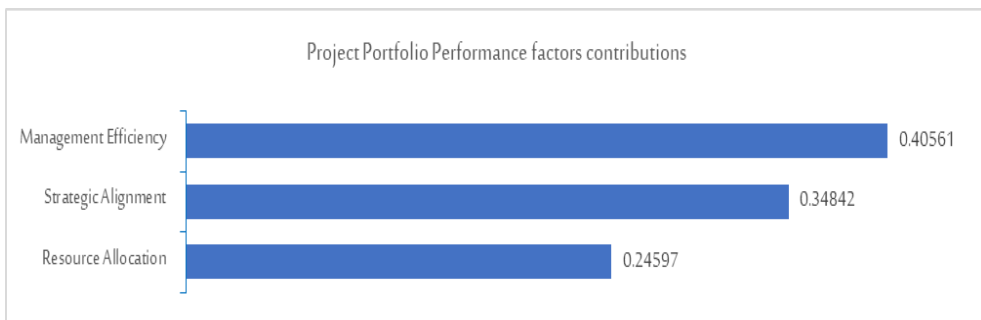


Figure 8 The contribution of each factor to the Project Portfolio Performance.

5.3 Formulating Project Portfolio Performance (PPP) as a multi-attribute utility function in linear additive form

The calculation of Project portfolio performance (PPP) will go through two main steps:

5.3.1 Calculating the project management efficiency factor (MEF) for each portfolio component (project):

As presented in the previous section, the result of the AHP analysis gives us the contribution of each project management efficiency factor to the overall project management factor. Table 6.

The $P_{n Fi}$ to be calculated as agreed by the organization, And the below equation will use to calculate the Management Efficiency Factor (MEF):

$$\text{Management Efficiency Factor (MEF)} \quad P_{n MEF} = \sum_{i=1}^8 w_{Fi} P_{n Fi}$$

Figure 9 & 10 shows the output report scheme at project level using the research result. The upper and lower thresholds limit can be the same or different for each factor.

Table 6 Management Efficiency Factors (MEF) Contribution to the projects

Portfolio Components	Management Efficiency Factor (MEF)	Scope Mgmt. Performance (F1)	Schedule Mgmt. Performance (F2)	Cost Mgmt. Performance (F3)	Quality Mgmt. Performance (F4)	Risk Mgmt. Performance (F5)	Proc Mgmt. Performance (F6)	Client/User Satisfaction (F7)	Safety and Environment Performance (F8)
		12.07%	12.45%	15.30%	12.39%	10.57%	7.80%	15.90%	13.52%
P ₁	P ₁ MEF	P ₁ f ₁	P _n f ₂	P _n f ₃	P _n f ₄	P _n f ₅	P _n f ₆	P _n f ₇	P _n f ₈
P ₂	P ₂ MEF	P ₂ f ₁	P ₂ f ₂	P ₂ f ₃	P _n f ₄	P _n f ₅	P _n f ₆	P _n f ₇	P _n f ₈
P _n	P _n MEF	P _n f ₁	P _n f ₂	P _n f ₃	P _n f ₄	P _n f ₅	P _n f ₆	P _n f ₇	P _n f ₈

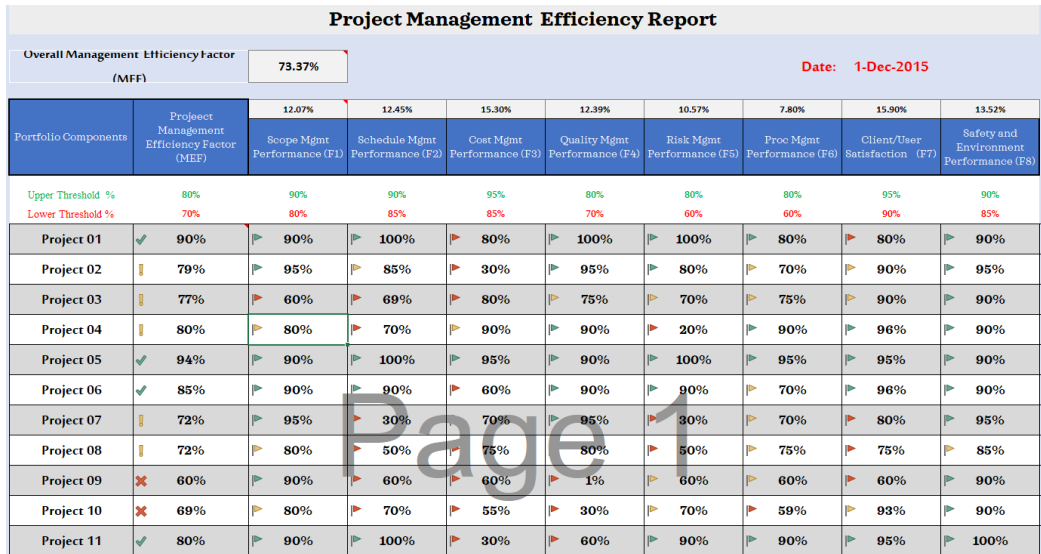


Figure 9: Output report scheme at project level

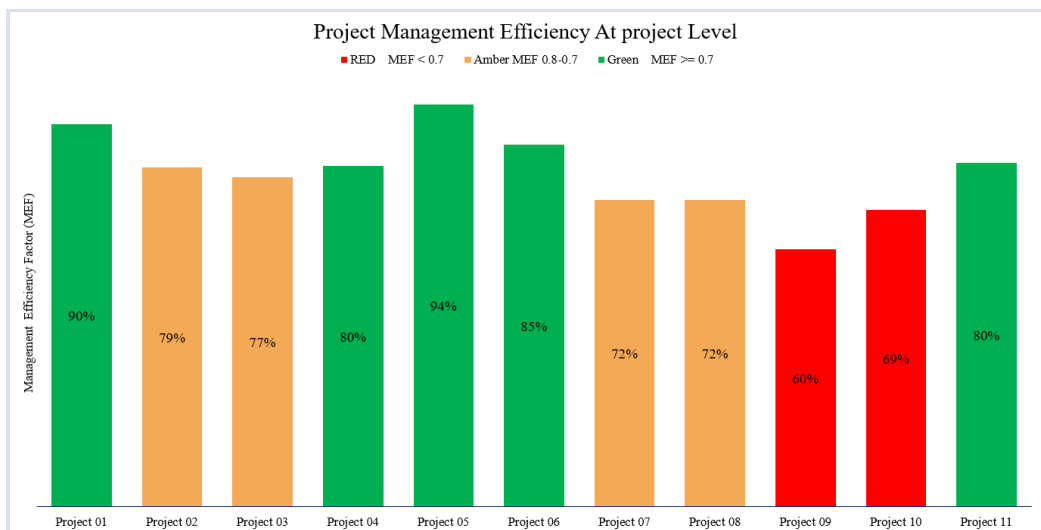


Figure 10: Project Management efficiency.

5.3.2 Calculating the overall project performance (POP) for each portfolio component (project):

The portfolio Project portfolio performance factors that contribute to the overall performance of the project has been calculated. (Table 7)

Table 7 Project portfolio performance factors contribute to the overall performance of the project.

Portfolio Component s	Project Priority Weight (PPW)	Project Overall Performance (POP)	Strategic Alignment Factor (SAF)	Resource Allocation Factor (RAF)	Management Efficiency Factor (MEF)
			34.84%	24.60%	40.56%
P ₁	P _{1 PPW}	P _{1 POP}	P _{1 SAF}	P _{1 RAF}	P _{1 MEF}
P ₂	P _{2 PW}	P _{2 POP}	P _{2 SAF}	P _{2 RAF}	P _{2 MEF}
P _n	P _{n PW}	P _{n POP}	P _{n SAF}	P _{n RAF}	P _{n MEF}

The $P_{n SAF}$ & $w_2 P_{n RAF}$ to be calculated as agreed by the organization, And the below equation will use to calculate the Project Overall Performance at portfolio level:

Equation 1 Project Overall Performance $P_{n POP} = w_1 P_{n SAF} + w_2 P_{n RAF} + w_3 P_{n MEF}$

5.3.3 Calculating the Project Portfolio Performance (PPP)

The last step is the Project Portfolio Performance (PPP), and the below formula will be used

Equation 2 Project Portfolio Performance $PPP = \sum_{i=1}^n P_{i PPW} \times P_{i POP}$

The final output report scheme at the portfolio level shown in Figures 11 & 12. The upper and lower thresholds limit can be the same or different for each factor. The Red, Yellow, and green method is used in the dashboard (Green = good, Yellow = caution, Red = bad). Also, the weight of each project can be considered as the column project priority weight (PPW) used for this purpose.

Portfolio level Performance Measurement Report						
Project Portfolio Performance (PPP)		83.57%	Date: 1-Dec-2015			
Portfolio Components	Project Priority Weight (PPW)	Project Overall Performance (POP)	34.84%	24.60%	40.56%	
			Strategic Alignment Factor (SAF)	Resource Allocation Factor (RAF)	Management Efficiency Factor (MEF)	
Upper Threshold %		95%	90%	80%	90%	
Lower Threshold %		80%	75%	70%	85%	
Project 01	500	90%	90%	90%	90%	
Project 02	500	79%	70%	90%	79%	
Project 03	300	80%	78%	90%	77%	
Project 04	100	87%	90%	98%	80%	
Project 05	500	95%	95%	95%	94%	
Project 06	200	81%	70%	90%	85%	
Project 07	100	71%	70%	70%	72%	
Project 08	100	74%	75%	75%	72%	
Project 09	100	60%	60%	60%	60%	
Project 10	200	72%	59%	93%	69%	
Project 11	200	91%	100%	95%	80%	

Figure 11 Output report scheme at portfolio level

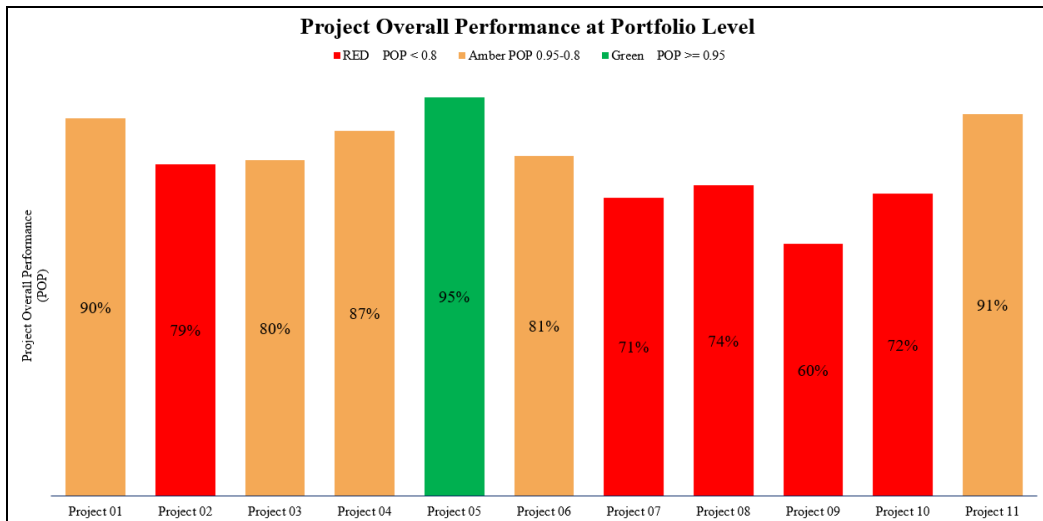


Figure 12: Project overall Performance at the portfolio level.

6. Conclusion

The emphasis of the research focused on the projects that are already selected and assigned to a specific portfolio and strive for identifying the performance and developing reporting structure that is applicable to current industry practice. Based on a questionnaire survey targeting construction industry experts, the study was performed. At the project level, the eight Project Management Efficiency factors listed during the literature review; Scope Management Performance (12.07%) with standard deviation (0.0810444) ,

Schedule Management Performance (12.45%) with SD (0.0771260), Cost Management Performance (15.30%) with SD (0.1029758), Quality Management Performance(12.39%) with SD (0.0569955), Risk Management Performance(10.75%) with SD (0.0603736), Procurement Management Performance(7.80%) with SD (0.04696), Client/User Satisfaction(15.90%) with SD (0.090757), and Safety and Environment Performance(13.52%) with SD (0.1046862).

At the portfolio level, The last part of the questionnaire was to calculate the overall Project Portfolio Performance; the following three factors have been considered;(1)Strategic Alignment Factor (34.84%) with SD (0.172259257); measures to what extent the project still aligned with the business purpose that initially initiated.,(2)Resource Allocation Factor (24.60%) with SD (0.118605593); measures the organization's commitment to the allocation of project required resources.,(3)Management Efficiency Factor (40.56%) with SD (0.178519659); measure the overall performance of project management.

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العوامل المؤثرة على قياس اداء حافظات المشروعات الإنشائية

الملخص العربي:

عادة ما تقوم شركات التشييد بتنفيذ مجموعة من المشاريع في نفس الوقت ضمن برامج أو محافظ مشاريع محددة، لتحقيق هدف استراتيجي معين. تختلف المشاريع الإنشائية حسب درجة التعقيد ومدة التنفيذ والميزانية وتنوع الأعمال وعدد أصحاب المصلحة لكل مشروع. لتحديد حالة المشاريع الجارية ومتابعة مدي تقدمها، يجب تحديد مقاييس الاداة المنهجية والتي يتم الاتفاق عليها لكلاً من المشروع ومجموعة المشاريع او البرامج التي تقع ضمن محفظة مشاريع محددة. من خلال مراجعة الابحاث السابقة وعمل استبيان لمجموعة من ذوي الخبرة في مجال التشييد والبناء ومن ثم تحليل نتائج الاستبيان باستخدام نموذج التحليل الهرمي AHP، قام البحث بتحليل عوامل قياس الأداء الشائعة، ومساهمة هذه العوامل في الأداء العام لحافظة المشروعات. وأيضاً تم توضيح كيفية تقييم كفاءة تنفيذ المشروع باستخدام النموذج المقترح بناءً على نتائج الدراسة.