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PERFORMANCE EVALUATION MODEL FOR ENGINEERING, PROCUREMENT AND CONSTRUCTION PROJECTS USING PERFORMANCE PRISM FRAMEWORK

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***Abstract*—Large construction projects like Engineering, Procurement and Construction (EPC) projects consist of multiple stakeholders in which the functions of each of the stakeholder plays an integral part in the successful completion of the project. Performance prism is one of the recent performance evaluation frameworks that enable to assess the performance of each stakeholder in the project thereby assessing the performance of the whole project. This study was conducted with an aim to establish a performance evaluation model for EPC projects in Kerala using Performance prism framework combined with Analytical Hierarchy Process (AHP) tool. A list of performance indicators relevant for evaluation of EPC projects in Kerala were identified from literature review. AHP tool was used to prioritize the indicators which were divided into five different stakeholder categories as per performance evaluation framework. From the results, it was seen that, client and contractor is two of the most important stakeholder categories of EPC projects along with its sub – indicators.**

Keywords—Performance evaluation, Engineering, Procurement and Construction (EPC), Performance prism, Analytical Hierarchy Process (AHP)

I. INTRODUCTION

The most frequent problem that usually arises within the construction projects is its budget or schedule overruns. Budget and schedule overruns in large construction projects can bring out huge crisis in the economic sector of the country. In order to analyze and evaluate these problems, construction projects largely need performance evaluation processes. Project performance evaluation in the construction industry mainly deals with measuring the efficiency and effectiveness of construction activities in a project. It helps to identify whether a project is a success or a failure by its continuous monitoring and by finding out any deviations from the pre-defined objectives. If any deviations are found out, then remedial measures can be taken appropriately. It involves a proper combination of the indicators of project performance, evaluation methods, evaluation team, result interpretation and rectification of errors.

Traditional performance evaluation frameworks like Earned Value Method (EVM) are based on the budget and schedule constraints alone. Those evaluation frameworks are designed to check whether there occurred any budget or cost overruns in the project. Even with the presence of those performance evaluation methods, the construction projects are susceptible to failures occurring due to these two constraints. It shows that there lacks a proper performance evaluation technique that can bring change to the whole working mechanism of the project instead of concentrating only on the budget and schedule constraints and also allows to correct the defects occurring during construction at the right time. Newly emerging performance evaluation models use various other parameters as the basis for evaluation like stakeholder satisfaction, business growth and health and safety considerations. By taking such parameters as the basis for evaluation, the projects can be monitored at the organizational level itself and some problems can be eliminated even before they occur (Wadugodapitiya et al., 2010).

Bassioni et al. (2004) discusses about the features and implementation of performance measurement frameworks used in the UK construction firms. The dissatisfaction with the traditional financial based performance measurement systems lead to the origin of other methods such as Balanced Scorecard (BSC), quality based excellence model like the European Foundation for Quality Management (EFQM). These methods can not only be used for a project level evaluation but also for an organizational level performance evaluation. In a similar manner, Lop et al. (2018) conducted a study to find out the strengths and weaknesses of existing performance evaluation techniques in the Malaysian construction industry like BSC, EFQM, Malcolm Baldrige for performance excellence, Performance Prism and Key Performance Indicator (KPI) systems. The authors classified each project evaluation models according to the type of construction projects for which it can be used. Deli et al. (2012) and Liu & Jiang (2019) have also carried out studies related to existing project evaluation models. The former study was based on EFQM model for PPP projects whereas the latter was about the effect of changes in scope and quality on the cost and schedule of the project using Earned Value Method (EVM). Balubaid & Alamoudi (2015) explained the process of Analytical hierarchy Process (AHP) as a prioritizing and decision making tool. The method was explained through an example in which AHP was used for decision making in contractor selection for a construction project. Wadugodapitiya et al. (2010) also used AHP process in combination with BSC model to formulate a building performance evaluation model. AHP was used to prioritize the indicators which were evaluated using BSC model.

In developing countries, construction contracts are mostly awarded through lowest bidder technique and studies show that this technique will not always guarantee success for the project. Deep et al. (2018) conducted a study to find out the critical factors that affected the performance efficiency of contractors selected through such modes for state funded projects. The consultant's influence was mainly found to be impacting the contractor performance. Critical success factors (CSFs) were also found out by El – Abidi et al. (2019) for the smooth implementation of Industrialized Building System (IBS) in Malaysian construction industry. 15 CSFs were identified and classified into five categories which were finally prioritized using AHP tool. Abbasi et al. (2020) determined the root causes of delay in construction projects in the Iran construction sector by representing them in the form of Ishikawa diagram (fish bone diagram) by dividing them into eight categories. Contractor's financial problem was found as the leading cause of delay and the authors also proposed some solutions for these delays in the paper.

This paper explains a performance evaluation model for EPC construction projects that takes construction as well as organizational management factors into consideration. For projects delivered through EPC modes, a large number of stakeholders will be involved in the different processes. So for such projects, while evaluating the performance, it is desirable to evaluate the performance of all the key stakeholders of the project. Therefore, this paper identifies performance indicators for EPC projects in Kerala that can be used to evaluate the performance of various stakeholders in the project. Out of the existing evaluation models, Performance Prism framework is used for evaluation and Analytical Hierarchy Process (AHP) is used to prioritize the indicators.

II. ENGINEERING, PROCUREMNT AND CONSTRUCTION PROJECTS

Engineering, Procurement and Construction (EPC) is a type of construction contract in which a contractor arranged by the client holds the responsibility for the design, procurement, construction as per the client's required specifications and handing over of the project for a pre - fixed budget and schedule. On failing to deliver the project on the fixed date of completion or for fixed budget makes the EPC contractor to bear the liability. As explained by Solabannavar and Jamadar (2017), some of the key features of EPC model are mentioned below:

- The client has to engage with only the EPC concessionaire
- The EPC concessionaire must deal with the rest of the personnel like contractors, sub – contractors and so on and must take most of the final decisions related to project execution
- All the risks related to the project execution can be transferred to the EPC concessionaire from the client
- The client has to put minimum efforts and less strain in the project but on the other side, they has only limited participation and control over the project

Solabannavar & Jamadar (2017) explained EPC as a common type of contract suitable for large infrastructure projects in which EPC contractor will design the facility, procure materials and equipments and constructs the facility which will then be returned to the owner. The authors compared PPP and EPC projects by stating their advantages and disadvantages. Leading EPC concessionaires in India were also mentioned in the paper. The factors that affect the success of EPC projects were also studied by different researchers. Habibi et al. (2018) studied about different cost and schedule related performance indicators for EPC projects in a stage wise manner (engineering stage, procurement stage and construction stage). They found that design changes was the main factor that caused delay and cost overrun in the engineering and construction phase whereas resource shortages delayed the project and price fluctuations increased the project cost in the procurement phase. Change order driven by owner in the engineering stage was proven to be the most important factor in causing schedule and cost overrun in EPC projects by Habibi et al. (2019) as he studied the impact of each performance indicator in EPC projects by classifying them into the three EPC phases and then prioritizing them using Epsilon - squared effect size technique to find their weight impacts. Some best practices for the construction industry to reduce cost and schedule overrun were also proposed by the authors. Similarly the stage wise performance indicator classification was also conducted by Kabirifar & Mojtahedi (2019). The indicators were the ranked using TOPSIS method which is a multi - attribute group decision making tool. From the study, engineering design, project planning and controls are the most significant indicators followed by construction and procurement stage respectively.

Implementation of affordable housing scheme in developing countries through PPP mode and their CSFs were studied by Alteneiji et al. (2020). This study was conducted with an aim to find out the factors that can increase private sector participation in providing housing. 30 CSFs for PPP projects were ranked according to their frequency of occurrence in the past literatures in which political support and stability stood first followed by trust and openness among the different stakeholders. Choi et al. (2020) examined and compared the effect of timing of change orders in the cost and schedule performance of Design – Build (DB) and Design – Bid – Build (DBB) projects. As a result, DB projects found to be outperforming DBB projects in terms of schedule but cost performance was almost same for both.

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III. Research Methodology

The study involves the collection of performance indicators relevant for EPC projects in Kerala which are to be identified from from extensive literature review. These indicators would then be shortlisted by conducting a pilot survey and informal discussions with some construction officials who are experienced in the implementation of EPC projects. The next step is to classify the shortlisted indicators using Performance Prism framework. In this study, five important categories of stakeholders of EPC projects namely, client (S1), contractor (S2), employees (S3), material and equipment suppliers (S4) and the end – users (S5) are considered. The indicators would then be classified into the five facets (F_1 – F_5) of Performance Prism framework for all the five stakeholder categories. The prioritization of the five categories of indicators will then be conducted using Analytical Hierarchy Process (AHP) tool. Using this tool, an AHP questionnaire survey was conducted in this study for each of the stakeholder separately showing the classification of indicators into different facets of Performance Prism framework. The survey questionnaire meant for clients was then given to some of the experienced people working among the client side and the questionnaire for contractors was given to some of the leading EPC contractors in Kerala. Likewise the questionnaire for employees, material suppliers and users were given to some of the experienced people in the respective categories. These weighted indicators can be applied to find the performance of a real time EPC project in Kerala.

A. Analytical Hierarchy Process

Analytical hierarchy process (AHP) is a prioritizing and decision making tool which uses mathematical calculations developed by Thomas L. Saaty in 1971 (Wadugodapitiya et al., 2010). The basic framework of AHP tool consists of three parts: the ultimate objective or the purpose for which AHP is used, criteria for judgement and the set of alternatives. AHP quantifies each criterion and each alternative for decision making in three stages: Pair wise comparison, Normalize the comparison and Consistency calculation. As per the calculations, only those samples with consistency values below 0.1 are to be accepted for further study. Otherwise, repeated survey must be conducted to make the value less than 0.1.

B. Performance Prism framework

Performance prism is the most recent performance measuring framework out of the existing, which was developed by Professor Andy Neely and Professor Chris Adams in 2001 to meet the stakeholder requirements in a project. Every large construction projects especially those implemented though Public – Private Partnership (PPP) or EPC mode will have numerous stakeholders and all of them need to be considered equally along with the organization's processes, strategies and capabilities for better performance of the project. This is what forms the basis for performance prism method. Performance prism comprises of five inter-related facets of measurement as shown in fig.1 which can be explained as (Liu et al., 2017):

- Stakeholder satisfaction – it identifies the key stakeholders of the project and their wants and needs
- Strategies – it decides the strategies that the organization must put in place to satisfy the stakeholder's wants and needs while satisfying its own requirements
- Processes – it identifies the processes that need to be operated in the organizational level to execute the strategies decided
- Capabilities – it evaluates the capabilities needed for the organization for operating the processes
- Stakeholder contribution – it demands the needs and wants of the organization from the stakeholders in return for the successful implementation of the project

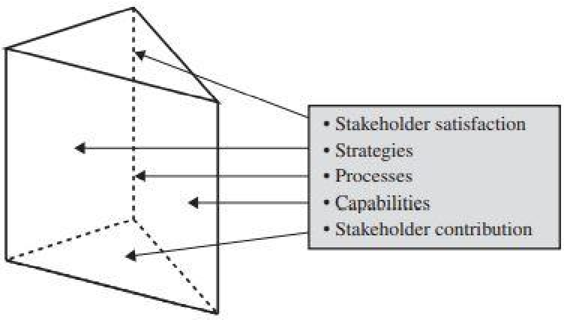

Fig. 1. Representation of Performance prism framework (Liu et al., 2017)

Neely et al. (2001) introduced Performance Prism framework for the purpose of performance evaluation of projects. The authors elaborate the five facets of the method and its usage in practical situations. The application of this method is not only restricted to the construction industry and therefore case studies which uses performance prism for performance evaluation have been explained in the paper.

Performance prism was introduced to replace the quality based excellence model and BSC model as they are vague and does not take into account the important parameters like a wide range of stakeholders and their partnership. Liu et al. (2014) and Liu et al. (2017) examined the usage of Performance Prism method for the ex – ante evaluation of PPP projects and the core performance indicators of PPP projects under each of the five facets were also determined.

IV. RESULTS AND DISCUSSIONS

After conducting extensive literature review, 95 performance indicators were found relevant for EPC projects. Since framing an evaluation model with all these 95 indicators was found difficult, these were shortlisted using a pilot survey and some informal discussions with construction officials. The pilot survey was conducted with around five professionals who were highly experienced in EPC project implementation in Kerala. The questionnaire for the pilot survey was developed by means of a 5 point likert scale in which 1 represented not significant indicator and 5 represented most significant indicator. From this survey, the indicators that got an average rating of 3 or more was shortlisted which reduced the number of indicators to 45 which are shown in Table 5.1. These 45 indicators were then divided into five facets of Performance Prism framework for each of the stakeholder in which each facet consisted of maximum of four to five indicators, in order to conduct the AHP survey.

TABLE I. SHORTLISTED PERFORMANCE INDICATORS FOR EPC PROJECTS

Sl. No.	Performance Indicators
F_1 1	Client's satisfaction for time, cost & quality
F_1 2	Contractor's satisfaction for time, cost & quality
F_1 3	Employee's satisfaction for time, cost & quality
F_1 4	Supplier's satisfaction for time, cost & quality
F_1 5	User's satisfaction for time, cost & quality
F_1 6	Profitability of the project
F_1 7	Appropriateness of the project size & location
F_2 8	Performance level of the service provided
F_2 9	Value for money for the project
F_2 10	Health, safety & environmental impact of the project
F_2 11	Technology diffusion in engineering, procurement & construction stages
F_2 12	Technology diffusion in material supply & management
F_3 13	Competitiveness & transparency in the procurement process
F_3 14	Effectiveness in communication and coordination between the stakeholders
F_3 15	Appropriateness of the contract criteria for the project
F_3 16	Provision of payments on time for completed work by the client
F_3 17	Effectiveness of facility maintenance and management
F_3 18	Efficiency of risk management (identification, analysis & allocation)
F_3 19	Appropriateness in the budget and schedule estimates
F_3 20	Degree of site management and supervision

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F_3 21	Claim and dispute management
F_3 22	Degree of project team work and partnerships
F_3 23	Transportation of materials and equipments on time
F_3 24	Appropriateness of supply contract criteria
F_4 25	Efficient TCQ & material management system
F_4 26	Favorability and efficiency of the legal framework
F_4 27	Financial stability of the client
F_4 28	Prior experience of client & EPC contractor
F_4 29	Reputable developer / strong and good private consortium
F_4 30	Presence of skilled working personnel (employees)

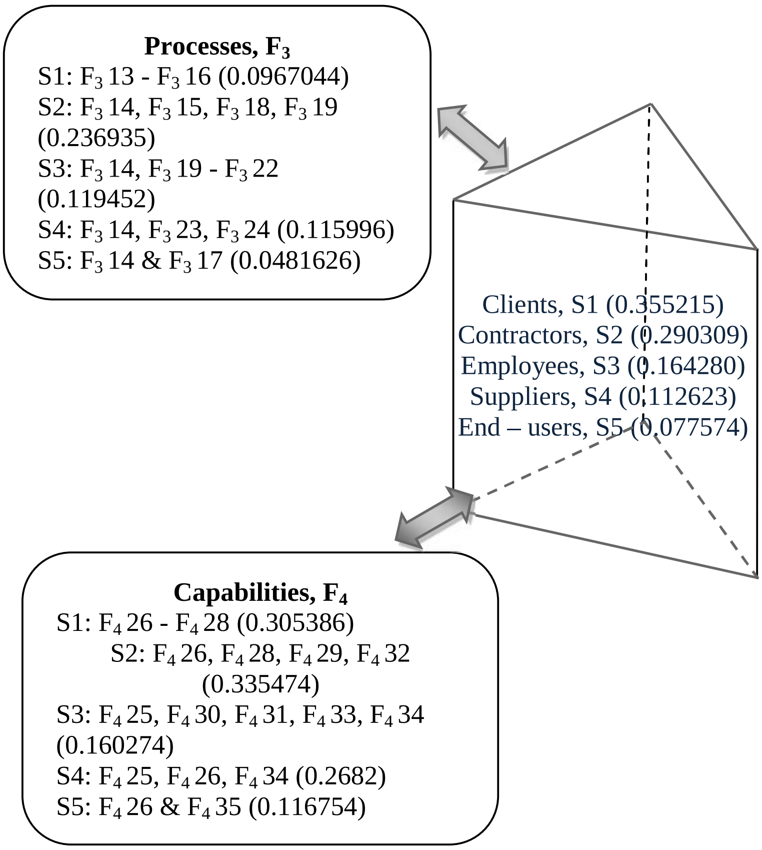

Fig. 2. Performance evaluation model developed using Performance Prism framework

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Sl. No.	Performance Indicators
F_4 31	Use of advanced planning and scheduling techniques
F_4 32	Financial stability of the EPC contractor
F_4 33	Capability for right selection of project teams
F_4 34	Sufficient availability of good quality construction materials, equipments and skilled labour for the project
F_4 35	Knowledge about the project for the users
F_5 36	Client's willingness to active participation
F_5 37	Client's contribution to contractor selection
F_5 38	Contractor's willingness to active participation
F_5 39	Contractor's overall performance
F_5 40	Employee's willingness to active participation
F_5 41	Employee's overall performance
F_5 42	Supplier's willingness to active participation
F_5 43	Supplier's overall performance
F_5 44	User's willingness to the infrastructure use
F_5 45	Presence of supporting & understanding community

Stakeholder satisfaction, F_1
S1: F_1 1, F_1 6, F_1 7 (0.257315)
S2: F_1 2, F_1 6, F_1 7 (0.089551)
S3: F_1 3, F_1 6, F_1 7 (0.423984)
S4: F_1 4 & F_1 7 (0.2728169)
S5: F_1 5 & F_2 8 (0.517719)

Strategies, F_2
S1: F_2 8, F_2 9, F_2 10 (0.158936)
S2: F_2 8, F_2 9, F_2 10 (0.8842)
S3: F_2 9 & F_2 11 (0.140641)
S4: F_2 9 & F_2 12 (0.0663495)
S5: F_2 9 & F_2 11 (0.131181)

Stakeholder contribution, F_5
S1: F_5 36 & F_5 37 (0.181658)
S2: F_5 38 - F_5 39 (0.249621)
S3: F_5 40 - F_5 41 (0.155649)
S4: F_5 42 - F_5 43 (0.27663)
S5: F_5 44 - F_5 45 (0.186183)

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Figure 5.1 represents the classification of indicators as per the performance prism framework. The stakeholders inside the prism are the ones taken for evaluation (S1 – S5) along with their AHP weights. The consistency values for all the samples were below 0.1 and hence are in the acceptable range. The performance indicators grouped under each of the five facets (F_1 – F_5) of the prism along with the AHP weights of the facets for each stakeholder category is also shown in the figure. The detailed classification of the indicators and their corresponding AHP priority weights are shown in the table 5.2. According to the AHP results, out of the five stakeholder categories, client sector (0.355215) was playing the most crucial role in the implementation of EPC projects followed by the EPC contractors (0.290309). Employee (0.164280) is the next important category followed by the material and equipment suppliers (0.112623) and finally the end – users (0.077574) of the facility.

TABLE II. RESULTS OF AHP ANALYSIS FOR FIVE DIFFERENT STAKEHOLDER CATEGORIES

Stakeholder	**Facets**	**Performance Indicators**	**Overall weight of indicators**
S1 0.355215	**F_1** 0.257315	$F_1$1 (0.617531)	0.05644
		$F_1$7 (0.25037)	0.02289
		$F_1$6 (0.132099)	0.01207
	F_2 0.158936	$F_2$9 (0.329246)	0.01859
		$F_2$8 (0.405274)	0.02289
		$F_2$10 (0.26538)	0.01498
	F_3 0.0967044	$F_3$16 (0.131397)	0.00451
		$F_3$15 (0.401474)	0.01398
		$F_3$13 (0.33734)	0.01158
		$F_3$14 (0.129789)	0.00458
	F_4 0.305386	$F_4$28 (0.502939)	0.05455
		$F_4$27 (0.349417)	0.0379
		$F_4$26 (0.147644)	0.01612
	F_5 0.181658	$F_5$36 (0.339498)	0.02191
		$F_5$37 (0.660502)	0.04262
S2 0.290309	**F_1** 0.089551	$F_1$2 (0.277908)	0.00722
		$F_1$7 (0.338207)	0.00879
		$F_1$6 (0.383885)	0.00998
	F_2 0.08842	$F_2$9 (0.634405)	0.01628
		$F_2$8 (0.289587)	0.00743
		$F_2$10 (0.076008)	0.00195
	F_3 0.236935	$F_3$19 (0.344263)	0.02368
		$F_3$15 (0.40171)	0.02763
		$F_3$18 (0.096178)	0.00662
		$F_3$14 (0.157849)	0.01086
	F_4 0.335474	$F_4$28 (0.406005)	0.03954
		$F_4$32 (0.0819839)	0.00798
		$F_4$29 (0.255009)	0.02484
		$F_4$26 (0.257002)	0.02503
	F_5 0.249621	$F_5$38 (0.240699)	0.01744
		$F_5$39 (0.759301)	0.05502
S3 0.164280	**F_1** 0.423984	$F_1$3 (0.213727)	0.01489
		$F_1$7 (0.309633)	0.02157
		$F_1$6 (0.47664)	0.03319
	F_2 0.140641	$F_2$9 (0.647142)	0.01495
		$F_2$11 (0.352858)	0.00815
	F_3	$F_3$19 (0.12513)	0.00246

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	0.119452	$F_3$20 (0.222016)	0.00436
		$F_3$21 (0.141996)	0.00279
		$F_3$14 (0.360666)	0.00708
		$F_3$22 (0.150192)	0.00295
	F_4 0.160274	$F_4$30 (0.397922)	0.01048
		$F_4$31 (0.138564)	0.00365
		$F_4$25 (0.127452)	0.00356
		$F_4$33 (0.15216)	0.00401
		$F_4$34 (0.183903)	0.00484
	F_5 0.155649	$F_5$40 (0.60815)	0.01556
		$F_5$41 (0.39185)	0.01002
S4 0.112623	**F_1** 0.2728169	$F_1$4 (0.68593)	0.02107
		$F_1$7 (0.31407)	0.00965
	F_2 0.0663495	$F_2$9 (0.733049)	0.05478
		$F_2$12 (0.266951)	0.00199
	F_3 0.115996	$F_3$14 (0.291197)	0.0038
		$F_3$23 (0.529821)	0.00692
		$F_3$24 (0.178982)	0.00234
	F_4 0.2682	$F_4$25 (0.492348)	0.01487
		$F_4$34 (0.342925)	0.01036
		$F_4$26 (0.164728)	0.00498
	F_5 0.27663	$F_5$42 (0.235474)	0.00734
		$F_5$43 (0.764526)	0.02382
S5 0.077574	**F_1** 0.517719	$F_1$5 (0.542753)	0.02179
		$F_2$8 (0.457247)	0.01836
	F_2 0.131181	$F_2$9 (0.843137)	0.00858
		$F_2$11 (0.156863)	0.00159
	F_3 0.0481626	$F_3$14 (0.194198)	0.00073
		$F_3$17 (0.805802)	0.00301
	F_4 0.116754	$F_4$35 (0.753846)	0.00683
		$F_4$26 (0.246154)	0.00223
	F_5 0.186183	$F_5$44 (0.862069)	0.01245
		$F_5$45 (0.137931)	0.00199

As per Table 5.2, ‘client’s satisfaction for time, cost and quality (0.05644)’ which comes under client category stands first among all the indicators followed by ‘contractor’s overall performance (0.05502)’ which comes under contractor category. In an EPC project, contractors construct the facilities for the clients, provided the client takes care of the finance. Therefore, as per Nassar & AbouRizk (2014), every contracting company’s prior aim will always be the scope for continued business and the best way to achieve that is by meeting the client’s expectations about the project performance. So clearly, these two indicators are the most important performance aspect of an EPC project. ‘Client’s delay in payments for the completed work (0.00451)’ is the least important indicator under client category and ‘health, safety & environmental impact of the project (0.00195)’ is the least important under contractor category. In an EPC project, the payments are pre – fixed for each piece of work to be done which helps the client to arrange the needed finance earlier itself thereby reducing the chances of delay in payments. On the other hand, a negative impact of the project on the health and safety of the people is one of the indirect causes of loss of reputation of the EPC contractor. Properly carrying out other activities can mostly reduce these negative impacts and that can explain its least importance among the indicators in the contractor category.

In the employee category, ‘project profitability (0.03319)’ under the satisfaction aspect comes first and ‘appropriateness in budget and schedule estimates (0.00246)’ under process aspect is the least important. Profitability of the project indicates the chances of the project to earn revenue and make profit. In cases of EPC highway projects, revenue from the project to the client sector plays a huge part (Nassar & AbouRizk, 2014). Likewise, the chances of cost overruns and time overruns for EPC projects reduce if the budget and schedule estimates are appropriate but cannot be totally avoided since other factors like claims and disputes, uncertainties in the contract terms and so on can call for additional time and cost. That gives the estimation of budget and schedule of the project as the lowest priority. In the materials and equipment supplier category, ‘value for money (0.05478)’ under the facet ‘strategies’ is the most important. As Liu et al. (2014) stated, value for money is the optimum combination of the life-cycle cost, service quality of the asset, and the end - user’s satisfaction. This criterion is therefore very much important in every construction project. Among the other indicators, 'technology diffusion in material supply and management (0.00199)' which is also under the 'strategies' facet became the least important under the supplier category. The client sector is constructing these infrastructures ultimately for the end – user category so that they can have better facilities and standard of living. This is clear from the analysis which showed that 'end – user's satisfaction for time, cost and quality (0.02179)' of the project is the most important whereas 'effective communication and coordination with other stakeholders (0.00073)' is the least important. Compared to all other stakeholders, role of end – users would be the lowest considering the fact that they are not involved in any technical activities. This is proven by showing that among the indicators, communication of end – users with stakeholders is having the lowest priority.

V. Conclusion

The study dealt with formulating a model for the performance evaluation of EPC projects concentrated in Kerala. For this purpose, performance prism was used as the evaluation framework and AHP was used as the prioritizing tool. Five categories of stakeholders relevant in EPC projects and the performance indicators which were selected from extensive literature review were categorized into these five stakeholder categories as per the performance prism framework. From AHP analysis, it was seen that out of the five stakeholders, the most important ones were the client and the EPC contractor. The EPC contractor's overall performance in the project and the client's satisfaction about the time, cost and quality of the project also comes first among the performance indicators. These results are obvious since in every EPC project, the contractor is the one who puts together all the resources and brings other stakeholders into the picture and the only major function of the client is to provide the finance for the project.

Performance prism is the most recent evaluation framework which allows considering a stakeholder's need and their contribution in return for the fulfillment of their need at the same time along with their strategies in the project, the processes to be implemented and capabilities they must possess for the successful completion of the project. On the other hand, AHP is a commonly used tool for multi- criteria decision making purpose. Combining performance prism with AHP gives the priority weights for all the indicators as well as for the five facets of the performance prism and for the stakeholders, which can be used in future for the performance evaluation of any other EPC projects in Kerala. Using this model, not only the performance of the project but also the performance of each stakeholder can be obtained and improved through proper measures.

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