Key Performance Indicators for Life Cycle Performance Measurement of PPPs in Sustainable Port Development Projects

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ABSTRACT

Public-Private Partnerships (PPP) are contractual relationships between the public and private sectors in infrastructure development and have been applied widely in the global construction market. The Port sector is one among the top sectors in which PPP arrangement is used widely. As a crucial part of the multimodal transport, ports are of great economic and strategic importance for the country. Therefore, the performance evaluation of Port projects implemented as PPPs should be given due importance. This project aims to develop a set of Key Performance Indicators (KPIs) for the life cycle performance measurement of PPPs in sustainable port development projects. 47 KPIs were identified from literature and opinions of practitioners in the field were investigated through a questionnaire survey. The significance and correlations between elements in the model were established using Principal Component Analysis, resulting in a refined version of the KPI set. New KPIs obtained from the survey were also incorporated into the final set. Based on the results, a conceptual model of KPIs and associated stakeholders was developed, as a phase wise relevance matrix.

Keywords: Public-Private Partnerships, Key Performance Indicators, Conceptual model

1 Introduction

Public-Private Partnership (PPP) is a mode of contract that is increasingly being used in the construction and infrastructure sector. Driven by the huge requirement of financial investment and advanced infrastructural expertise in the Port sector, it is one among the top sectors in which PPP arrangement is used widely [1]. As a crucial part of the multimodal transport, ports are of great economic and strategic importance for the country. International shipping is highly associated with world trade and port management that accompanies it have a greater influence on the environment and surrounding communities. Hence there is a need to develop sustainable port and logistics operations.

Regular appraisal during the course of the project life cycle is inevitable in maximizing financial and operational performance and minimizing risk, so that it contributes to the success of the project. Implementing Key Performance Indicators (KPIs) to assess performance in construction projects is one of the most effective, yet a straightforward, construction management practice in developed economies [2]. KPIs are compilations of data measures used to assess and evaluate the performance of a PPP operation [3]. It is crucial to determine the appropriate KPIs in order to measure the performance or calculate the effects of any given change on the process of PPP projects.

This study aims at developing a conceptual model of KPIs for the life cycle performance measurement of PPPs in sustainable port development projects. Identifying relevant KPIs that are best aligned with the needs of the sector is achieved through extensive literature review, coupled with experts' input through questionnaire survey.

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2 Methodology

Extensive literature survey was carried out on previous research works conducted on the performance evaluation of PPPs and Ports. Over 100 indicators were identified [4]–[17], from which 47 indicators were sieved out based on significance. These proposed KPIs were then put forth for gathering opinions from PPP practitioners and professionals in the Port sector, through a questionnaire survey. Respondents were requested to rate the significance of the proposed KPIs on a Likert scale of 1 to 5, where: 1, indicated least significance and 5, extreme significance. It also included open-ended questions that prompted the respondents to suggest KPIs that they felt were significant, along with their significance ratings. Responses were received from 41 experts/ professionals, working in Ports and/or PPPs from across India. This included professionals in different strata such as administration (CEOs, directors, managers) and port operations management (engineers, business heads, chief operating officers), consultants in technical and legal spheres, as well as port users who worked in shipping lines and other port related ventures. These were professionals who had considerable experience (about 12 years average) in the field, and were familiar with the nature of the sector, its operations, weaknesses etc.

To reduce the KPIs into major dimensions on the basis of statistical evidences, the data collected was subjected to Principal Component Analysis (PCA) using IBM SPSS 27.0.1.0.0 software. For the purpose of assigning KPIs according to the phase of the project in its lifecycle, KPIs relevant for performance measurement of each phase, i.e., planning and construction phase, and operational phase were picked out separately. Many of the KPIs were relevant to both phases, hence included in both sets. These were then subjected to PCA separately.

The KPIs suggested by the respondents were also considered and analysed qualitatively. From the findings of studies and analyses carried out, a conceptual model of KPIs relevant to the port sector was developed.

3 Analysis

Principal Component Analysis was carried out on the collected data.

Table 1 and 2 shows the factor loadings after Varimax Rotation for the 2 phases.

Table 1: *Rotated Component Matrix (Planning and Construction phase)*

KPI	Component						
	1	2	3	4	5	6	7
Efforts on emission reductions and air quality improvements	**.896**	-.049	.090	.097	.075	.111	.082
Compliance to Environment and Wetland Conservation & Protection Policies and Legislation	**.869**	.212	.175	.071	.081	.039	.123
Implementation of Storm Water and Spill pollution prevention and control	**.854**	.016	.127	.073	.003	.016	-.011
Annual energy consumption and percentage of renewable energy purchased or generated	**.841**	.065	-.107	.091	.163	.099	.188
Climate change adaptation - Identification and updating of appropriate port policies and operating procedures	**.840**	.169	.229	.070	.172	.179	.016
Conservation and Protection of marine resources	**.784**	.404	.200	-.011	.188	.031	.065
Budget on Green Performance	**.750**	-.010	.372	-.180	.175	.067	.237

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Waste reduction and diversion through recycling policy	**.648**	-.091	.071	-.022	.083	.050	.544
Well-defined Financial Agreements	.177	**.776**	.123	.194	.378	.032	.172
Competitive Tender/Bidding process	-.095	**.774**	.207	-.123	.028	.291	-.087
Contractual obligations protecting the interests of both the parties	.288	**.751**	.208	.346	.067	.046	-.029
Level of technological advancement	.120	.146	**.764**	.073	.279	.150	.071
Adequate designs w.r.t site conditions	.128	.153	**.664**	.121	.068	.211	.306
Quality Control- Well defined quality plans and satisfactory test results	.362	.308	**.640**	.122	.009	-.086	.263
Safety measures at construction site	.373	.129	**.620**	.434	.023	.267	-.100
Control over construction cost overrun	-.037	.273	**.618**	.172	.204	-.027	-.061
Government authority's proactive approach- approvals and permits in time	.066	-.144	.143	**.765**	-.114	.139	.312
Appropriate Risk Allocation, Risk Sharing and Risk Transfer Protocol	.085	.529	-.032	**.679**	.195	-.051	.346
Disputes/ Conflicts management	.174	.287	.129	.088	**.799**	.094	-.064
Managing Force Majeure Events at site	.364	-.055	.165	.168	**.651**	.243	.288
Distinct Force Majeure and Termination Clauses	.222	.574	.185	-.089	**.624**	-.055	.164
Budget for Human Resource Development	.231	.085	.296	-.062	.002	**.818**	-.073
Investment in Research & Development for innovation	.093	.051	-.017	.255	.350	**.802**	.151
Construction Productivity	.273	.249	.401	.218	.076	.116	**.622**
Achievement of project milestones as per Project Completion Schedule	.250	-.023	.233	.364	.177	.051	**.612**
Economic and Social benefits	.057	.405	.198	-.064	-.116	.462	.592

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Rotation converged in 11 iterations.

Table 2: *Rotated Component Matrix (Planning and Construction phase)*

KPI	Component							
	1	2	3	4	5	6	7	8
Efforts on emission reductions and air quality improvements	**.903**	.058	.107	.105	.122	-.029	.032	-.022
Compliance to Environment and Wetland Conservation & Protection Policies and Legislation	**.876**	.220	.090	.079	.001	.061	.058	.122
Climate change adaptation - Identification and updating of appropriate port policies and operating procedures	**.849**	.247	.007	.129	.144	.062	.192	.166

Implementation of Storm Water and Spill pollution prevention and control	**.824**	.003	.236	-.039	-.159	.236	.182	-.072
Annual energy consumption and percentage of renewable energy purchased or generated	**.802**	.140	.041	-.035	.219	.340	.030	-.206
Budget on Green Performance	**.797**	.173	-.048	.241	.154	-.025	.026	.026
Conservation and Protection of marine resources	**.783**	.401	-.115	.033	.167	.068	.219	.121
Waste reduction and diversion through recycling policy	**.718**	-.065	.130	.224	.111	.054	-.225	-.112
Labour expenditure per ton of cargo	.550	.173	.292	.330	-.072	.372	-.327	-.247
Number of employees employed per ship per shift	.148	**.781**	-.028	.044	-.041	.234	.082	.090
Tons per ship hour in port	-.088	**.771**	.435	-.090	.071	-.117	-.098	.176
Tons per ship hour at berth	.190	**.770**	.089	-.094	.262	.022	.030	.239
Annual Operation & Maintenance expenses	.391	**.719**	.121	.264	.088	-.005	.162	-.213
Level of technological advancement	.144	**.657**	.236	.280	.157	.063	.051	.164
Competitive Tariff mechanism	.182	.568	.089	.380	-.307	.150	.233	.095
Tons per employee-hour	.202	.564	.332	-.062	.004	.365	.250	.180
Capital equipment expenditure per ton of cargo	.325	.485	.436	-.036	.101	.434	-.238	-.061
Turnaround time per ship	.043	.026	**.895**	.223	-.002	.028	-.041	.100
Waiting time per ship	.069	.092	**.859**	.123	.144	.231	.098	.057
Service time per ship	.143	.371	**.750**	.066	.300	-.171	.171	.124
Investment in Research & Development for innovation	.125	.181	.082	**.774**	-.001	.147	-.033	-.058
Multimodal Logistics	.195	.032	.108	**.766**	.277	.053	-.130	.071
Budget for Human Resource Development	.197	.072	.203	**.719**	-.084	.094	.451	.081
Economic and Social benefits	.039	.127	.083	**.607**	.465	.384	.304	.124
Berth occupancy revenue per ton of cargo	.149	.170	.180	.047	**.835**	.100	.177	-.045
Total tonnage/ containers handled annually vis-a -vis port capacity	.407	.141	-.004	.181	**.615**	.048	-.211	.341
Cargo handling revenue per ton of cargo	.346	-.086	.471	.122	**.606**	.098	-.160	.062
Disputes/ Conflicts management	.225	.145	-.175	.191	-.036	**.767**	.047	-.454
User Protection Clauses	.008	.258	-.198	.277	.107	**.670**	.404	.009
Managing Force Majeure Events at site	.364	-.055	.165	.168	.243	**.651**	.094	-.064
Distinct Force Majeure and Termination Clauses	.222	.574	.185	-.089	-.055	**.624**	.243	.288
Daily ship arrival rate	.180	.119	.107	.353	.202	.547	.041	.078
Value for Money	.226	.371	.092	.041	.062	-.032	**.784**	.004
Fraction of productive time of berthed ships	-.057	.333	.147	.200	.195	.030	.084	**.739**
Fraction of time employees engaged in productive work	.359	.316	.054	.341	.051	.284	-.063	**.658**
Tonnage per ship/ Vessel size	.082	.068	.477	-.114	-.133	.378	-.010	.579

Extraction Method: Principal Component Analysis.

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Rotation Method: Varimax with Kaiser Normalization.
Rotation converged in 10 iterations.

Factor loadings indicate the extent of relevance of variables in explaining a construct. Lower loading of a KPI shows that it may not be an effective measure of its construct (component) and is hence removed. Factor loadings below 0.6 (absolute value) are suppressed. This resulted in the elimination of one variable, "Economic and Social benefits" (0.592), from Planning and Construction phase. Variables with low factor loadings eliminated from Operation phase are: "Labour expenditure per ton of cargo" (0.550), "Competitive Tariff mechanism" (.568), "Tons per employee-hour" (.564), "Capital equipment expenditure per ton of cargo" (.485), "Daily ship arrival rate" (.547), and "Tonnage per ship/ Vessel size" (.579).

4 Results and Discussion

After the analysis, 40 KPIs out of the proposed 47 were retained. These were grouped into 8 components in the Planning and Construction phase, and 7 components in the Operation phase, as follows:

4.1 Planning and Construction Phase

1) *Environmental Sustainability Component*: Since all the KPIs belonging to the first component are related with conservation of environment and sustainability, the component is named Environmental Sustainability component. During the period of evolution of ports, its economic impact was given priority and sustainability was not given much attention. As times changed, there is a growing need and call for sustainability, but it has still not reached a maturity level wherein its implementation is considered in equal importance as that of other dimensions of performance.

2) *The Concession Component*: "Well-defined Financial Agreements" (0.776), "Competitive Tender/Bidding process" (0.774), and "Contractual obligations protecting the interests of both the parties" (0.751) are variables with significant factor loadings in this component. Since these KPIs deal with the contract agreements between the parties, and the process of conceiving it, it is named Concession Component.

3) *Construction Efficiency Component*: KPIs "Level of technological advancement" (0.764), "Adequate designs w.r.t site conditions" (.664), "Quality Control" (0.640), "Safety measures at construction site" (0.620), and "Control over construction cost overrun" (0.618) have significant positive factor loadings. These KPIs measure the efficiency of the construction practices adopted at site, and hence collectively contribute to the component named Construction Efficiency Component.

4) *Partnership Component*: "Government authority's proactive approach- approvals and permits in time" (0.765), "Appropriate Risk Allocation, Risk Sharing and Risk Transfer Protocol" (0.679) are the variables with significant factor loading in this component. Since these KPIs measure the level of partnership between the parties in contract, it is named Partnership Component. These measure the level of commitment and responsibility shared by the partners in PPP, which is a crucial factor for the success of the project.

5) *Crisis Management Component*: This component contains KPIs that deal with the management of critical times: "Disputes/ Conflicts management" (0.799), "Managing Force Majeure Events at site" (0.651), and "Distinct Force Majeure and Termination Clauses" (0.624). It is hence named Crisis Management Component.

6) *Development Component*: "Budget for Human Resource Development" (0.818), "Investment in Research & Development for innovation" (0.802) are the variables with significant factor loading

in this component. These variables give an indication of the potential and willingness of port authorities to expand beyond the existing system, hence named Development Component.

7) *Efficacy in Project Management Component*: "Construction Productivity" (0.622), and "Achievement of project milestones as per Project Completion Schedule" (0.612) are the variables with significant factor loading in this component. Since these measure the efficacy in project management, it is named so.

4.2 Operation Phase

1) *Environmental Sustainability Component*: The same components that loaded into the first component in planning and construction phase KPIs, loaded in the operation phase also. This is because environmental sustainability is a factor that is relevant throughout the lifecycle of a PPP.

2) *Operational Efficiency Component*: "Number of employees employed per ship per shift" (0.781), "Tons per ship hour in port" (0.771), "Tons per ship hour at berth" (0.770), "Annual Operation & Maintenance expenses" (0.719), "Level of technological advancement" (0.657) are variables that load into this component. As these KPIs are measures of the efficiency of operational features of port, this component is named Operational Efficiency Component.

3) *Efficiency of Service Component*: "Turnaround time per ship" (0.895), "Waiting time per ship" (0.859), "Service time per ship" (0.750). Since these variables give an idea of the efficiency of ship movement, and hence, services at the port, the component is given the name Efficiency of Service Component.

4) *Development Component*: "Economic and Social benefits" (0.607) and "Multimodal Logistics" (0.766), also loaded into the Development Component in operation phase, along with "Investment in Research & Development for innovation" (0.774) and "Budget for Human Resource Development" (0.719), in the Development Component in the construction phase.

5) *Profitability Component*: "Berth occupancy revenue per ton of cargo" (0.835), "Total tonnage/ containers handled annually vis-a-vis port capacity" (0.615), "Cargo handling revenue per ton of cargo" (0.606) are KPIs that load into this component. These measure the profitability of the project and are inevitable component when it comes to performance measurement.

6) *Crisis Management Component*: The KPIs that loaded into this component are "Disputes/ Conflicts management" (0.767), "User Protection Clauses" (0.670), "Managing Force Majeure Events at site" (0.651), and "Distinct Force Majeure and Termination Clauses" (0.624). These deal with the management of critical times during operational phase, hence named Crisis Management Component.

7) *Value Creation Component*: The single variable "Value for Money" (VfM) (0.784) had a significant factor loading in the seventh component. Value creation in monetary terms is one major aspect of the very idea of conceiving projects as PPPs [18], [19].

8) *Productivity Component*: "Fraction of productive time of berthed ships" (0.739) and "Fraction of time employees engaged in productive work" (0.658) are the variables with significant factor loadings in the last component. Since these measure the productive times in the port operations, the component is named Productivity Component.

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4.3 KPIs Suggested by Respondents

The survey yielded several KPIs that the respondents felt were of significance in measuring the performance of Port PPP projects. Some of these were found to overlap with the already proposed KPIs, and few others lacked clarity. However, seven KPIs which were found to be of relevance were adopted after careful considerations.

1) *Provision for amendments- Revision/incorporation of additional clause*: A major challenge in PPPs is to keep construction progress cost-efficient and on schedule, under continuously changing circumstances [20]. One way to do this is to resort to clever contracts, proactively anticipating potential change in the planning phase and providing flexible contract mechanisms.

2) *Occurrence of unregistered risks*: Risk allocation in PPPs is done at the planning phase to the party best equipped to manage the risk. Despite this, unforeseen risks may occur, and these can have an adverse effect on the PPP performance, as the parties wouldn't be prepared to deal with it in the best possible way.

3) *Financial management*: The overall finances of the project including costs, revenues, tariffs etc. need to be continuously monitored. The variations of the actual finances from the estimated financial projections can be indicative of the performance of the project.

4) *Government's commitment to provide essential land for development*: As construction can only progress once the land is available, there is a risk both in terms of costs and time if the land is not available on time. Best practice is for the procuring authority to retain the risks related to both the cost and availability of the land, including costs of relocating current occupants.

5) *External infrastructure requirements taken up by the government*: External infrastructure refers especially to those related with connectivity. As the port is an important interface between maritime and land transport, inland connectivity becomes significant. It mainly constitutes of road, rail, pipeline etc. These requirements being taken up by the government can ensure better economic growth of the region besides boosting the performance of the port.

6) *Availability of port equipment vis-a-vis rated capacity of the port*: Constraints on the availability of equipment such as lifting equipment, vessels, chassis, rail cars etc. can affect the ability to eliminate the backlogs of movement of containers and vessels, and cause congestion. Thus, availability of enough equipment as per the rated capacity of port is important for the smooth functioning of port operations and can be indicative of the port's performance.

7) *Compliance with conventions and treaties of International Maritime Organization (IMO)*: The IMO is the UN specialized body responsible for the safety and security of shipping and the prevention of marine pollution. It develops international treaties and law concerning safety and marine pollution prevention and emphasizes on their implementation. Compliance with the conventions and treaties of IMO can thus be a potential measure of the port's performance regarding sustainability.

4.4 Conceptual Model

The consolidated KPIs belong to performance measurement of different phases of the project and are of interest to different stakeholders in the project [21]–[23]. Based on this, a conceptual model (Table 3) is developed. The model tries to allocate the KPIs according to the phase(s) in which they are implemented, to the stakeholder(s) accountable for, or are of relevance in the performance of the project in that particular dimension.

Table 3: *Conceptual model of KPIs and stakeholders- Phase wise relevance matrix*

(P: Pre-construction stage; C: Construction stage; O: Operation stage)

Component	Key Performance Indicator	Stakeholders									
		Primary			Secondary						
		Government (public sector)	Developer cum Operator (private sector)	Port Users	Public	Legalistic & Policy makers	Planners & Experts	Consultants	Contractors and Suppliers	Lenders & Financial Institutions	Regulatory Authorities
The Concession	Well-defined Financial Agreements	P C O	P C O			P	P	P		C O	
	Competitive Tender/Bidding process	P	P				P	P			
	Contractual obligations protecting the interests of both the parties	P C O	P C O			P	P	P C			
	Provision for amendments- Revision/incorporation of additional clauses					P	P				
Construction Efficiency	Level of technological advancement		C						C		
	Adequate designs w.r.t site conditions	C	C						C		
	Quality Control- Well defined quality plans and satisfactory test results	C	C						C		C
	Safety measures at construction site	C	C						C		C
	Control over construction cost overrun		C					C	C	C	
Partnership	Government authority's proactive approach- approvals and permits in time	P C O	P C O	O							
	Appropriate Risk Allocation, Risk Sharing and Risk Transfer Protocol	P C O	P C O			P	P	P			
	Government's commitment to provide essential land for development	C	C								
	External infrastructure requirements taken up by the government	C O	C O								
Crisis Management	Disputes/ Conflicts management	P C O	P C O				P C O				

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	Managing Force Majeure Events at site	C O	C O	P C					C	C O	
	Distinct Force Majeure and Termination Clauses	P C O	P C O	P C		P	P		C		
	User Protection Clauses	O	O	O		P	P				
Development	Budget for Human Resource Development	P C O	P C O			P	P	P		C O	
	Investment in Research & Development for innovation	P C O	P C O			P	P	P		C O	
	Multimodal Logistics	O	O	O					O	O	
	Economic and Social benefits	C O	C O	O	C O					C O	
Efficacy in Project Management	Construction Productivity	C	C						C		
	Achievement of project milestones as per Project Completion Schedule	C O	C O						C		
	Occurrence of unregistered risks	C O	C O								
	Financial Management	C O	C O							C O	O
Operational Efficiency	Number of employees employed per ship per shift		O								
	Tons per ship hour in port		O								
	Tons per ship hour at berth		O								
	Annual Operation & Maintenance expenses		O					O		O	
	Level of technological advancement		O					O	O	O	
	Availability of port equipment vis-a-vis rated capacity of the port		O					O	O	O	
Efficiency of Service	Turnaround time per ship		O								
	Waiting time per ship		O								
	Service time per ship		O								
Profitability	Berth occupancy revenue per ton of cargo		O					O		O	
	Total tonnage/ containers handled annually vis-a-vis port capacity		O								
	Cargo handling revenue per ton of cargo		O					O		O	
Productivity	Fraction of productive time of berthed ships		O								
	Fraction of time employees engaged in productive work		O								
Value Creation	Value for Money	O	O				O				
Environmental Sustainability	Efforts on emission reductions and air quality improvements	C O	C O	C O	C O	C O					O

	Implementation of Storm Water and Spill pollution prevention and control	O	O	O	O	O					O
	Compliance to Environment and Wetland Conservation & Protection Policies and Legislation	C O	C O		C O	C O					C O
	Climate change adaptation - Identification and updating of appropriate port policies and operating procedures	C O	C O		C O	C O					O
	Annual energy consumption and percentage of renewable energy purchased or generated	O	O								O
	Conservation and Protection of marine resources	C O	C O		C O	P					O
	Budget on Green Performance	O	O			P		P		O	O
	Waste reduction and diversion through recycling policy	C O	C O	O	C O	P					O
	Compliance with conventions and treaties of International Maritime Organization	O	O								O

The classification of the KPIs into distinct groups better demonstrates the performance outcomes. The performance in a certain project may be assessed with a higher degree of objectivity and neutrality with the model. It may thus be viewed as a theoretical reference for the allocation of duties of performance measurement among different parties of interest, and different departments within a project, according to their respective speciality.

5 Conclusion

There are certain KPIs that are relevant exclusively for planning, construction and operation phases of port PPP projects, while others have to be employed throughout the life cycle of projects. Based on statistical evidences, KPIs were grouped into 15 components based on the interrelations established between them. Seven new KPIs identified from survey also fit into this classification. These were: provision for amendments- revision/incorporation of additional clause, occurrence of unregistered risks, financial management, government's commitment to provide essential land for development, external infrastructure requirements taken up by the government, availability of port equipment vis-a-vis rated capacity of the port, and compliance with conventions and treaties of International Maritime Organization.

A conceptual model of KPIs and associated stakeholders was developed, as a phase wise relevance matrix. The model can serve in the favour of the user when distributed between different departments within a project, according to their respective speciality.

This study may be used as the foundation for future works concerning KPIs in port PPPs. Case studies may be conducted by employing the identified KPIs and conceptual model in on-going port PPPs. Furthermore, the possibility of developing Artificial Intelligence based systems for performance monitoring

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may be explored. This may aid port concessionaires and authorities in making timely decisions, resulting in better port performance.

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