Three Management and Planning Tools in Megaproject Management: A Literature Review

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Abstract. The management of megaproject is an emerging-topics to be studied by researchers. As an established management theory, quality management has a potential role to support studies and implementation of megaprojects. This study aims to explore the potential of Seven Management and Planning Tools (SMPT) in supporting megaproject management. A literature review method was utilized to analyse pertinent literatures that used the SMPT in megaproject studies. Based on 28 published articles, it is concluded that SMPT have been widely applied by scholars to analyse megaproject's study in various aspects. In addition, based on the project guideline PMBOK and the international standard project management ISO 21500:2012, the SMPT have opportunity to support the megaproject practice in each stage. This preliminary study gives the potential chance for further studies related to the use of SMPT in megaproject's real case as well as the opportunity to develop megaproject management tools specifically. These issues become a research opportunity in the field of quality management and megaproject management in the future.

1. Introduction

Megaprojects are special projects. Regarding the cost, size, and complexity, they are above the common projects [1]. The general thing to classify a project into megaprojects is the cost category [2]. Megaprojects are the projects that cost at least US$1 billion [1][5], some researchers also define the minimum cost of megaproject is 0.01% of a country's Gross Domestic Products (GDP)[2][4].

Megaprojects appear along with the growth of the population, human desires, and the technological developments [1][5]. The development of megaprojects happened in the infrastructure sector [2][4][5], defense security [5][6], tourism [7], sports [8][9] as well as social poverty alleviation and education projects [6]. The emergence of this megaprojects stimulates the development of strategies for managing the projects better and more effectively [10] in order to reduce the risk of the failure [11].

In the project management guidelines, Project Management Body of Knowledge (PMBOK), there are ten knowledge areas of project management to achieve success [12]. Quality management is one area of knowledge considered as a critical point in project success. In the project stages, quality management plays a role in planning, executing, and controlling stages that consist of quality planning, assurance, and control which are in line with the quality trilogy presented by Juran [13].
Reference [14] stated that three basic concepts of quality management can be integrated to manage the projects, namely customer focus, teamwork, and continuous improvement. Not only the concepts as previously mentioned, but quality management analysis—the Seven Basic Tools (SBT)—which consist of pareto diagram, cause-effect diagram, scatter diagram, control chart, flow chart, run chart, and histogram have also been proven to be used to manage the projects [12].

As the development of quality management theory, SBT are considered inadequate for solving complex problems that sometimes require broader analysis of statistical measures[15]. Additional analysis tools began to be developed, known as "New Seven Tools" or "Seven Management and Planning Tools" (SMPT). The SMPT are based on the concept of qualitative, creative, but still logical and structured approach [16]. The SMPT do not replace the SBT, but they are complementary to support the achievement of the quality targets [15].

In megaproject's system consists of not only quantitative structural problems but also social and cultural complexity [17] especially in developing countries [20], therefore analysis tools are needed not only bases on quantitative measures such as the SBT but also qualitative approaches. Based on this reason, the SMPT has opportunity to support the megaproject management, which the problems are more complex than ordinary projects. To identify the extent to which the SMPT have been used in megaproject research, a structured literature review from scientific articles is required. Achieving this target's study, the Research Question (RQ) is formulated as follows:

RQ 1: Have the SMPT been applied in megaproject management research?

Beside from the scientific articles, it is also necessary to explore the International Standards of Project Management ISO 21500: 2012 and the project guideline PMBOK to get a clear depiction of the SMPT usage in its each stage of the megaproject. RQ to support this objective is presented below:

RQ 2: What tools from the SMPT are potentially used at each stage of the megaproject?

After the background exposure and study problems are presented in the introduction, this paper will be outlined further in several sections, that are a literature of the SMPT, research methodology, results and discussion, conclusions and the future research opportunity.

2. Literature

The Seven Basic Tools (SBT) in PDCA (Plan, Do, Check, Act) cycle are considered lack of qualitative things, such as ideas, thoughts, and opinions [15]. In the planning phase, sometimes things cannot be planned. The personnel in a company or organization are limited to explain the concept or the abstract idea to make improvements. In order to accommodate the ideas, concepts, and opinions, the personnel in the organization collected them through unstructured mechanisms, such as small notes in meetings, ideas that were raised during discussions between personnel, and solutions that were triggered for a moment. These things are not followed up in the end, even though the ideas, concepts, and opinions that were collected and managed have the potential opportunities to be developed into improvements and innovations [15].

In order to accommodate this, quality management methods began to be developed with a qualitative approach, called Seven Management and Planning Tools (SMPT) [21]. Analytical tools in this method allow managers or leaders of organizations to collect, manage and document the creative ideas in verbal form [22]. The SMPT consist of affinity diagram, interrelationship diagram, tree diagram, matrix diagram, process decision program chart (PDPC), network activity diagram, and prioritization matrix [15][23]. These tools are useful when used comprehensively. However, these tools can be used separately to support problem analysis according to the needs [12][15]. The summary of the SMPT are shown in Table 1.
Table 1. Summary of SMPT

| Tools                        | Description                                                                                      |
|------------------------------|-------------------------------------------------------------------------------------------------|
| Affinity Diagram             | Tool for gathering ideas, opinions, issues, then grouped according to their natural relationship (a creative process) [12][15] |
| Interrelationship Diagram    | Tool to describe all factors that are interrelated, and then connect these factors logically (an analysis of causality) [12] [15][23] |
| Tree Diagram                 | Tool that systematically details tasks and activities that must be completed. [12] [15]                                                                 |
| Matrix Diagram               | Tool to provide an overview of the correlation between ideas or issues between tasks with personnel, teams, and implementation activities. [12] [15] [23] |
| Process Decision Program Chart (PDPC) | Tool to map all possible solutions of each problem. It is used to plan each set of possible solution activities. [12] [15] [23] |
| Activity Network Diagram     | Tool that is used to schedule the activities based on the target. It is used to map all activities based on time and relationship between activities. [12] [15] [23] |
| Prioritization matrices      | Tool that is used to make priority sequences based on weighting criteria. [15] [21]                                                                 |

Source: [12] [15] [21]

3. Methodology

This study was conducted with a systematic literature review (SRM). SRM is a method for identifying, measuring, and analyzing the contribution of scientific article publication to answer research questions [24]. The SRM method uses the keyword search approach in the scientific databases, so that all related scientific articles can be obtained [25].

The stages of exploration and selection of scientific articles were carried out in the following stages: (1) Selecting scientific articles that published in Scopus, Science Direct, IEEE, Springer Link, and Google Scholar databases using Boolean logic mechanisms: AND, OR, ("__") for more accurate scientific article keyword searches. The keywords used to explore scientific articles were "megaproject management" AND "quality management tools", (2) Identifying article selection criteria: scientific articles must be available in full paper, published in English language and must be reviewed, (3) Downloading articles and managing them using Mendeley software, (4) Doing final selection by reading the scientific articles obtained and creating a table to map the articles according to the target study, (5) Analyzing the results of the literature review and identifying the opportunity of the future research.

There were obtained 28 scientific articles, consisting of 22 journals articles and 6 conference proceedings articles, that suitable with the target of this study. Table 2 shows the results of the scientific articles exploration from megaproject researchers that use the SMPT.

In addition to exploring scientific articles, this study also reviews the SMPT through PMBOK [12] and ISO 21500: 2012 [26]. This is done as an effort to examine the potential of the SMPT in supporting the activities at each stage of the megaproject.
4. Result and Discussion

The targets of megaprojects success are in line with the target of common projects, those are being on time, on budget, and meeting the client’s requirement for the quality. Customer satisfaction, project team satisfaction, and long-term benefits also become the parameter of megaproject success [8][51].

In this case, megaproject management can refer to the existing project management. However, something critical to the management of megaprojects are both related to the structure and the context. Megaprojects are characterized by high investment, which is above US$1 billion or above €0.5 billion [3][54][55], with large scale in terms of construction, entities, technology, and duration [8][43][45] [56]. These things obviously have an impact on the management of megaprojects which requires more effort compares to the management of common projects.

Based on the exploration of 28 articles, the researchers used the SMPT to analyze megaproject stakeholders, evaluate megaproject targets, and analyze the complexity of the megaproject, either to develop the model (e.g.[27][28]) or analysis of a particular case study (e.g.[18][19]) (see Table 2 for the detailed).

Table 2. Megaproject management research studies using the SMPT

| No | Articles | Objective | Theme | Seven Management and Planning Tools | Affinity Diagram | Interrelationship Diagram | Tree Diagram | Matrix Diagram | PDPC Activity Network Diagram | Prioritization Matrix |
|----|----------|-----------|-------|-------------------------------------|------------------|--------------------------|--------------|---------------|--------------------------------|----------------------|
| 1  | [18][19][29][30][31][32][33][28][34][35][36][37][38][39][40][41][42][43][44][45][46][47][48][49][50] | Case study analysis | Model Development | Stakeholder strategy | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 2  | [36][37][38][39][40][41] | Case study analysis | Model Development | Megaproject evaluation (decision making tools, project team evaluation, long term benefit) | | ✓ | ✓ |
| 3  | [40][41] | Case study analysis | Model Development | Megaproject complexity measurement | ✓ | ✓ |
| 4  | [42] | Case study analysis | Model Development | Cultural adaptation method | ✓ | ✓ |
| 5  | [43] | Case study analysis | Model Development | Facility tools, methods & mechanism for team communication & collaboration, client requirement | ✓ | ✓ | ✓ |
| 6  | [44] | Case study analysis | Model Development | Megaproject hardware & software (brain) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 7  | [45] | Case study analysis | Model Development | Megaproject supplier improvement | ✓ | ✓ |
| 8  | [46] | Case study analysis | Model Development | Megaproject/Megaevent stages | ✓ | ✓ |
| 9  | [47] | Case study analysis | Model Development | Strategic method, risk prioritization method | ✓ | ✓ |
| 10 | [48][49] | Case study analysis | Model Development | Megaproject classification challenges | ✓ | ✓ |

The matrix diagram is the most frequently used tool to support analysis in megaproject research (57%), followed by the interrelationship diagram (32%), tree diagram (32%) and affinity diagram (25%). Based on this, it can answer the first research question “Have the SMPT been used in megaproject management research?” The results of the study showed that the SMPT were used by researchers to support megaproject management analysis. The matrix diagram mostly used to support the analysis, especially in the field of megaproject team resources [27][45], analysis of social networks and stakeholders [32][35][43][44], areas of strategic decision making [57], evaluation of the
megaproject performance targets, potential solutions identification [36][38][46] and analysis of cultural change [17].

Interrelationship diagram was used to support the management of megaproject teams [45], analysis of stakeholder networks [18][33][39][44] risk and knowledge management in megaproject organizations [39], management of procurement and material purchases [42] and support the structural complexity assessment in megaprojects [41].

Tree diagram was used to support megaproject team management [27][45], diagnose the megaproject challenges in the initial phase [46], support the social and political of the stakeholder [29], identify the risk of megaprojects [49], and support the structural complexity analysis based on the activities and organization [40].

Affinity diagram was used in megaproject team planning included mechanisms for coordination and communication [27][45], classification of the challenges of megaprojects in the initial stages [46], and identification of stakeholder groups based on their needs [18][28][34][43].

Process Decision Program Chart (PDPC), activity network diagram, and prioritization matrix were also used to support various megaproject management analyzes. PDPC was used for megaproject management in the planning, implementation, and evaluation stages [46]. PDPC with prioritization matrix was used for megaproject team management analysis [45] and stakeholder analysis that concerned with the rejection of the community against megaprojects (community resistance) [18]. Prioritization matrix was mainly used in determining risk priorities [49] and determining the procurement of goods and services in megaprojects [42].

Activity network diagram is an analytical tool that was used to support megaproject studies in the field of scheduling in a structured context [45] and uncertain conditions [48]. It was also used to assess the long-term benefits of megaproject activities and entities based on the risk perspective, knowledge management, and stakeholder management [39].

These results need to be studied further with the PMBOK and ISO 21500: 2012 to analyze more the potential of these tools at each stage of the megaproject, to answer the second research questions “What tools from the SMPT are potentially used at each stage of the megaproject?” Based on the exploration of project activities from PMBOK and ISO 21500:2012, the SMPT support analysis at each stage of the project, and this also has the potential to be expanded in the context of the megaproject.

In the initiating and planning phase, the uncertainty of the project is in the highest level [58]. The uniqueness of project type that sometimes just happen in the special case and never handled before [59] or the new concept or method that proven yet [60] is the example of the project uncertainty's source, so why the judgment from the expert is needed in these phases. In these phases, the affinity diagram, the matrix diagram, the tree diagram, the interrelationship diagram, and the prioritization matrix are five of the SMPT that used mostly in the initiating dan planning phases. Even tree diagram is tool that have long been used in the field of projects, especially when planning project scope in work breakdown structure activities [12].

In the initiating phase, the stakeholder identification is critical activity because it need for the social network building for the next process [43]. The tools that potentially support this activity are the affinity diagram, the interrelationship diagram, the tree diagram, the matrix diagram, and the prioritization matrix [12][26]. Further, these diagrams and the matrix tools also useful in supporting planning project's phase, such as the planning of schedule activity, cost, quality, and risk mitigation. These activities, particularly in megaproject, involves many choices for several decisions [61]. Therefore, especially the prioritization matrix would help the manager and the team to list activity or task that must be held first based on some criteria (e.g. cost, time, quality specification) that can be combined with relative weighting methods analytical hierarchy process (AHP) [15].

Beside these five tools, the activity network diagram has also been known to practitioners to support the project schedule, especially to determine critical path analysis in the project planning phase [23]. While in the project executing phase, all off the SMPT are potentially used, especially in the quality assurance activity, for example when build the standard operating procedure of project task
PDPC is the tool that mostly use to support the analysis of the controlling and monitoring phase [12][26]. The activity in this phase such as the controlling of the task, the scope, the time, the communication and so on, need monitoring consistently. In case something not running as it should be in this stage, the PDPC could support the manager and team to mapping the possible solution activity to find the optimal completion [12][26].

5. Conclusion
The SMPT have been used to support the analysis of megaproject management studies in various aspects. The tools can be used in single or integrated. The SMPT used by scholars mostly are the matrix diagram, the interrelationship diagram, the tree diagram, and the affinity diagram.

Based on the PMBOK and the ISO 21500:2012 that expanded in megaproject field, the SMPT have opportunity to support the megaproject practice in each stage. In the initiating and planning phase, the tools that potentially use to support the megaproject activity are the affinity diagram, the matrix diagram, the tree diagram, the interrelationship diagram, the activity network diagram and the prioritization matrix. In the executing phase, all the SMPT can be used to support the activity especially in quality assurance tasks. In the controlling and evaluating phase, the PDPC is the tool that used to support the manager and team to find the solution of the tasks that are not running in accordance with the planning target.

The methods and tools for megaproject management are still being explored and developed. In this study, the SMPT have been identified and proven could supported the research analysis in the field of megaprojects and potentially used at each stage of the megaproject activity. This study opens the potential for further studies related to the use of the SMPT in the real case of megaproject as well as the opportunity to develop megaproject management tools specifically. These potentials issues become a research opportunity in the field of quality management and megaproject management in the future.

6. References
[1] Flyvbjerg B 2014 Proj. Manag. J. 45 6–19.
[2] Hu Y, Chan A P C, Le Y and Jin R 2015 J. Manag. Eng. 31 1–11.
[3] van Marrewijk A and Smits K 2016 Int. J. Proj. Manag. 34 533–44.
[4] Zhou Z and Mi C 2017 Int. J. Proj. Manag. 35 1378-90.
[5] Kardes I, Ozturk A, Cavusgil S T and Cavusgil E 2013 Int. Bus. Rev. 22 905–17.
[6] Morris P W G 1988 Technol. Soc. 10 71–98.
[7] Lamberti L, Noci G, Guo J and Zhu S 2011 Tour. Manag. 32 1474–83.
[8] Zidane Y J-T , Johansen A and Ekambaram A 2013 Procedia – Soc. Behav. Sci. 74 349–57.
[9] Gibson H J, Walker M, Thapa B, Kaplanioud K, Geldenuys S and Coetzee W 2014 Tour. Manag. 44 113–22.
[10] Drouin N and Besner C 2012 Int. J. Manag. Proj. Bus. 5 175–79.
[11] Flyvbjerg B, Bruzelius N and Rothengatter W 2003 Megaprojects and Risk: An Anatomy of Ambition (United Kingdom: Cambridge University Press).
[12] PMI 2017 A Guide to The Project Management Body of Knowledge 6th ed (Pennsylvania: Project Management Institute, Inc).
[13] Juran J M and Godfrey A B 1998 Juran’s Quality Control Handbook (New York: McGraw-Hill).
[14] Orwig R A and Brennan L L 2000 Int. J. Qual. Reliab. Manag. 17 351–63.
[15] Anjard R P 1995 Training for Quality 3 34–7.
[16] Groenendijk E M and Dopheid E J M 2003 Planning and Management Tools (Enschede: ITC).
[17] van Marrewijk A 2007 Int. J. Proj. Manag. 25 290–99.
[18] Jordhus-Lier D 2015 Habitat. Int. 45 169–76.
[19] Lee C, Won J W, Jang W, Jung W, Han S H and Kwak Y H 2017 Int. J. Proj. Manag. 35 1683-96.
[20] Damayanti R W Hartono B and Wijaya A R 2019 2018 IEEE Int. Conf. Ind. Eng. Eng. Manag. 1366–70.
[21] Stockley A 1995 Int. J. Health Care Qual. Assur. 8 24–9.
[22] Ahmad R, Kamaruddin S, Khan Z A, Mokhtar M and Putra A I 2006 Management of Environmental Quality: An International Journal 17 390–408.
[23] Duffy G L 2012 Qual. Prog. 1.
[24] Staples M and Niazi M 2007 J. Syst. Softw. 80 1425-37.
[25] Tranfield D, Denyer D and Smart P 2003 Br. J. Manag. 14 207–22.
[26] ISO 2012 ISO 21500:2012 International Standard for Project Management vol. 2012 (Geneva).
[27] Homayounfard H and Safakish G 2016 Procedia – Soc. Behav. Sci. 226 209–17.
[28] Ma H, Zeng S, Lin H, Chen H and Shi J J 2017 Int. J. Proj. Manag. 35 1365–77.
[29] zhao Liu Z, wei Zhu Z, jia Wang H and Huang J 2016 Int. J. Proj. Manag. 34 202–18.
[30] Pohner H 2016 Glob. Environ. Chang. 38 205–16.
[31] Zeng S X, Ma H Y, Lin H, Zeng R C and Tam V W Y 2015 Int. J. Proj. Manag. 33 537–48.
[32] Rozema J G, Cashmore M, Bond A J and Chilvers J 2015 Geoforum 59 98–108.
[33] Ruuska I, Arto K, Aaltonen K and Lehtonen P 2009 Int. J. Proj. Manag. 27 142–53.
[34] Lin H, Zeng S, Ma H, Zeng R and Tam V W Y 2016 Int. J. Proj. Manag. 35 1415-26.
[35] Irimitia-Díéguez A I, Sanchez-Cazorla A and Alfalla-Luque R 2014 Procedia – Soc. Behav. Sci. 119 407–16.
[36] Aoun O and Teller J 2016 Front. Archit. Res. 5 254–64.
[37] Eweje J, Turner R and Muller R 2012 Int. J. Proj. Manag. 30 639–51.
[38] Zeybek H and Kaynak M 2008 Project Proceedings of Codatu XIII: Sustainable Development Challenges of Transport in Cities of the Developing World: Doing What Works 1–10.
[39] Brookes N, Sage D, Dainty J, Locatelli G and Whyte J 2017 Int. J. Proj. Manag. 35 1213–24.
[40] Lu Y, Luo L, Wang H, Le Y and Shi Q 2015 Int. J. Proj. Manag. 33 610–22.
[41] He Q, Luo L, Hu Y and Chan A P C 2015 Int. J. Proj. Manag. 33 549–63.
[42] Nicał A K and Wodyński W A 2015 Procedia Eng. 123 342–51.
[43] Hassan T, McCaffer R and Thorpe T 1999 Engineering, Construction and Architectural Management 6 21–9.
[44] Chung J K H, Kumaraawamy M M and Palaneeswaran E 2009 Autom. Constr. 18 966–74.
[45] Brockmann C 2009 LEAD Conference 2000 12.
[46] Othman A 2014 African J. Eng. Res. 2 73–84.
[47] Locatelli G, Littau P, Brookes N J and Mancini M 2014 Procedia – Soc. Behav. Sci. 119 625–34.
[48] Jussila A, Mainela T and Nätti S 2016 J. Bus. Ind. Mark. 31 575-86.
[49] Boateng P, Chen Z and Oguluana S O 2015 Int. J. Proj. Manag. 33 1795–1811.
[50] Ahmed A and Othman E 2013 Organ. Technol. Manag. Constr. 5 730–46.
[51] Zidane Y J T, Johansen A and Ekambaran A 2015 Procedia Comput. Sci. 64 409–16.
[52] Zidane Y J T, Johansen A, Ekambaran A and Hald L C 2015 Procedia Comput. Sci. 64 844–51.
[53] Sato C and Chagas Jr M 2014 Int. J. Manag. Proj. Bus. 7 624–37.
[54] Müller P R, Sato C E Y and Chagas Jr M 2014 Int. J. Manag. Proj. Bus. 7 624–37.
[55] Mišić S and Raduškovíc M 2015 Procedia Eng. 122 71–80.
[56] Miller R and Lessard D 2000 The Strategic Management of Large Engineering Projects (Hongkong: QuarkXpress).
[57] Eweje J, Turner R and Muller R 2012 Int. J. Proj. Manag. 30 639–51.
[58] PMI 2017 Project Manager Competency Development Framework 3rd ed (Pennsylvania: Project Management Institute, Inc).
[59] Maylor H R, Turner N W and Murray-Webster R 2013 Res. Manag. 56 45–51.
[60] Hartono B 2018 Int. J. Manag. Proj. Bus. 11 734–60.
[61] Rad E K, Sun M and Bosché F 2017 J. Manag. Eng. 33 04017009.