Criteria to consider in selecting and prioritizing infrastructure projects

Seng Hansen[1], *Eric* Too[1,*], and *Tiendung* Le[1]

[1]School of Property, Construction and Project Management, RMIT University, Melbourne, Australia

Abstract. Infrastructure project selection and prioritization is a challenging decision-making problem. Thus, decision makers are required to develop and use a decision-making framework to evaluate the proposals. The first step in developing such framework is to establish the decision criteria. This research aims to identify these criteria based on a systematic review of literature. A total of 34 decision criteria for infrastructure project selection was identified. In addition, this research has also identified three major facts related to decision criteria and presented a structured model to integrate these decision criteria into a Decision-Making Framework. As a preliminary study, the findings from this research are expected to assist further research on developing a Decision-Making Framework for infrastructure project selection.

1 Introduction

The selection and prioritization of infrastructure project proposals is an important and challenging decision-making problem faces by decision makers, particularly the government. In general, infrastructure projects are funded using public funds through development programs set by the government. The process of selecting and prioritizing infrastructure project proposals is characterized by multiple goals and uncertainties due to incomplete information [1]. Previous studies have also recognized the complexity of the selection problem [2,3]. By knowing the significance of influencing decision-making factors would allow decisions to be better reviewed [4].

According to Purnus and Bodea [5], there are five steps in developing a model to evaluate and prioritize project proposals, namely: (1) establishment of evaluation criteria, (2) establishment of score scale for each criterion, (3) establishment of the scoring method for each criterion, (4) calculation of the score, and (5) establishment of project priority list based on the calculated score. This research focuses on the first step, i.e. to establish the evaluation criteria.

Evaluation criteria are those criteria or parameters that will be used to assess the project proposals [6]. It is also known as decision criteria and decision parameters. According to Frame [7], there are several types of decision criteria that can be used to evaluate project proposals, including: financial criteria, technical criteria, risk-related criteria, resources-related criteria, contractual conditions criteria, and qualitative criteria. Other works discuss different types of criteria that may differ one another [8-12].

In addition to evaluate project proposals, the establishment of decision criteria is also important to provide transparent process [13]. These criteria can be both quantitative and qualitative [5]. The process of selecting and prioritizing project proposals is carried out through an assessment of each proposal towards these decision criteria.

With the increasing project complexity and a large number of success factors for infrastructure projects, there is a need to identify decision criteria in selecting and prioritizing infrastructure project proposals. The identification and establishment of these criteria should follow a systematic process to ensure the validity and transparency of this establishment process. Although there has been a lot of research conducted to study the selection process of infrastructure projects, mostly focus on the selection method rather than on the decision criteria themselves. Therefore, this research aims to investigate a comprehensive list of decision criteria from literature.

2 Method

In this research, a systematic literature review was carried out. It was conducted in accordance to the guidelines prescribed by [14-16]. The tactics involved five steps as follows.

2.1. Searching for literature sources

To comprehensively locate relevant literature, all sources must be considered. Generally, there are two types of

* Corresponding author: eric.too@rmit.edu.au

sources, namely journal libraries and online sources. For journal sources, peer-reviewed journals that have their own virtual libraries (VLs), including ASCE Library, Emerald Insight, Taylor & Francis, ScienceDirect, Wiley Online Library, and SAGE were used. As for online sources, only trusted online sources were used. These credible sources including government agency and institution websites.

2.2 Searching for related literature

Once the literature sources were identified, keyword search was performed using search engines in each source. Keywords were used to narrow the search so that only related papers and documents will be retrieved. Table 1 shows the keywords used in this research. A total of 105 publications were retrieved.

Table 1. Keywords used in literature search.

Keywords	Narrowed by
Decision criteria Decision parameters Selection criteria	Infrastructure projects Front-end planning Early planning Pre-project planning

2.3 Selecting relevant literature

A visual examination was employed to sieve the papers and documents. It was done through reading the abstracts or document summaries and skimming the contents in order to identify relevant publications that are more aligned to the research topic. A total of 30 publications were selected for further analysis in this research.

2.4. Analysing the content

Thematic content analysis was conducted to analyse the content of the selected publications and to extract the relevant decision criteria. It is a common approach in analysing qualitative data [17]. Here, the selected publications were analysed and grouped based on common themes. It involves the procedure of data familiarization which includes the reading and re-reading of documents [17], the data coding, as well as theme elaboration and review [18].

There were two coding processes carried out in this research. During the initial coding process all information related to the decision criteria for infrastructure project selection was read and filtered. Table 2 below illustrates an example of the initial coding process outcome.

Table 2. Example of initial coding process.

Economic Stability	Economic Feasibility
Consistency	Site Characteristics
Social Impacts	Politic
Project Costs	Socio-Economic Issues
Environmental Impacts	Value Engineering

At this stage, there might be many criteria that intersect with one another from various literatures. Therefore, a subsequent coding process needs to be carried out where all relevant information and initial coding were reviewed. This process is important to ensure the overall concept of the data as well as the relationships between them were strengthened. In this case, some codes were modified and new codes were introduced. An example of revised codes from the subsequent coding process is displayed in table 3 below.

Table 3. Example of subsequent coding process.

No	Decision Criteria	Code
1	Investment Studies	IS
2	Funding & Programming	FP
3	Needs & Purposes	NP

After two coding processes, a synthesis of content analysis through an inductive process [19] was performed. The synthesis established the patterns, categories and frameworks that answers the research question.

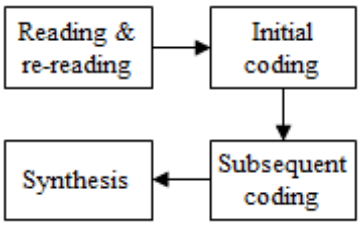

Fig. 1. The content analysis procedure in extracting the criteria.

2.5 Reporting The Findings

Finally, the findings and recommendations were discussed with respect to the research question raised in this research. They were presented in tables and figures in the 'Results & Discussion' section.

3 Results and discussion

Based on the analysis of the existing literature, the findings are grouped and discussed in three subsections. Firstly, the major facts related to the decision criteria for infrastructure project selection were identified. Next, the decision criteria in infrastructure project selection problem were identified and classified. Finally, the structured model to integrate these criteria into a Decision-Making Framework (DMF) for infrastructure project selection was presented.

3.1. Major facts of decision criteria

The review of existing literature has resulted in identifying the following major facts about decision criteria:

(1) Literature related to decision criteria can be grouped based on the designation, namely for general infrastructure projects [8-12] and for specific type of infrastructure projects, such as road infrastructure [20-21], irrigation [22], etc.
(2) The decision criteria will be used as evaluation criteria in a ranking of alternatives system or weightage-based system [5, 21, 23].
(3) These criteria are then being structured to evaluate project proposals so that they can form a hierarchical

model that assists decision makers in selecting the most appropriate projects to fund. An example of the hierarchy can be seen in figure 2.

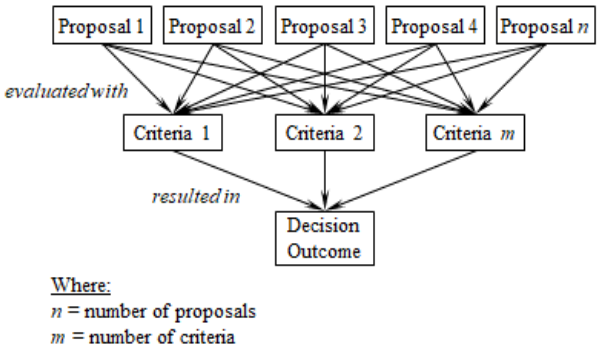

Fig. 2. The decision hierarchy for project proposals selection.

3.2 Identification of decision criteria

Figure 3 and table 4 below present 34 decision criteria that have been identified from the review. These criteria have been used to select and prioritize infrastructure project proposals. They were organized into five groups: (1) strategic fit, (2) owner philosophies, (3) project funding & timing, (4) project requirements, and (5) value engineering.

Table 4. Decision criteria for infrastructure project selection.

No	Criteria	References
I	Strategic Fit (SF)	
1	Needs & Purposes (NP)	[8-9, 20, 24, 25]
2	Consistency (C)	[9, 11]
3	Government Priority (GP)	[10-11]
4	Investment Studies (IS)	[7, 9-12, 20-21, 24, 26-27]
5	Economic Issues & Impacts (EII)	[8-11, 20-21, 24]
6	Social Issues & Impacts (SII)	[8-11, 20-21, 24, 28-29]
7	Environmental Issues & Impacts (En.II)	[8-11, 20-21, 24, 28]
8	Team Member & Stakeholder Coordination (TMSC)	[10, 24]
9	Public Involvement (PI)	[24, 30]
10	Good Governance (GG)	[31]
II	Owner Philosophies (Ow.P)	
11	Design Philosophy (DP)	[20, 24, 25-26]
12	Operating Philosophy (OP)	[12, 20, 24]
13	Maintenance Philosophy (MP)	[12, 20, 24]
14	Future Expansion (FE)	[24]
15	Innovation (I)	[30]
16	Risk (R)	[9, 20, 24]
17	Contractual Conditions & Procurement Model (CCPM)	[7, 9, 10, 27, 32-33]
18	Funding & Programming (FP)	[12, 24, 27, 32-33]
19	Preliminary Project Schedule (PPS)	[12, 24]
20	Contingencies (Contg.)	[24]
IV	Project Requirements (PR)	
21	Project Objectives Statement (POS)	[24]
22	Functional Classification & Use (FCU)	[12, 24]
23	Evaluation of Compliance (EC)	[24]
24	Existing Environmental Conditions (EEC)	[20, 24-25]
25	Site Characteristics (SC)	[20, 24-25]
26	Dismantling & Demolition (DD)	[24]
27	Determination of Utility Impacts (DUI)	[24]
28	Work Force (WF)	[7, 25]
29	Resource Handling & Utilization (RHU)	[7, 25-26]
30	Scope of Work (SW)	[24]
V	Value Engineering (VE)	
31	Value Engineering Procedures (VEP)	[24]
32	Design Simplification (DS)	[24]
33	Material Alternatives (MA)	[24]
34	Constructability Procedures (CP)	[20, 24-26, 30]

Decision criteria are important to be established and defined because they are decisive to the selection of the most appropriate project proposals. The explanation of the above criteria can be seen as follows.

Group I: Strategic Fit

It is a group of criteria that will address project strategic issues and contribute significantly towards national objectives [9]. This group consists of ten criteria as follows.

Needs & Purposes: this criterion assesses the need and purpose of a project. It asks why the project is important to be implemented. Some indicators that may be taken into consideration includes high-level project scope and definition [24], geographical constraints [24], political constraints [20], and existing physical conditions [20, 24].

Consistency: this criterion assesses the conformity of the proposed project to the National Development and Defence Goals [11].

Government Priority: this criterion assesses the significant impacts of the proposed project on the national economy at the central and regional levels [11].

Investment Studies: this criterion relates to the feasibility and other investment studies required during a project planning process. Some issues that must be considered include profitability studies [21, 24], project costs [20, 26], and alternatives assessment [24].

Economic Issues & Impacts: this criterion examines the issues and effects of a project on the economy. It includes

economic stability and economic issues that limiting productive capacity, reducing productivity, constraining economic capability, constraining global competitiveness [9, 20-21].

Social Issues & Impacts: this criterion examines the issues and effects of a project on the well being of the community. It discusses problems which result in, maintain or exacerbate social and quality of life issues [9], including the job creation [29] and reduction of regional inequalities [21].

Environmental Issues & Impacts: this criterion examines the issues and effects of a project on the environment. It mainly focuses on environmental protection [20, 28]. It includes issues such as reduction of greenhouse gas emission, waste, noise pollution, visual intrusion [9, 21].

Team Member & Stakeholder Coordination: this criterion assesses the positive alliance among all key stakeholder and team members of a proposed project [24].

Public Involvement: this criterion assesses the level of public involvement as well as public attitudes regarding the proposed project [24]. Some issues to consider include types of public involvement, local support and/or opposition, and strategies to improve community engagement.

Good Governance: this criterion assesses the level of good governance implementation. OECD [31] defines infrastructure governance as 'the processes, tools and norms of interaction, decision-making and monitoring used by governmental organisations and their counterparts with respect to making infrastructure services available to the public and the public sector.'

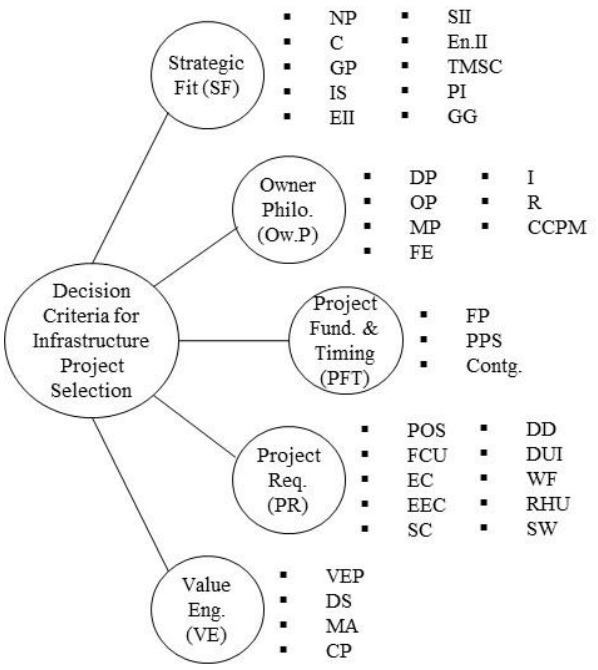

Fig. 3. Decision criteria relationship diagram.

Group II: Owner Philosophies

It is a group of criteria that provide necessary information to understand the project from the owner/operator's perspective [24]. It consists of seven criteria as follows.

Design Philosophy: this criterion examines the general design principles to ensure a successful project. It has to fulfil the functional requirements [24]. Some issues to consider include life time expectancy [20, 26], aesthetics requirements [24], and design for safety principle [20, 24].

Operating Philosophy: this criterion examines 'the level of service desired at a sufficient capacity over an extended period of time' [24]. Some issues to consider include capacity change, operating schedule, and control requirements [24].

Maintenance Philosophy: this criterion examines the 'guidelines to maintain adequate and safe operations over an extended period of time' [24]. It focuses on the specific operational controls and maintenance plans.

Future Expansion: this criterion assesses the possibility of expansion and/or alteration of the proposed project [21, 24].

Innovation: this criterion assesses the degree of innovation of the proposed project throughout its life cycle. It may include innovative planning, innovative contracting, automation, etc. [30].

Risk: this criterion assesses the level of risks and uncertainties involved of the proposed project [20].

Contractual Conditions & Procurement Model: this criterion examines the contractual conditions and procurement model that the proposed project might take into consideration [9-10].

Group III: Project Funding & Timing

It is a group of criteria that deals with specific project goals related to funding and timing. It consists of three criteria as follows.

Funding & Programming: this criterion assesses the sources of funding provided for the proposed project [24]. Some sources and forms of funding may include PPP [24, 32-33], BOT financing model [27], and government entities [24].

Preliminary Project Schedule: this criterion analyses the preliminary schedule of the proposed project. Some components of this preliminary schedule include project milestones, master schedule contingency time, and unusual schedule consideration [24].

Contingencies: this criterion examines the allocated contingencies in order to mitigate project's risks [24].

Group IV: Project Requirements

It is a group of criteria that provide necessary information regarding project requirements. It consists of ten criteria as follows.

Project Objectives Statement: this criterion assesses the proposed project objectives and priorities. It relates to project need and purpose criterion [24].

Functional Classification & Use: this criterion examines the functionality of the proposed project. Here, the project will be classified whether is for private or public use [24].

Evaluation of Compliance: this criterion is used to analyse the adherence requirements of the proposed project to various existing plans, standards [24] and regulations [11].

Existing Environmental Conditions: this criterion examines the existing environmental conditions to enable

better decision-making and allow adequate time to address and mitigate any problem arise [24].

Site Characteristics: this criterion assesses 'the discrepancy between the available site characteristics and the required site characteristics' [24].

Dismantling & Demolition: this criterion evaluates the dismantling and demolition requirements of the proposed project. It may include the timing/sequencing, permits, operations, etc. [24].

Determination of Utility Impacts: this criterion analyses 'the adjustment of utilities to accommodate the design and construction of the proposed project' [24].

Work Force: this criterion assesses the work force requirement of the proposed project. Work force is an important resource in construction project and thus, the work force levelling must be considered. Health and safety for work force also need to be discussed [25].

Resource Handling & Utilization: this criterion examines the resource handling and utilization. It is important since resource handling and utilization contribute to construction costs [26].

Scope of Work: this criterion is used to examine the scope of work of the proposed project whether it has been developed or not. It focuses on the development of work breakdown structure (WBS) and sequencing of work [24].

Group V: Value Engineering

It is a group of criteria that examines project function in order to enhance its value. It consists of four criteria as follows.

Value Engineering Procedures: this criterion assesses whether the proposed project has followed a VE procedure or not. VE is important to assess the overall project effectiveness [24].

Design Simplification: this criterion identifies strategies to reduce the number of process steps or the amount of equipment needed in the design [24]. It focuses on innovation in the project design.

Material Alternatives: this criterion considers material alternatives for the proposed project. The evaluation may include cost effective materials selection, use of local materials, and cost effectiveness during construction [24].

Constructability Procedures: this criterion assesses the level of constructability of the proposed project. It should be initiated in the front-end planning phase [24]. Some issues to consider include construction method [26], construction equipment [25, 30], and development of site layouts [24].

3.3 Structured Model to integrate decision criteria

By synthesizing the results, a structured model was developed. This structured model as illustrated in figure 4, describes the procedure for integrating the identified decision criteria into a Decision-Making Framework (DMF) for infrastructure project selection. According to Nnaji et al. [34], a DMF is an important managerial tool to be used before a decision can be made objectively. It will help decision makers in making better decisions [35].

This structured model consists of three steps, namely criteria identification, criteria selection, and project selection. The first step – identification of criteria, has been achieved in this research through the comprehensive literature review which identified all criteria to decide the selection problem of infrastructure project proposals. This research has also provided the explanations and classification of these criteria.

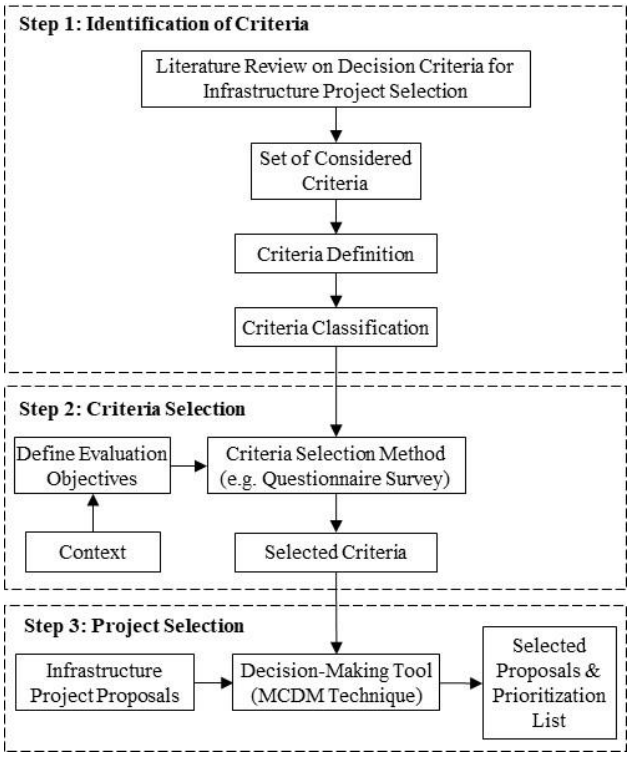

Fig. 4. The structured model to integrate decision criteria into a DMF for infrastructure project selection.

The second step is crucial to filter and evaluate the identified criteria so that only appropriate criteria will be used and incorporated into the DMF. For that, an objective to evaluate the criteria must be established. For instance, the objective is to determine the most appropriate decision criteria to select infrastructure project proposals in a specific context. The context is limited by the research scope. It can be in form of a country or agency context. Next, specific methods (e.g. questionnaires, interviews) can be employed to evaluate and select these criteria. From the analysis, the most appropriate decision criteria can be determined as the selected criteria.

Finally, in the third step – project selection, the selected criteria are used as part of the decision-making tool to select and prioritize infrastructure project proposals. A Multi-Criteria Decision-Making (MCDM) technique can be used to calculate the contribution of each criterion and thus, can determine the score for each criterion. The selection and prioritization of infrastructure project proposals are done by calculating and sorting the total score from the highest to the lowest.

4 Conclusion

From the review study, three categories of decision criteria issues were identified. First, it has identified three major facts about the decision criteria for infrastructure project selection problems. Furthermore, this research has also identified 34 criteria used in making decision regarding investment of infrastructure projects. To provide better understanding, summaries of these criteria were provided. The final issue raised in this research is on how to integrate the identified decision criteria into a DMF that can be used to select and prioritize infrastructure project proposals.

The contribution of this paper is twofold. Firstly, through a consolidated synthesis of literature, a list of decision criteria commonly present in the infrastructure project selection problem was established. The identification of these criteria is the first crucial step in developing a decision-making tool to select and prioritize project proposals. Secondly, this research presents a structured model to integrate the decision criteria into a DMF for infrastructure project selection. This structured model can be used to assist further research on developing the DMF. Thus, the development of DMF is expected to be conducted based on a systematic procedure.

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References

1. C.C. Dutra, J.L.D. Ribeiro, M.M. de Carvalho, *An economic-probabilistic model for project selection and prioritization*, Int. J. Proj. Manag **32**, 1042 (2014)
2. T. Bakshi, A. Sinharay, B. Sarkar, S.K. Sanyal, *Introduction to soft-set theoretic solution of project selection problem*, BIJ **23(7)**, 1643 (2016)
3. K. Salehi, *A hybrid fuzzy MCDM approach for project selection problem*, DSL, **4**, 109 (2015)
4. M.W. Lifson, E.F. Shaifer, *Decision and Risk Analysis for Construction Management* (Wiley, New York, 1982)
5. A. Purnus, C-N. Bodea, *Project prioritization and portfolio performance measurement in project oriented organizations*, Procd. Soc. Behv **119**, 339 (2014)
6. *Standards Australia Guide: Project Prioritisation Process and Criteria* (2017)
7. J.D. Frame, *Project Finance: Tools & Techniques* (UMT Press, 2003)
8. CDIA, *City Infrastructure Investment Programming & Prioritisation Toolkit: User Manual* (2010)
9. Infrastructure Australia, *Assessment Framework – For Initiatives and Projects to be included in the Infrastructure Priority List* (2017)
10. Infrastructure New South Wales, *Infrastructure Investor Assurance Framework – Gateway Coordination Agency Framework for Capital Projects under the NSW Gateway Policy* (2016)
11. KPPIP, *Proyek Strategis Nasional* (2016, retrieved from https://kppip.go.id/proyek-strategis-nasional/)
12. Queensland Treasury, *The State of Queensland Project Assessment Framework* (2015)
13. W. Pan, A.R.J. Dainty, A.G.F. Gibb, *Establishing and weighting decision criteria for building system selection in housing construction*, J. Constr. Eng. Manage **138(11)**, 1239 (2012)
14. Y. Le, M. Shan, A.P.C. Chan, Y. Hu, *Overview of Corruption Research in Construction*, J. Manage. Eng **30(4)**, 02514001 (2014)
15. R. Osei-Kyei, A.P.C. Chan, *Review of studies on the critical success factors for Public-Private Partnership (PPP) projects from 1990 to 2013*, Int. J. Proj. Manag **33**, 1335 (2015)
16. A.P.C. Chan, E.K. Owusu, *Corruption forms in the construction industry: literature review*, J. Constr. Eng. Manage **143(8)**, 04017057 (2017)
17. A. Bryman, E. Bell, *Business Research Methods 4th Edition* (Oxford University Press, New York, 2015)
18. V. Braun, V. Clarke, *Using Thematic Analysis in Psychology*, Qual. Res. Psychol **3(2)**, 77 (2006)
19. E.Z.H. Zheng, M.M. de Carvalho, *Managing uncertainty in projects: a review, trends and gaps*, GeP 7(2), 95 (2016)
20. M. Yadollahi, R. Zin, *Applied Multi-Criteria Ideal Rehabilitation Model for Budget Allocation Across Road Infrastructure*, IJIS **3(4)**, 193 (2011)
21. S.G.R. Quadros, C.D. Nassi, An evaluation on the criteria to prioritize transportation infrastructure investments in Brazil, Transp. Policy 40, 8 (2015)
22. Sutardi, I.C. Goulter, *Governmental Priorities in Irrigation Project Selection in Indonesia*, J. Water Resour. Plann. Manage **119(3)**, 406 (1993)
23. F. Arif, m.e. Bayraktar, A.G. Chowdhury, *Decision Support Framework for Infrastructure Maintenance Investment Decision Making*, J. Manage. Eng. **32(1)**, 04015030 (2016)
24. CII, *PDRI: Project Definition Rating Index – Infrastructure Projects* (The University of Texas at Austin, 2013)
25. S. Lindhard, S. Wandahl, *Looking for Improvement in Last Planner System: Defining Selection Criteria*, ICCREM ASCE, 27 (2013)
26. H. Blocksidge, J. Zurawski, *Pipe Selection Criteria for Trenchless Projects: Microtunneling to Large Tunnels*, Pipelines ASCE (2007)
27. E. Cheung, A.P.C. Chan, *Is BOT the best financing model to procure infrastructure projects?: a case study of the Hong Kong-Zhuhai-Macau Bridge*, JPIF **27(3)**, 290 (2009)
28. H. Doloi, *Assessing stakeholders' influence on social performance of infrastructure projects*, Facilities **30(11/12)**, 531 (2012)
29. T-A. Shiau, *Evaluating transport infrastructure decisions under uncertainty*, Transport Plan Techn. **37(6)**, 525 (2014)
30. P.M. Goodrum, Y.Wan, P.C. Fenouil, *A decision-making system for accelerating roadway construction*, Eng. Constr. Arc. Manage. **16(2)**, 116 (2009)

31. OECD, *Towards a framework for the governance of infrastructure* (2015)
32. N. Sciulli, *Public private partnerships: an exploratory study in health care*, Asian Rev. Acc **16(1)**, 21 (2008)
33. K.C. Iyer, R. Balamurugan, *Evaluation of private sector participation models in highway infrastructure in India – a system dynamics approach*, J. Adv. Manage Res **3(1)**, 44 (2006)
34. C. Nnaji, H.W. Lee, A. Karakhan, J. Gambatese, *Developing a Decision-Making Framework to Select Safety Technologies for Highway Construction*, J. Constr. Eng. Manage **144(4)**, 04018016 (2018)
35. Z. Chen, H. Li, A. Ross, M.M.A. Khalfan, S.C.W. Kong, *Knowledge-driven ANP approach to vendors evaluation for sustainable construction*, J. Constr. Eng. Manage **134(12)**, 928 (2008)