Images by the author.

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Master Construction Management and Engineering
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Local Community Involvement for
Indonesian National Bridge Management Systems
Master Thesis

Delft University of Technology

Local Community Involvement for Indonesian National Bridge Management Systems

Master Thesis

By

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All praise is (due) to Allah, who has sent down upon His Servant (Muhammad) the Book and has not made therein any deviance (QS 18:1). Thank you, Lord, for choosing me as an *umma*. Humanity's lifetime guidance in The Quran is impactful during the knowledge pursuit in one of the world's revered universities.

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I want to thank my family. Mom and Dad have been exceptionally compassionate and patient in nurturing me. Never will I forget their best efforts in any circumstance. I do not even think all adornments combined in this world are enough to reciprocate their deeds. My brothers: Anca, Sakti, and Sulo have always been inspiring role models for me. I will not reach this point without your shared experience and advice. In addition, my girlfriend Kanty is tremendous mental support, and we have been managing to understand each other for a 2-year long-distant relationship.

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Muhammad Sulthoanuddin Akbar,

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Executive summary

Within the Indonesian national road network, Bina Marga, assisted by regional offices (Balai), manage nearly 18,000 bridges scattered across 34 provinces. Maintaining its reliability is vital as inland transportation remains the most effective mobility means for ± 270 million inhabitants. Therefore, as a road service provider under the Ministry of Public Work and Housing, they aim to achieve a high maturity level in public infrastructure asset management (PIAM) practices. It is done by improving the current Bridge Management Systems (BMS) 1992 guideline. However, managing such a vast network is challenging. The limited human resources in quality & quantity hinder Bina Marga and Balai to strive for reliable data and adequate routine maintenance.

Inspired by Indonesian collectivism, the study explores local community involvement to improve bridge data quality and adequate routine maintenance, i.e., BMS x Locals. Its objective is to recommend Bina Marga to improve the current BMS practices through a BMS x Locals guideline. The study sketches the current state of BMS, identifies drivers in outsourcing locals, identifies the type of works and groups, identifies locals' willingness to be outsourced, and generates situational strategies. The research question is formulated as: *How can the local community be involved as the external resources to assist Bina Marga's in Indonesian Bridge Management Systems (BMS)*. This study uses interviews and desk study to collect data on six Bina Marga & five Balai NTB officials, and five locals in West Nusa Tenggara province. In addition, various data analyses are performed, consisting of Causal Loop Diagram (CLD), Multi-criteria Decision-Making Analysis (MCDA), SWOT & TOWS analysis. The study results and the BMS x Locals guideline have been validated by a high-level Balai official.

For the result, CLD reveals that Bina Marga is struggling for a high PIAM maturity level because of the absence of specific quadrennial strategic planning (RENSTRA) and limited human resources in BMS, making them unable to obtain reliable data and perform adequate routine maintenance within a year. It also identifies Bina Marga's drivers to outsource locals: up-to-date data monitoring, additional human resources, economy, and public engagement. The MCDA, amounting to 4 analyses, identifies nine criteria: cost, time, bridge literacy, technological literacy, labouring skill, quality, continuity, level of education, and age. Such criteria generate inventory and condition data – conducted by local university elements and cleaning works (garbage, rubble, grass, and drainage) – by locals in the municipality's list. Locals' willingness to be outsourced is also unveiled through CLD, consisting of economy, i.e., additional income and knowledge & local pride. Moreover, SWOT & TOWS analysis identifies 11 strengths, 12 weaknesses, 9 opportunities, and 10 threats for BMS x Locals; and generates situational strategies (maxi-maxi: 7, maxi-mini: 7, mini-maxi: 6, and mini-mini: 7). Finally, synthesised situational strategies amounting to 1 to 2 items have been presented according to the empirical challenges.

Based on the research outcome, BMS x Locals guideline is recommended to Bina Marga and Balai comprising six primary activities: screening, assessment of capacity, organisation forming & linking, planning & design, implementation, and monitoring & evaluation.

Keywords: Bridge Management Systems, Causal Loop Diagram, Infrastructure Asset Management, Local community involvement, Multi-criteria Decision Analysis, Road Service Providers, SWOT & TOWS Analysis.

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List of Acronyms

AHP	Analytical hierarchy process
Balai	Bina Marga's Regional office in a provincial level
Bina Marga	Directorate General of Highways Indonesia
BMS	Bridge Management System
BMS x Locals	The proposed programme for Bina marga
CLD	Causal loop diagram
CM	Condition mark of the bridge
FWP	Forward works plan
INVIJ	Smartphone-based app – Visual Inspection tool for bridge inspector
JAKI	Smartphone-based app - Public reporting for roads
LIP	Labour-intensive project
MCDA	Multi-criteria decision analysis
PIAM	Public Infrastructure Asset Management
PPK	Commitment Making Officials – The spearhead of Balai in the field
PUSJATAN	Institute of Road Engineering Indonesia
PUPR	Ministry of Public Works and Housing Indonesia
RENSTRA	Quadrennial Strategic Planning
SIMAJI	Information System for Bridge Asset Management in Indonesia
SWAKELOLA	Self-management contract

1 Introduction

This chapter consists of 4 sub-chapters. First, the background describes an overview of current Indonesian bridge management practices and problems faced by the road authority, particularly in data and maintenance. Secondly, the knowledge gap mentions the study gap, including engagement between the road service provider & the local community and scientific contribution. The third part presents the research objective as a recommendation to Bina Marga. Lastly, the formulation of the research question is presented.

1.1 Background

Indonesia's Directorate General of Highways (Bina Marga), as the public road authority under the Ministry of Public Works and Housing (PUPR), is responsible for managing over +47,000 km long of the national road in 2016 (Bina Marga, 2016). Bina Marga targets developing a new road network from 2020-2024 for 500 km of national roads. In the preservation aspect, Bina Marga expects a significant increase in the national road's "good performance index" for 92.81 to 97% from 2020 to 2024 (RENSTRA PUPR 2020-2024, 2020).

Bina Marga generally focuses only on the major rehabilitation or reconstruction of the road infrastructure treatment aspect because they can hardly perform proper routine maintenance (James, 2016). It implies significant reconstructions will be committed when the road condition is in a state of a high level of deterioration or severely damaged. The notion of "fix it when it is broke" represents the immaturity of managing road for the 21st-century asset management practice (Moubray, 1997).

Bridge infrastructures, located in the national road, is an indispensable element to ensure accessibility and reliability, and any disruption can cause severe impacts, e.g., traffic congestion and problem in logistical means (PwC, 2017). Bina Marga possesses over +18,000 bridges, and during 2015-2019 there are 445 km maintained bridges, 15 km improved bridges, and 58 km new bridges across the country (Bina Marga, 2020; RENSTRA PUPR 2020-2024, 2020). Bina Marga conducts the bridge management systems (BMS), e.g., the bridge preservation, as an integral part of infrastructure asset management. Nevertheless, the current bridges in the national road network are still hard to maintain, not to mention the future addition to the bridge assets given the national ambition (Suthanaya & Artamana, 2017). Therefore, Bina Marga is advised to improve data reliability and develop adequate routine maintenance of all bridges scattered across the country (Mihani, 2019; PwC, 2017; Utary et al., 2018). Furthermore, data-driven decision-making and adequate routine maintenance in infrastructure asset management of bridges are required to consolidate the government focus in maintaining road infrastructure at the national level (Boubaz et al., 1990; Honfi et al., 2018; James, 2016; Shah et al., 2017).

In the emergence of Information Communication and Technology (ICT), embedding remote sensing devices on the bridge is an approach to collecting data, but it requires considerable investment and is subject to vandalism (Liu et al., 2009). However, with the increase of mobile devices & the prevalence of public reporting and the presence of people living in vicinities, Bina Marga can explore the opportunity to empower locals in BMS (Gebremedhin et al., 2020; Kopackova & Libalova, 2018, 2019; M.-H. Lee, 2018; Seto et al., 2019).

The lack of human resources is another challenge to conduct routine maintenance. Locals involvement as a solution can be explored. With the eagerness of Bina Marga on infrastructure development and the opportunity of utilising the local community, there is a shared value that could work when combining them. It implies that practice in public infrastructure done by Bina Marga contributes to the improved quality of infrastructure itself and the empowerment of society. Also, the ideal situation for the infrastructure to function well is to include the public's participation (Li et al., 2012; Ngowi, 1997; World Bank, 2004).

However, the involvement of the local community to solve problems in public authority poses a challenge. Despite the increase in community-based involvement in development projects, the notion can be misunderstood, misapplied, and eventually discarded (Khwaja, 2004). The ambiguity of local community involvement in the infrastructure domain requires a tailor-made approach. Thus, the BMS requires a good management strategy to develop a suitable solution, especially the lack of human resources.

Indonesia becomes the 4th largest smartphone user globally, amounting to 191 million and projected to reach 256 million by 2025 (Statista, 2020). Moreover, the World Bank's labour force surveys reveal that Indonesia's informal sector employs 61%-70% of the total labour force (Alatas & Newhouse, 2010). A considerable portion of people who own a smartphone and the prevalence of informal workers to be exerted as a resource to assist in reporting bridge conditions and perform routine maintenance across the country are considered promising to incorporate in BMS. Besides, the empowerment of locals in BMS opens up a new opportunity to have additional income to earn and contribute to job creation. This highlights the importance of creating shared value (CSV) to develop the practice of BMS. Given the necessity of Bina Marga to conduct adequate and routine maintenance, local community involvement in the data reporting and a labour-intensive job to preserve bridges is a promising subject to be explored.

1.2 Knowledge Gap

Studies on Creating Shared Value (CSV) between enterprises and local communities are emerging (Dembek et al., 2016), yet it still lacks for other entities, such as public government and social enterprises (Kwon & Park, 2019). The public authority needs to utilise the existence of the local community to ensure the success of their agenda (Slingerland et al., 2018). That implies public authorities should build good cooperation with the local community to ensure the sustainability of their practices.

There has been limited research on infrastructure and culture, i.e., involving the local community, especially roads and bridges (Meng et al., 2016; Wattam, 1998). Moreover, a study conducted in asset management, i.e., BMS involving the local community, is not yet available. Therefore, this research is aimed to complement infrastructure asset management with novelty by exploring the bridge management system in Bina Marga.

1.3 Objective and Scope

This study aims to improve the current practice of BMS by incorporating community involvement in the BMS. The phrase “BMS x Locals” is used recurrently in this report. The extent of local community involvement in public bridge asset management is explored, and BMS x Locals guideline is generated.

The bridge infrastructure used in this research is a short span bridge located in the national links and is usually characterised by truss structure, beam, cantilever, and arch bridge under the jurisdiction of the regional office (Balai). This research will observe various bridges, including span <20 m, 20 – 40 m, 40 – 60 m, and 60 – 100 m. Any bridges entailing complex/megastructures or span over 100 meters are outside the scope of the study. The prevalence of short-span bridges is considered manageable for the local community level and does not require extensive knowledge and skill.

1.4 Research Question

The main research question (MRQ) is:

“How can the local community be involved as the external resources to assist Bina Marga in Indonesian Bridge Management Systems (BMS).”

The following sub-research questions (SRQ) are derived to assist in answering MRQ:

1. What is the current state in terms of regulation and practice of Indonesian BMS?
2. What are the drivers enabling Bina Marga to outsource the local community?
3. What type of works in BMS can be done by the locals?
4. What type of group in the local community is eligible for Indonesian BMS in reporting and maintenance?
5. What are the factors which drive the community’s willingness to be outsourced in Indonesian BMS?
6. What are Bina Marga and Balai strategies concerning the involvement of the local community in Indonesian BMS?

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2 Literature background

This chapter presents the essential information in profiling local community involvement in public infrastructure asset management. First, the theory of asset management in public infrastructure is described in Sub-chapter 2.1. Secondly, Sub-chapter 2.2 presents the organisations used in this research, i.e., Bina Marga and Balai NTB. Lastly, Sub-chapter 2.3 explains the local community involvement, including roles and opportunities and challenges.

2.1 Public Infrastructure Asset Management (PIAM)

This sub-chapter contains three explanations about public infrastructure asset management (PIAM) theory. First, the management's lifecycle activity and the responsible organisation are explained in Sub-chapter 2.1.1 and Sub-chapter 2.1.2, respectively. The last part is meant for the bridge management systems and the practices in Indonesia.

2.1.1 Public Infrastructure Lifecycle

External environment and traffic load are significant contributors to road deterioration during its lifecycle (Adey, 2019). In general, the lifecycle of road infrastructure consists of planning, construction, operation and maintenance, and demolition (Too et al., 2006). Apart from providing exemplary service to the users, road authority can achieve a good value of money within the effective practice of road asset management by determining strategy, programme and intervention within its lifecycle (Adey, 2019; Spatari & Aktan, 2013; Too et al., 2006).

A multidisciplinary approach is required within the asset lifecycle; otherwise, ineffective treatment may occur. The approach entails subjects such as civil (structural, geotechnical, hydraulics), economy (cost/benefit analysis, lifecycle cost, multi-criteria), strategic management (KPIs and policies), safety, social science, and environment (Spatari & Aktan, 2013).

Technology plays an essential role in the success of PIAM. A complex road infrastructure network with multiple stakeholder involvement requires advanced tools to equip with (Adey, 2019). Lots of computer-based technology or platform have been developed over the last 30 years, e.g., web-based application, desktop field inspection tool, and smartphone apps, that enable road authority to collect, store, and process the data to a various extent, e.g., budget forecast, treatment prioritisation, and online visual validation with video (M. Halfawy & Figueroa, 2006; M. M. R. Halfawy et al., 2006; Putri & Sastrawiria, 2018). Those technologies can also be used to involve stakeholders in various steps (M. M. R. Halfawy et al., 2006).

2.1.2 Public road service provider

Road authority/service provider can be a government institution that falls below the Ministry of Public Works, assisted by regional offices. Too et al. (2017) highlight two essential road asset management roles: operational and strategic. The operational level involves practical business, ensuring the good working condition of the asset, while the strategic level entails integrating user needs, the environment, and the organisation's business model. The operational level requires them to understand the road users. At the strategic level, the road authority should understand their working realm, be able to obtain reliable data and enough budget to understand the user behaviour, the impact of an exposed asset to the environment, e.g., weather influence and natural disaster, and the sustainability of the organisation (Adey, 2019).

There are two common challenges faced by a road authority: a limited budget and human resources within the organisation. The road is an infrastructure mainly financed by tax payer's money. Often, the constrained budget becomes a hindrance to treat the asset overarchingly. It implies a prioritisation that regulates certain sections or bridges within a road network, e.g., strategic transportation area and required traffic volume (Suthanaya & Artamana, 2017). Hence, the reliability of data, e.g., international roughness index (IRI), annual average daily traffic (AADT), bridge condition mark (CM), and axle load, are essential to allocate the budget wisely given the budget constraint. However, the top management level in the organisations is struggling to echo asset management to the lower level (Adey, 2019; Shah et al., 2017). Such a situation generates a lack of awareness among staff in the road authority, threatening to conduct continuous improvement in PIAM (Too et al., 2006). Also, the lack of human resources in the organisation hinders the effective PIAM practice, especially in developing countries (Faizal & Suprayoga, 2014; James, 2016; Utary et al., 2018).

2.1.3 Bridge Management Systems and its practices in Indonesia

The bridge management system (BMS) is part of asset management. There is a virtue of cost implications if capacity impairment occurs or fails outright (Harding et al., 1990). BMS covers the whole period from concept to ultimate replacement or demolition, similar to that explained in Sub-chapter 2.1.1. The following aspects are also included in BMS: inventory and condition data, safety judgement/condition mark, future predictive behaviour, maintenance strategies back-coupled through its designs, budget allocation, execution strategy (including men and means), and scenarios for bridge replacement (Toorn & Reij, 1990).

The presence of reliable data and adequate routine maintenance adds significantly to the expected design life of the asset (Boubaz et al., 1990; Manning & Masliwec, 1990; Toorn & Reij, 1990). It should be carefully addressed to generate good value for money; otherwise, it will cost a fortune, primarily upon the reliance of "fix it when it is broken" (Toorn & Reij, 1990). As primary and minor disturbances can have a considerable impact on the performance of a road network, resilience is critical to keep the transport running efficiently (Calvert & Snelder, 2018).

Bina Marga has developed an Indonesian Bridge Management Systems (BMS) 1992 within its manual/guidelines (Bina Marga, 1993b, 1993a). Regional offices (BALAIs) of Bina Marga across Indonesia have been gradually established, and, to date, there are 33 BALAIs. BMS is a framework for bridge-related infrastructure, including development and its preservation. To complement BMS, Bina Marga has also developed an asset management information system called the Indonesian Bridge Management information System (SIMAJI) (Kementerian Pekerjaan Umum, 2017). In BMS, the condition is represented based on the condition mark described in Table 2.1.

Table 2.1 Guidelines for Assignment of Inventory Condition Marks (Bina Marga, 1993b)

Condition Mark 0	As new condition with no defects or the bridge element is in good condition
Condition Mark 1	Minor defects (defects can be treated by routine maintenance and do not affect the safety or function of the bridge), e.g., minor scour, surface corrosion, loose or missing bolts, loose timber planks.
Condition Mark 2	Defects that require monitoring or maintenance in the future, e.g., minor rot in timber members, deteriorated mortar in masonry elements, extensive rubbish or soil build-up around bearings, signs which need replacement.
Condition Mark 3	Defects that require attention soon (defects which may become serious within 12 months), e.g., concrete members with minor cracks, rotted timber members, potholes in running surface, bumps in running surface at abutments, moderate scour at piers/abutments, corroded steel members.
Condition Mark 4	Critical condition (serious defect requiring immediate attention), e.g., failed members, extensive cracking or spalling of the deck, undermined foundations, concrete members with exposed and corroded reinforcement, missing handrail/guardrail.
Condition Mark 5	Element broken or no longer functioning, e.g., collapsed superstructures, washed-out embankments.

SIMAJI is used to store and manage bridge datasets used for planning and programming, i.e., forward works plan (FWP). Furthermore, SIMAJI can analyse the collected data using a computer which allows Bina Marga to monitor the inventory and condition data and perform necessary measures to ensure the reliability of the bridge based on the allocated budget (Kementerian Pekerjaan Umum, 2017). The following abilities of SIMAJI include:

- Input and retrieve inspection and other relevant data.
- Prepare standard bridges reports.
- Inspect database and retrieve various data combinations.
- Screen, rank, and prepare maintenance programmes of bridges.
- Prepare the programme, including short, mid, and long term.
- Perform case-by-case analysis to each respective bridge (tailor-made).

SIMAJI is supported by a smartphone-based application, namely the Application for Bridge inspection (INVIJ). INVIJ has introduced flexibility for bridge inspectors, particularly at the regional office level (Putri & Sastrawiria, 2018).

2.2 Road service provider in Indonesia

This chapter presents Bina Marga and Balai NTB as a road service provider in Indonesia and the research subject. The general overview, the size of the organisation, and its responsibility coverage are included.

2.2.1 Bina Marga

Bina Marga is assisted by 33 regional offices consisting of 7 *Balai Besar Pelaksana Jalan Nasional* (BBPJN) *and 26 Balai Pelaksana Jalan Nasional* (BPJN), see Figure 2.1. The distinction is that the BBPJN is responsible for multiple provinces, whilst BPJN belongs to a single province. For clarity purposes, both BBPJN and BPJN are mentioned as Balai.

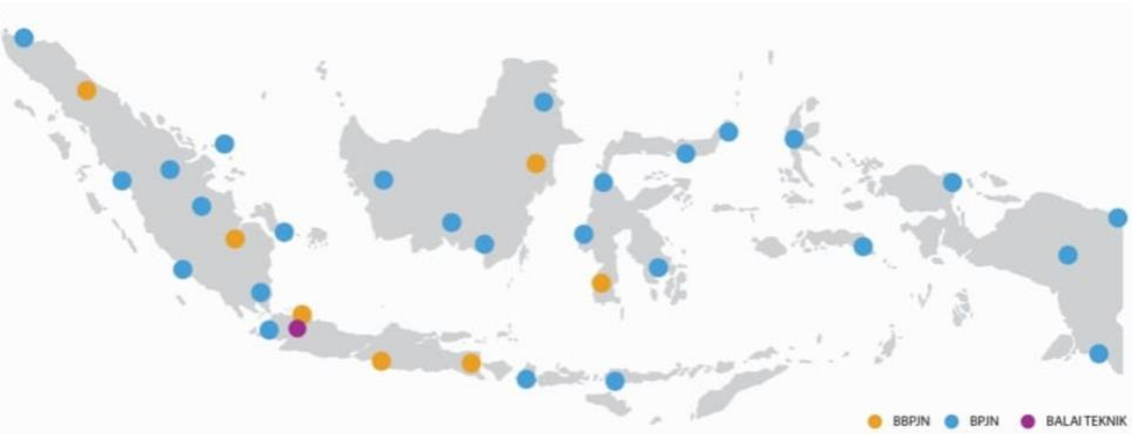

Figure 2.1 Distribution of Regional Offices in Indonesia (RENSTRA PUPR 2020-2024, 2020)

Based on the PUPR Ministerial Regulation No.3 the year 2019, Bina Marga has to carry on the following tasks (Bina Marga, 2019):

1. Formulating policies in the field of road administration by the laws and regulations
2. Implementing policies for national road administration
3. Implementing policies to strengthen national connectivity
4. Preparing norms, standards, procedures, and criteria in the field of road administration
5. Providing technical guidance and supervision in the field of road management
6. Evaluating and reporting in the field of road administration
7. Performing administrative tasks in Bina Marga
8. Implementing other functions assigned by the Minister of Public Works and Public Housing.

2.2.2 Balai NTB

Balai NTB was established in 2016, located in Mataram, West Nusa Tenggara Province. It is a part of the technical unit under Bina Marga in managing the national roads network (see Appendix A for Balai NTB organisational chart and national roads coverage). Roads that fall under the jurisdiction of Balai NTB is summarised in Table 2.2. Also, as of 2016, Balai NTB has been responsible for managing 435 bridges.

Table 2.2 National roads sections in NTB (Balai NTB, 2020)

No	Island	Number of sections	Length of section (km)
1	Lombok	42	307
2	Sumbawa	39	627
Total		**81**	**934**

The following are the functional tasks of Balai NTB (Balai NTB, 2020):

1. Preparing data and information as material for the preparation of road network development and preservation programs.
2. Implementing and controlling environmental impact analysis
3. Preparing plans and documents for the procurement of goods and services as well as their implementation
4. Carrying out unit price analysis of road and bridge works
5. Implementing and controlling land acquisition for national roads
6. Implementation of disaster mitigation and management that has an impact on roads
7. Controlling and supervising the construction of the national road network, including highways and toll roads, as well as the adjustment of the construction implementation contract
8. Conducting road safety audit
9. Monitoring and evaluating minimum road service standards
10. Performing quality management system and construction quality testing
11. Procuring, utilising, storing, maintaining, and carrying out service of materials and equipment for roads and bridges.
12. Carrying out employment and legal affairs
13. Providing physical security and certification of land acquisition for national roads
14. Implementing, controlling, supervising, and securing national roads and the determining national road ledgers
15. Preparing financial accounting reports and accounting for state property
16. Procuring goods and services
17. Carrying out general administrative tasks, maintaining the Balai's internal affairs, and coordinating with related agencies and public communication.

2.3 Local Community Involvement

This section explains local community involvement containing two parts. First, Sub-chapter 2.3.1 explains the local community as an element in society and its roles. Second, Sub-chapter 2.3.2 exhibits opportunities and challenges in identifying the possibility for the involvement of locals.

2.3.1 The local community in a society

Community is often associated with involvement in society (Cnaan et al., 2008). Such an involvement or willingness to participate nested in the interactions between internal (motivation) and external (driver) motivators. Motivation comes from within the community, initially started with ideas that can incite human behaviour and actions, such as not polluting the river for irrigation and preserving forest/planting trees to avoid a massive flood. The driver is a contextual condition and subject to an institutional process that usually provides incentives enabling local people to get involved. It occurs due to the shared values institutions and communities strive to improve agriculture's productivity and quality by maintaining the raw water (river) and managing the forest for biodiversity (Ruiz-Mallén et al., 2015). Also, the involvement is driven by apparent triggers. For example, the community is motivated to conserve nature against environmental degradation, situational conflict, and natural disasters (Seixas & Davy, 2007).

2.3.2 Opportunity and challenges in involving the local community

The previous sub-chapter implies creating shared value (CSV) between the institution and the local community. CSV creates organisational value while simultaneously embedding value to the society and the environment (Dubois & Dubois, 2012). The principle of CSV strives for economic value to address the needs and challenges from the organisation and its surrounding environment, which eventually expands the total pool of economic and social values (Porter & Kramer, 2011). The CSV gradually evolves from the enterprises-oriented concept to the governmental and social organisational/NGOs due to its applicability which orientation is not merely on "economy". CSV between public authority and the local community should be more prompted to improve decision-making quality and co-create mutual benefit among the entities in the public infrastructure domain.

Involving the local community has many challenges, e.g., culture's internal motivation, lack of global inclusiveness, and the degree of continuity including control (Ruiz-Mallén et al., 2015). In a particular community, the value of money is feared to undermine culture's value. Extrinsic rewards such as direct payment can lead to overjustification and a subsequent decrease in internal motivation (Ruiz-Mallén et al., 2015). Inclusivity-wise, local community involvement is often perceived as an organisational tool that serves instrumental perspectives related to reputational, financial, and social objectives. This situation does not allow the concept of involvement to fully maximise its potential where competitive two-way dialogues within phases can fully function (Jelen-Sanchez, 2017). Though workshops are essential in the initial process, the expert's adequate supervision/guidance/direction likewise institutionally deployed is the key for any community who just engaged in the involvement to maintain its continuum. The cultural dimension by Hofstede can be used as an approach to understanding the respective communities and embracing challenges and will be explained in the following sub-chapter.

2.4 Remarks

The lifecycle of public infrastructure management (PIAM) includes planning, construction, operation, maintenance, and demolition. Such activities are managed by a public road service provider (central and regional), and the success entails a multidisciplinary approach and technological intervention. However, budget constraints and inclusivity in human resources are the significant challenges that should be considered.

Bridge Management System (BMS) is part of PIAM dedicated to bridges. In Indonesia, BMS 1992 is used as a guideline for bridge development and its preservation. As an information system for bridges, SIMAJI can store inventory and condition data, e.g., by representing condition marks that are indispensable for the future planning for the assets.

Bina Marga and Balai NTB are used as a subject in this research. Bina Marga is a central office assisted by 33 regional offices (Balai), eight main tasks ranging from management to technical aspects. Balai NTB, as one of the regional offices, is responsible for managing 81 national road sections, 934 km long, and including 435 bridges located in West Nusa Tenggara province. Balai NTB has 17 tasks, also ranging from technical to management aspects.

Local community involvement in the public context can be generated in two ways. The motivation that can incite human behaviour and action is considered as the internal driver. The external driver often comes from apparent triggers, e.g., a damaged environment. Both ways can allow the community to interact in bringing betterment opportunities to its surrounding environment. The locals and the public institution engagement can generate a so-called Creating Shared Value (CSV), leading to an economic aspect. However, locals' involvement requires a consistent internal motivation, inclusivity of the groups, and continuity.

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3 Research Design

Seven main stages were performed in the research, including preliminary design, theoretical background, data collection, data analysis (followed by discussion of results), guideline development, validation, and result. See Figure 3.1 for the research framework.

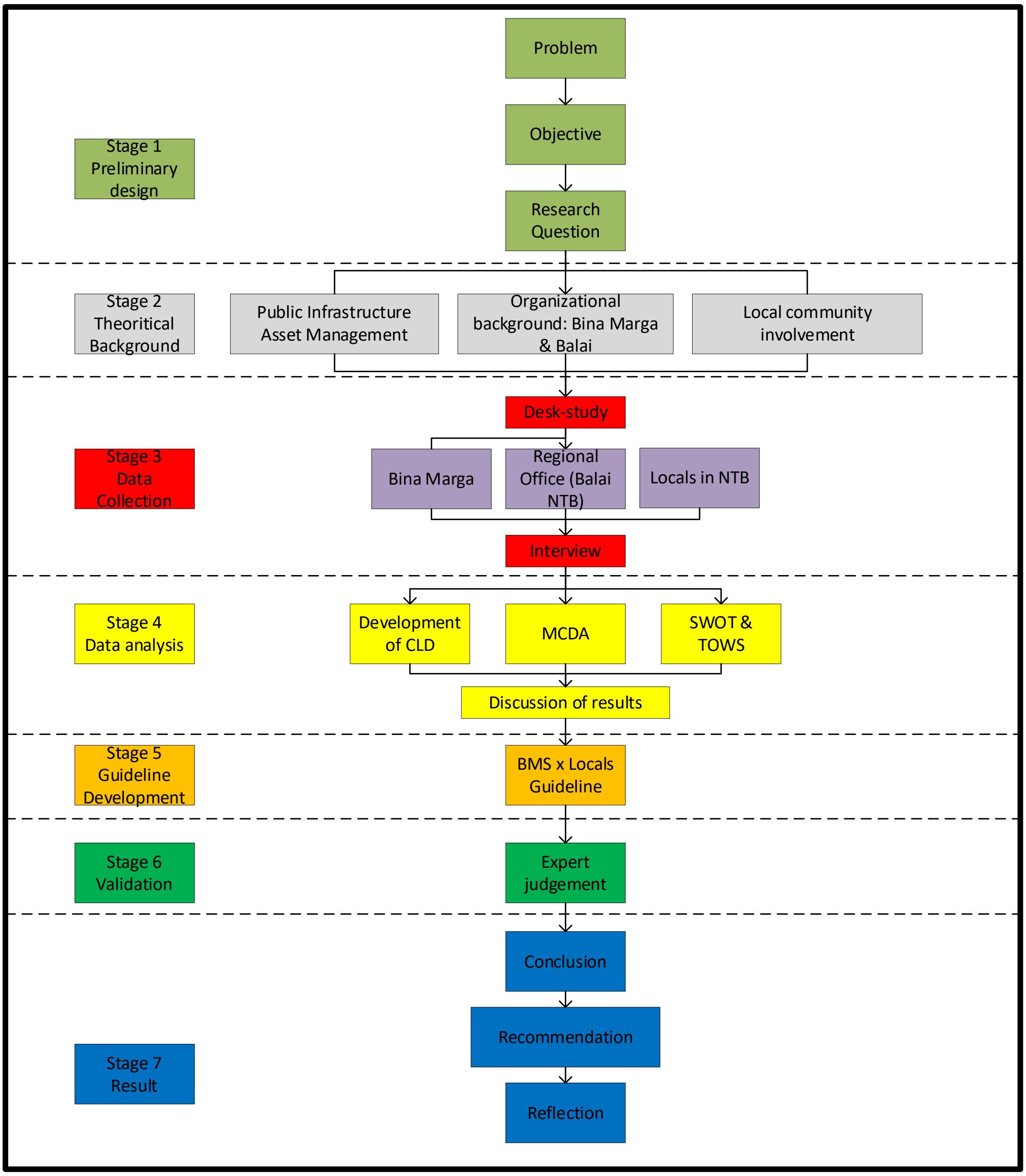

Figure 3.1 Research framework

3.1 Preliminary design and theoretical background

In stage 1, a preliminary literature review was conducted. The problem, objective, and research question were generated by finding a gap based on academic papers and practical organisational information. The preliminary design result was presented in Chapter 1. In stage 2, the theoretical background result was presented in Chapter 2.

3.2 Methods: Data Collection and Data Analysis

Stage 3 involves three research subjects: Bina Marga, Balai NTB, and Locals in NTB. First, data collection was conducted by doing a desk study by reviewing organisational documents for two organisations. Second, it was followed by a series of online interviews involving six Bina Marga officials, five Balai NTB officials, and five locals; see Appendix B for interview questions. Finally, the sessions were recorded and transcribed into text, amounting to 16 transcripts coded qualitatively in *ATLAS.ti* software.

ATLAS.ti acts as an intelligent container that keeps tracking the BMS x Locals research project data, e.g., PDF and text documents (transcripts, articles, reports, papers) once the various documents have been added or linked to an ATLAS.ti project, the "coding" were conducted. In practical terms, coding refers to the process of assigning categories, concepts, or codes to segments of information that are of interest to BMS x Locals research.

In stage 4, three methods for data analysis were employed, including Causal Loop Diagram (CLD), Multi-criteria Decision Analysis (MCDA), and SWOT & TOWS analysis. Those methods use the synthesised data gathered in stage 3. The methods employed in stage 3 and stage 4 assist the author to answer SRQs, which are summarised in Table 3.1.

Table 3.1 Sub-question on the selected method

SRQ	Method: Data collection	Method: data analysis
1. What is the current state in terms of regulation and practice of Indonesian BMS?	Interview and desk study	CLD
2. What are the drivers from Bina Marga to outsource the local community?	Interview and desk study	CLD
3. What type of group in the local community is eligible for Indonesian BMS in reporting and maintenance?	Interview and desk study	MCDA
4. What type of works in BMS can be done at the local community level?	Interview and desk study	MCDA
5. What are the factors which drive the community's willingness to be outsourced in Indonesian BMS?	Interview	CLD
6. What are Bina marga and Balai strategies concerning the involvement of the local community in Indonesian BMS?	Interview	SWOT & TOWS

3.2.1 Causal Loop Diagram

Causal Loop Diagram (CLD) is a “hypothetical causality” model used to analyse a particular system. CLD for BMS x Locals was analysed qualitatively in Sub-chapter 4.1. The loops in CLD can be a reinforcing loop (R) or a balancing loop (B). The reinforcing loop entails that the interaction from one variable to another is incremental; thus, it represents the addition of some specific units. In the balancing loop, the variation effect in any variable propagates within the loop. Thus, it returns to the variable a deviation opposite to the initial one, i.e., if the variable increases in a balancing loop, the effect through a cycle will return a decrease to the same variable (Sterman, 2000). As a qualitative mental model, logical steps should be established to develop a CLD. The following steps are followed in developing CLD (Enserink et al., 2010):

1. Setting up the initial problem demarcation and level of analysis (Means-ends analysis)
2. Determining objectives and outcome of interest (criteria)
3. Developing causality map, i.e., CLD diagram.

3.2.2 Multi-criteria decision analysis

Multi-criteria Decision Making (MCDA) is a method to determine the best alternative based on multiple alternatives using the preferred criteria (Macharis, 2007). Alternatives and criteria were taken from the data collection (mainly interview transcripts) and then labelled in Atlas.ti, see Sub-chapter 4.2.1 for the conducted procedure.

After that, the appraisal of relative importance for alternatives and criteria was performed using Analytical Hierarchy Process (AHP). Saaty (1980) developed AHP to compute the priority vectors used in the MCDA ranking process. Finally, the MCDA, which involves eight officials, was aggregated using the Aggregation of Individual Judgement (AIJ). It generates a top alternative on each MCDA. See Appendix C.1 for detailed AHP and AIJ procedures.

3.2.3 SWOT & TOWS analysis

SWOT & TOWS is commonly used to plan the strategy of a programme. SWOT analysis was done by identifying strengths and weaknesses (internal) from the proposed BMS x Locals and by identifying the opportunity and threat from its environment (external) (Dyson, 2004). In the BMS x Locals context, each SWOT element is listed and categorised, see Sub-chapter 4.3.1.

Strength is the positive possessions, while weakness hinders the successiveness. As an internal appraisal, strengths and weaknesses include resources, capabilities, and organisational core competencies. Furthermore, the opportunity is the aspect that can be capitalised on to increase the chance of success, while the threat is the aspect that should be avoided, which can threaten the programme. Finally, both are characterised by an external appraisal, i.e., the social, technological, political, economic, and competitive environment (Weihrich, 1982).

After the identification of SWOT, the list was enumerated in a TOWS matrix. TOWS is a variation of SWOT, which requires a pairing process of the identified lists to stimulate a new strategic initiative (Weihrich, 1982). First, the categorised SWOT elements were attached to the corresponding matrix, followed by a subjective formulation by the author. Many iterations were performed, and most importantly, the validation interview by the top-level Balai officials was conducted. The full result is presented in Sub-chapter 4.3.

In SO strategy (**maxi-maxi**), an organisation always wants to be lucrative by maximising strengths and opportunities. The WO strategy (**mini-maxi**) is done by minimising the weaknesses and maximising the opportunity. The organisation can benefit from the opportunities from the external environment, but having the weakness can impede the ability to take advantage of the external environment. The ST strategy (**maxi-mini**) aims to maximise the former while minimising the latter. The organisation that wants to perform its programme can exploit their strength to overcome possible threats from the external environment. The WT strategy (**mini-mini**) is when both weaknesses and threats are minimised, yet this position is one that any organisation will try to avoid (Weihrich, 1982).

3.3 Guideline Development

Stage 5 involves the development of the BMS x Locals guideline. Such a guideline serves as a deliverable for Balai and Bina Marga, according to the research objective stated in Sub-chapter 1.3. Therefore, the guideline that consists of activities was presented in Chapter 6.

3.4 Validation

In stage 6, the study results and BMS x Locals guideline were validated. Validation serves for the validity of the research outcome and reduces the researcher's bias. A high-level Balai official validated the research. It was done by discussing mainly the results and BMS x Locals guidelines through online interviews. The question and answer during the validation process mainly discuss: "to what extent is the validity of the results?", "what are your insights?", "what can be improved?".

3.5 Result

Chapter 7 presented the concluding remarks, which is the final result of the research. First, the conclusion answers six sub-research questions and the main research question. Second, Limitations and future recommendations are divided into research, data collection, and methods. Third, reflection flashes back to the research process, including towards kick-off, towards mid-term, towards green light, and towards thesis defence.

4 Data Synthesis and Analysis

Data synthesis and analysis comprises three sub-chapters. First, the development of CLD explained and its sub-systems are explained in Sub-chapter 4.1. Second, Sub-chapter 4.2 provides MCDA analysis. Finally, in Sub-chapter 4.3, SWOT & TOWS analysis is presented for the situational strategy of BMS x Locals.

4.1 Development of Causal Loop Diagram (CLD)

The CLD development method has been previously explained in Sub-chapter 3.2.1. Onwards, Sub-chapter 4.1.1 explains means-ends analysis, and Sub-chapter 4.1.2 explains objective tree analysis; both are the foundation that generated the causality loop in Sub-chapter 4.1.3.

4.1.1 Problem demarcation: Means-Ends Analysis

Four problems are identified through and interviews and desk study combined, consisting of bridge data quality, locals in public reporting, expected design life, and traffic reliability. These four problems manifest an overarching goal, namely "Proper bridge monitoring and maintenance".

Bridge data quality

Bridge data used to generate forward works plan (FWP) is prone to the absence of its quality; the problem is depicted in Figure 4.1. In addition, the metadata, including inventory and condition in the database, might be discrepant as compared on-site, e.g., the span lengths, type of materials, expansion joint, and drainage condition. Hence, data quality improvement is vital.

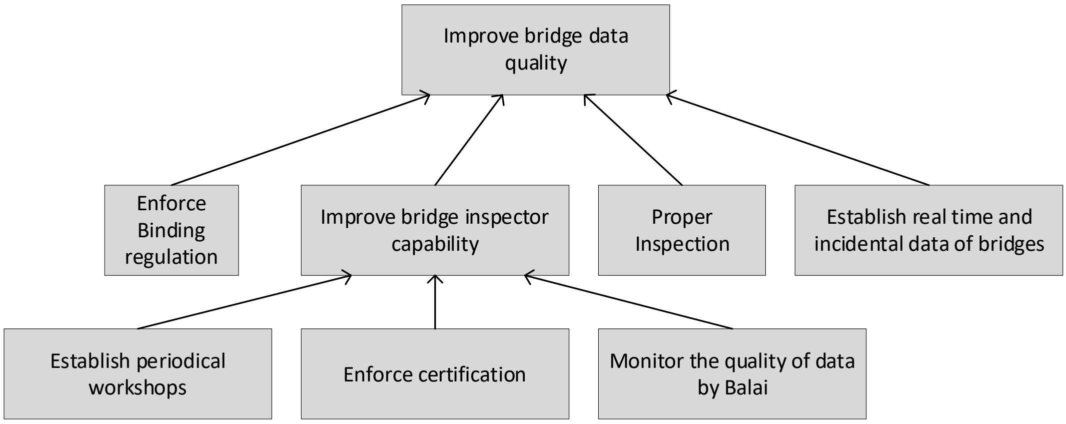

Figure 4.1 Improve bridge data quality

In improving the quality, there are four ways to perform. The first means is by enforcing the current regulation. For instance, minimum reliability of data quality or validation of data must be conducted by Balai before submitting the data officially to Bina Marga. Secondly, improve bridge inspector capability is required because it is a person who collects the data on the field; hence data quality is significantly dependent on their knowledge and skill. Therefore, to improve bridge data inspector capability, establishing a periodical workshop, enforcement of certification, and monitoring the quality of collected data by Balai are required. It implies that both Balai and Bridge inspector is responsible for striving for improvement. Thirdly, proper inspection is conducted while inspecting bridges on-field. It is an integral part of the bridge inspector capability. However, both are mutually exclusive. The bridge inspector may not perform a proper inspection due to negligence, unclear information from the superordinate weather condition, and the accessibility of the bridge. Lastly, establish up-to-date and incidental data of bridge is a means by allowing data to be constantly updated either by the installation of remote sensing device or by public participation, i.e., crowdsourcing. Such data is precious as a means of an early warning system so that PPK can immediately take action before unwanted defects or events occur.

Locals in public reporting

Locals usually report poor bridge conditions on social media as currently there is no tailor-made platform dedicated to "bridges" (see the problem in Figure 4.2). Locals' uploads frequently trigger virality on social media like Instagram or Facebook. The availability of public participation in bridge reporting can connect the engagement between the road service provider and the locals. Moreover, the absence is feared that Balai might be less responsive towards the bridge condition given the broadness of the road network. Eventually, the issues may be avoided, and most importantly, the bridge data are up-to-date concerning its current condition.

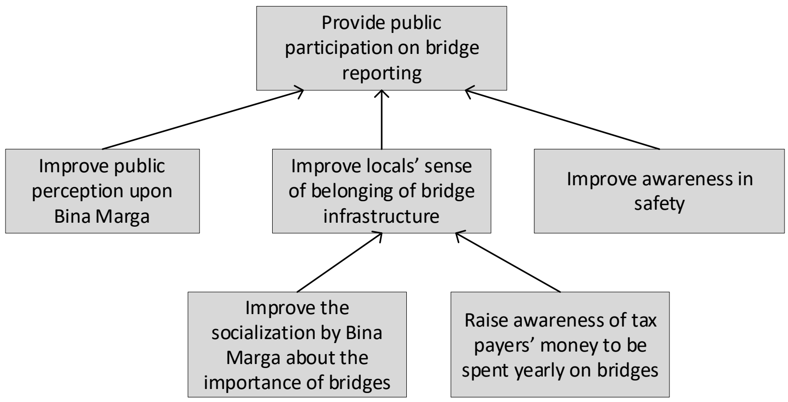

Figure 4.2 Provide public participation on bridge reporting

Provide public participation allows engagement with locals to take place. Firstly, public perception of Bina Marga must be improved so that locals are aware that Bina Marga works in the society to provide bridge infrastructure service. Secondly, improving locals' sense of belonging to bridge infrastructure is required to understand the importance of bridge infra as the connector of national roads and the essential element of their economic backbone, for example, by understanding that a disrupted bridge is subject to economic vulnerability. Thirdly, improved awareness of safety is required so that locals are mindful that the bridge's condition contributes to the transportation safety level. The awareness improvement includes defects, deflection, potholes, structural failures, natural disasters.

Expected design life

Preserving design life is imperative to maintain the bridge value of money. A failure to meet the expected design life can cause early replacement to take place. A replacement is costly, may result in loss of traffic time and isolation of the two related areas. As depicted in Figure 4.3, there are three sub-objectives to preserve the expected design life.

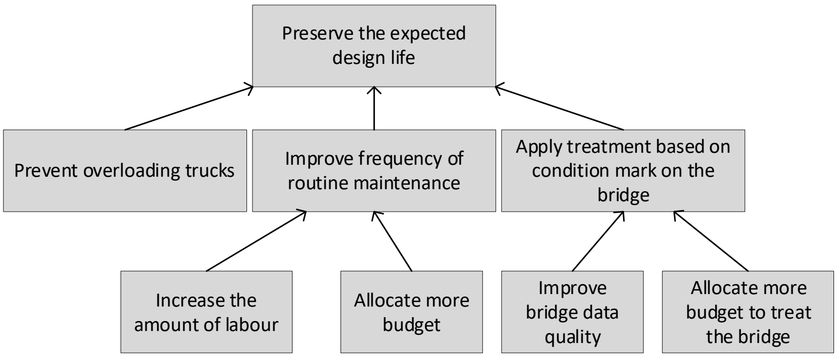

Figure 4.3 Preserve the expected design life

Firstly, prevent overloading trucks entails the monitoring to limit and charge overloading trucks from passing by the national roads. The absence of stringent measures can undermine the structural member of bridges. In this case, Balai must coordinate with the Transportation Ministry responsible for regulating loading measurement of the heavy axle fleets at specific points within the road network. Secondly, improve the frequency of routine maintenance is essential to avoid defects get too extreme. The works include cutting grass, garbage-pile removal, cleaning debris/rubble/branches, specifically piers and abutments, and fixing clogged drainage. A sufficient amount of routine maintenance allows the bridge to be visually observable and to anticipate excessive structural damage. Thirdly, apply treatment based on bridge condition mark (CM), which is data-driven and budget dependent. For example, CM 3 requires minor rehabilitation, condition mark 4 required structural construction. However, treatment is not immediately applied or well programmed in practice because of the complexity of structural elements and immaturity in determining CM for bridges. The treatment sometimes could not be specific to a particular element, which implicates the "over-generalisation".

Traffic reliability

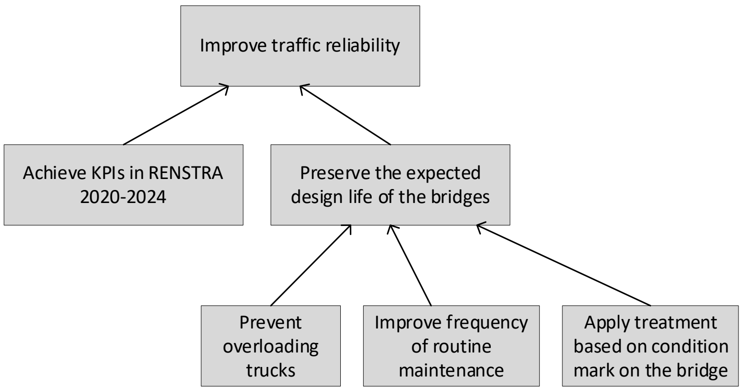

Figure 4.4 Improve Traffic reliability

An unreliable bridge leaves the road network in congestion or a total disruption. The congestion reduces travel time as vehicle populates the road. Moreover, in extreme events such as natural disasters, the area can be isolated, making the locals unable to use the road. Therefore, two objectives are devised to improve traffic reliability: achieve Key Performance Indicators (KPIs) prescribed in quadrennial strategic planning (RENSTRA) 2020-2024 and preserve the expected design life of the bridge, see Figure 4.4. Hence, the upcoming RENSTRA should consider bridges more precisely so that road service providers can set up concrete targets.

Improve bridge infrastructure quality by preserving the expected design life by maintaining the CM ≤ 2 (Table 2.1). There are three sub-objectives to follow, including preventing overloading trucks, improving the frequency of routine maintenance, and applying treatment based on the condition mark of the bridge, which has been explained in the expected design life section.

The overarching goal

In Figure 4.5, the identified means/ends analysis manifested an overarching goal: Proper bridge monitoring and maintenance. Such a goal helps Bina Marga and Balai improve the current PIAM on bridges and generate a reliable FWP in the planning stage.

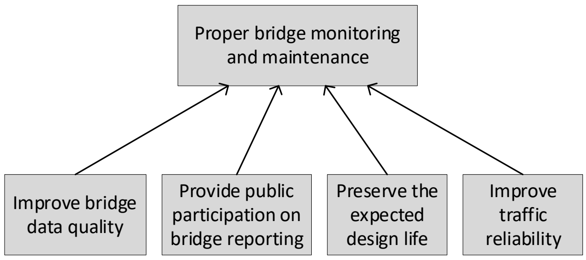

Figure 4.5 An overarching goal from means/ends analysis

4.1.2 Specification of criteria: objective tree

The identification from problem/means-end analysis manifests a three-level objective where improvement in BMS becomes the top (see Figure 4.6). There are four level-2 objectives where each of those has two level-3 objectives.

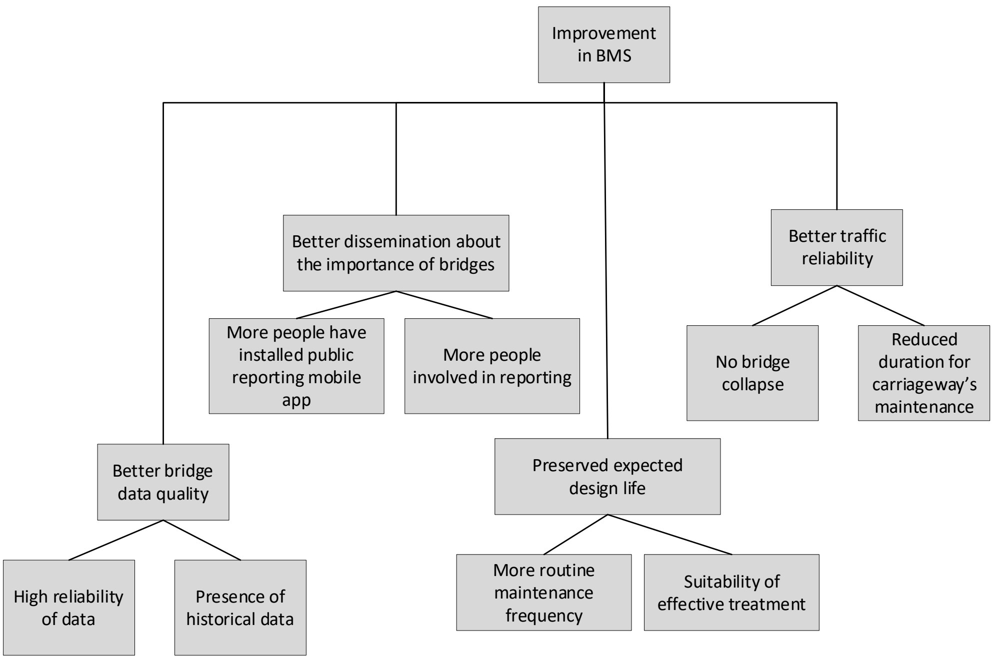

Figure 4.6 Objective tree for Improvement in BMS

Data reliability and the presence of historical data ameliorates data quality. For instance, "95% of data collected matching the field condition" can specify the data reliability. In addition, road service providers mentioned that each bridge is expected to provide at least historical condition data for the last five years. By meeting these objectives, improvement in BMS can be represented in the generation of on-target planning and maintenance, i.e., FWP.

Better dissemination about the importance of bridges can be defined by more people who have installed public reporting mobile-app and more people involved in reporting. Both can be measured by the increase in a certain amount of time, e.g., monthly basis. By meeting this level-2 objective, engagement between the road service provider and locals can be represented in a friendly-interactive way and significantly contribute to up-to-date information.

The preserved expected design life criteria can be defined: routine maintenance frequency and effective treatment suitability. First, the increased routine maintenance frequency against the current practice, i.e., four times a year, can be set as a criterion. For example, officials suggested that instead of performing quarterly in a consolidated way, the practice can be bi-monthly distributed in a lesser workload by increasing frequency to 6 times a year. Second, it can be measured by the absence of mistreatment against the bridge condition in a year for effective treatment. For example, if a bridge with CM > 3 (See Table 2.1) is only treated by routine maintenance, the objective is violated. Eventually, the compliance of this objective can improve the bridge's value of money.

The absence of bridge collapse and reduced duration for carriageway's maintenance represent better traffic reliability. The number of bridge collapses can be measured per year. The maintenance duration can affect the bridge's carriageway leaving the access for traffic hindered or completely blocked. It can be measured in the amount of disruptive time given the maintenance. The pursuant of this objective can improve BMS by having less congested access, which maintains users' travel time.

4.1.3 Causal Loop Diagram (CLD)

The CLD amounting to 23 variables following the means-ends and objective tree analysis is depicted in Figure 4.7. CLD aims to explain the current state of BMS, to identify Bina Marga's drivers to outsource the locals and to identify the locals' drivers to participate in BMS.

The current state is defined as the status quo. In governmental institutions, it is frequently associated with regulation and practice performance. For BMS, it implies Bina Marga's current regulation and practices concerning PIAM maturity level. Drivers are generally factors that have a positive influence (enablers, potentials, driving forces). In BMS x Locals, it implies what urges Bina Marga to employ locals as external resources. Willingness is defined as a state of being prepared and internally motivated to perform a particular act. In BMS x Locals context, it implies what makes locals are willing to be employed in bridge-related works.

The CLD represents multiple aspects ranging from technical, institutional, social, and management. These different aspects are related and influence each other, e.g., technical will not work fine if the social support is hampering. The CLD can be distinguished into five sub-systems, four reinforcing (R1, R2, R3, R4) and one balancing (B1).

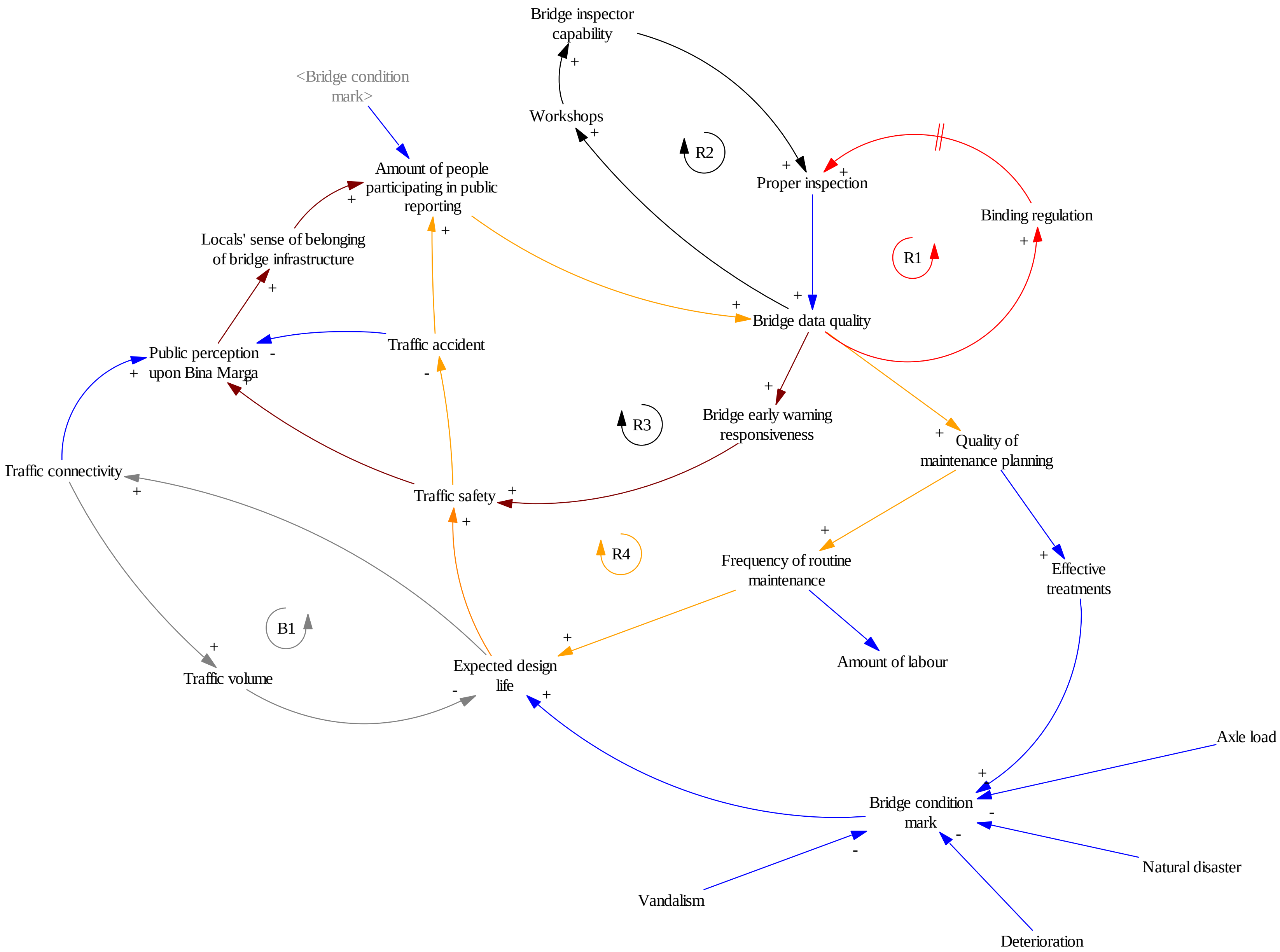

Figure 4.7 CLD for BMS x Locals

4.1.3.1 Sub-system R1 (amount of strategic planning) and R2 (Bridge inspector capability)

Sub-models R1 and R2 are reinforcing, see Figure 4.8. Bridge data quality is primarily affected by the proper inspection. The proper inspection entails reliable bridge inspectors and specific BMS quadrennial strategic planning in RENSTRA. Eventually, the improved bridge data quality positively influences bridge early warning responsiveness and quality of maintenance planning.

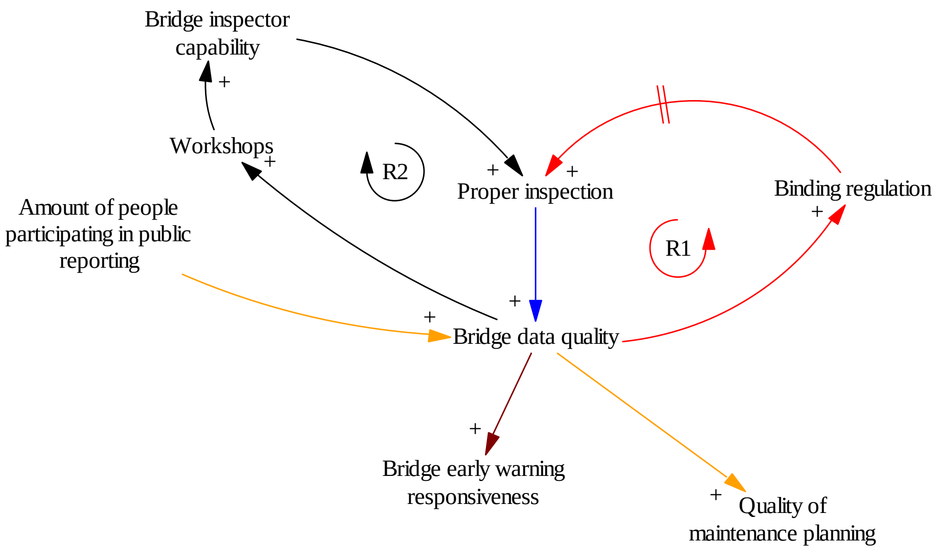

Figure 4.8 Sub-system R1 (amount of strategic planning) and R2 (bridge inspector capability)

In the R1 loop, pursuant of bridge data quality requires a specific inclusion in RENSTRA. For example, if RENSTRA pursues 95% of data reliability, a validation strategy must be prescribed to the inspector. It is done progressively over time due to institutional capacity constraints; hence the arrow indicates a positive delay mark to the proper inspection.

The R2 loop highlights the importance of many workshops to train the bridge inspectors. Lack of Human resources has always been an issue, which can be solved by adequate training. Hence, the raised awareness for better bridge data quality can add more bridge-related workshops, increasing reliable bridge inspectors.

Bridge data quality also are affected by the number of people participating in public reporting. Such participation can use JAKI (Smartphone-based app - Public reporting for roads). In addition, the reception of visual-based information to the command centre allows the Balai's personnel to juxtapose it against the database to devise further measures.

Holistically, the increase in bridge data quality influences bridges early warning responsiveness and quality of maintenance planning. PPK can quickly address the bad bridge condition can be quickly addressed within days by PPK to prevent unwanted events, e.g., bridge closure. Furthermore, FWP can apply the treatment suitably to preserve the expected design life or its condition mark at the planning level. It implies that the quality of data can prevent misallocation of budget and avoid improper maintenance treatment. These two variables are explained further in Sub-system R3 and R4.

4.1.3.2 Sub-system R3 (Locals' participation in public reporting)

The locals' participation in the public reporting loop is reinforcing, see Figure 4.9. In addition to officials' expectations, five interviewed locals in NTB are willing for such an activity. The increased number of people in public reporting ameliorates bridge data quality, including visual-based imagery of bridges. Furthermore, it implies that up-to-date monitoring and additional human resources become vital for Bina Marga to employ the locals. Two factors influence the participation: locals' sense of belonging to the bridge infrastructure and bridge condition mark.

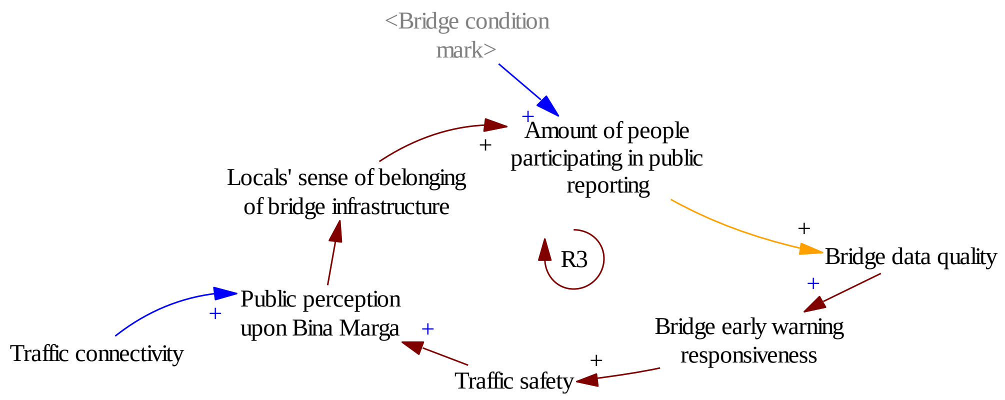

Figure 4.9 Sub-system R3 (Local's participation in public reporting)

According to officials, a better society's public perception of Bina Marga should be present to raise awareness of the importance of bridges in their day-to-day activity. Observably, traffic connectivity and safety can be judged by locals as to represent Bina Marga's delivery service. Traffic connectivity is prone to perturbation, e.g., excessive inundation on the bridge deck leading to potholes (Honfi et al., 2018). When the hindrance is left unaddressed, and locals have no means to report it, they are likely to viral it to social media, which can undermine Bina Marga's public reputation.

There are two bridge safety issues in which the officials and locals have in common. Firstly, the incompleteness of upper structure components, e.g., the absence of hand railings/guardrails and parapet walls, can inconvenience users who pass by. Secondly, the broken expansion joint is located at both bridge edges, resembling a dangerous speed bump. To positively influence traffic safety, proper maintenance treatment should be conducted in due time, and again it entails reliable data.

4.1.3.3 Sub-System R4 and B1 (Expected design life)

The reinforcing R4-loop and the balancing B1-loop affect the expected design life, see Figure 4.10. The expected design life is defined as the serviceability duration of the bridge infrastructure, from commencement to disposal (Harding et al., 1990). Generally, bridges within the Bina Marga's national road network account for 50 years (Bina Marga, 1993b). In addition, the expected design life is positively influenced by the bridge condition mark (CM), and the frequency of routine maintenance as the outgoing arrow improves traffic safety, which also belongs to R3).

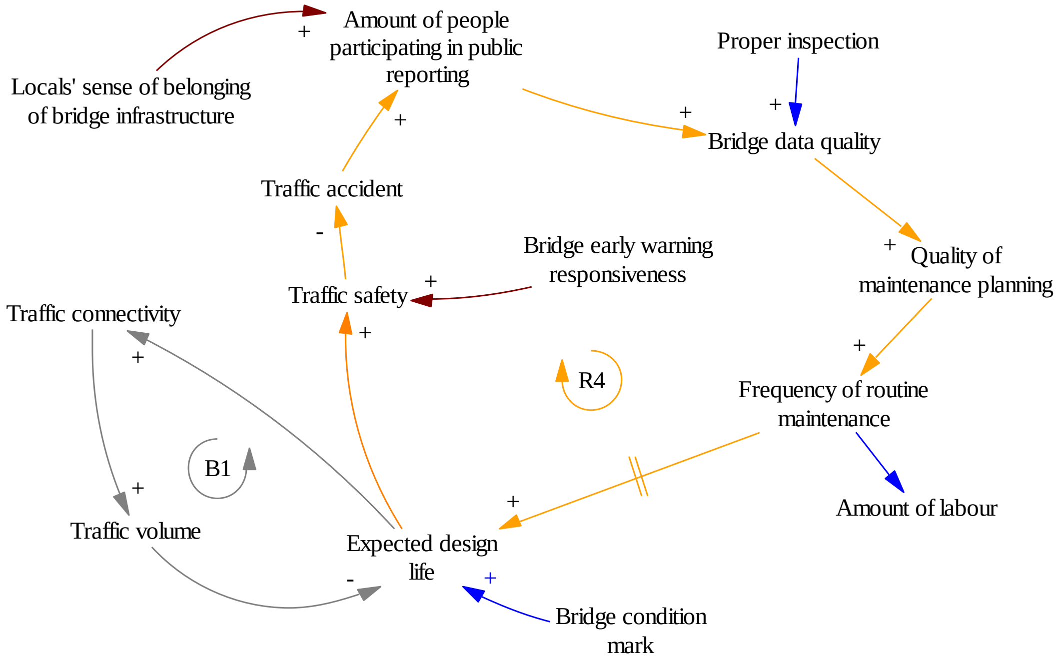

Figure 4.10 Sub-system R4 and B1 (expected design life)

The bridge condition mark (CM) is defined in Sub-chapter 2.1.3. CM is affected by vandalism, deterioration, natural disaster, and axle load. The reliability of CM is heavily dependent on the quality of the inspection and the absence of data validation.

The frequency of routine maintenance is defined as the number of routine maintenances given to the bridge within a year (Toorn & Reij, 1990). Routine maintenance does not significantly affect the expected design life; hence, the arrow is represented by a delay tag. Officials argue that the current 4-times execution in a year is inadequate. However, the quality of maintenance planning can influence this variable. Moreover, routine maintenance frequency increases the amount of labour – associated with labour intensive projects (LIP).

The employment in LIP allows Bina Marga to improve the regional employment rate. It implies economy and engagement between road service providers and locals as the factor for Bina Marga to employ locals. From the locals' perspective, firstly, the economy, i.e., additional income, is the most significant interest because the struggle to attain a decent income, especially in a rural area, is challenging. Secondly, the pursuant of knowledge and local pride, since many skilful labours are taken from Java, they want to excel and be productively exerted in their region. Thus, both of which become the willingness of the locals to be employed.

The preservation of the expected design life may improve traffic safety, i.e., a safer bridge reduces accidents. Traffic accidents are likely to make locals aware that safety becomes the issue in the bridge, which can add to the number of locals participating in public reporting (also affected by Locals' sense of belonging to bridge infrastructure). Balai can better obtain the bridge's current condition information to treat it further accordingly.

The expected design life also influences traffic aspects represented in the B1 loop. For example, good serviceability can increase traffic connectivity, implying more traffic volume passing by the bridge. Nonetheless, the overtime load imposes – the heavy-axle fleet such as trailers and dump trucks can significantly reduce the reliability of the bridge. Eventually, the increase of the traffic volume can negatively influence the expected design life of the bridge.

4.1.4 Remarks on CLD

Constructing CLD for BMS x Locals is an iterative process that comprises multiple aspects. Technically, bridge data quality is vital for maintenance planning and treatment, eventually preserving the expected design life. Management aspects, including strategic planning and bridge inspector capability, significantly influence the expected data quality, which can also be supported by social aspects, i.e., participation of locals.

The relationship of various aspects in CLD is dependent on each other. Therefore, all involved actors (Bina Marga, Balai, Locals, local universities, and external institutions) must embrace all variables to make the system function properly. In that way, the improvement of BMS involving locals may be highlighted in the quality of data and adequate routine maintenance. To specify the type of work elements and group in locals for data collection and routine maintenance, the MCDA method is conducted in the following Sub-chapter 4.2.

4.2 Multi-criteria decision analysis (MCDA)

This chapter consists of three parts. First, Sub-chapter 4.2.1 provides the identification of criteria and alternatives. Next, Sub-chapter 4.2.2 explains how the relative importance of criteria and alternatives are determined. Finally, Sub-chapter 4.2.3 presents 4 MCDA calculation results.

4.2.1 Identification of criteria and alternatives

In MCDA, road service providers are bound to determine the criteria based on individual or collective preference. Alternatives are the option enlisted in MCDA so that when an analysis comes into being, the most weighted alternative is chosen. Alternatives are presented in terms of “Package”. In general, criteria and alternatives are identified by the following steps:

1. It was mainly compiling interview transcripts, complemented by relevant organisational documents and academic literature in ATLAS.ti
2. Labelling of codes from the compiled documents
3. Performing quotation synthesis to come up with general “heading” of each criterion and alternative
4. Criteria and alternatives in MCDA are formulated to fit the certain variables identified in previous CLD analysis.

The details regarding criteria and alternatives, including its description, number of quotations, and quote are attached in Appendix C.2 (Table 8.1 Specification and identification of MCDA criteria) Appendix C.3 (Table 8.2 Specification and Identification of MCDA alternatives), respectively.

There are 4 MCDAs in total. Referring to SQ 3 and SQ 4, each SQ contains two aspects: data collection and routine maintenance. It results in the categorisation presented in Table 4.1. In addition, the “semi option” – the combination of Package 1 and 2 are present in MCDA 1, MCDA 2, and MCDA 3.

Table 4.1 The summary of MCDA's criteria and alternatives

MCDA 1 - Type of work in data collection			
Criteria	**Alternatives**		
	Package 1	Package 2	Package 3
Cost: The cheapest value of money to be allocated against a specific work package and type of group	Periodical and incidental public reporting	Inventory and condition data	Package 1 and 2 combined (MCDA 1)
Time: The least amount of duration that is required against a specific data collection work package. The more complex set of data is collected, the longer it takes			
Bridge literacy: The least amount of duration that is required against a specific data collection work package. The more complex set of data is collected, the longer it takes			
Technological literacy: The extent of the required technical skill to operate devices such as laptops or phones or tablets, etc., against a specific data collection work package and against a specific type of group in performing data collection			
MCDA 2 - Type of work in routine maintenance			
Criteria	Alternatives		
	Package 1	Package 2	Package 3
Cost: as explained in MCDA 1	Debris and garbage cleaning, grass cutting, drainage cleaning	Non-structural patching, cosmetic painting, stoneworks	Package 1 and 2 combined (MCDA 2)
Time: as explained in MCDA 1			
Labouring skill: The technical capability required against a specific routine maintenance work package and a specific type of group package in performing routine maintenance			
Quality: The extent to which a specific routine maintenance package can relatively bring improvement to the bridge condition			
MCDA 3 - Type of group in data collection			
Criteria	**Alternatives**		
	Package 1	Package 2	Package 3
Continuity: The extent of the continuation of a specific type of group package in performing data collection	Locals in general, non-governmental organisation	Local university (students and lecturers) and jobless graduates	Package 1 and 2 combined (MCDA 3)
Level of education: Level of education is the extent of locals concerning the required degree of education in performing data collection. This criterion allows Bina Marga better to choose the package as the level of education can commit the locals much easier			
Bridge literacy: The knowledge of bridge component required against a specific data collection work package and against a specific type of group package in performing data collection			
Technological literacy: The extent of required technical skill to operate devices such as laptops or phones or tablets, etc., against a specific data collection work package and against a specific type of group in performing data collection			
MCDA 4 - Type of group in routine maintenance			
Criteria	Alternatives		
	Package 1	Package 2	Package 3
Cost: as explained in MCDA 1	Municipality's list	A specific group including farmers, fishers, foremen, workers, and youth organisations	Jobless people and semi-jobless people
Time: as explained in MCDA 1			
Age: The required productive age required against a specific type of group in performing routine maintenance, which entails 30 years≤ ideal age ≤50 years			
Labouring skill: The technical capability required against a specific routine maintenance work package and a specific type of group package in performing routine maintenance			

4.2.2 Determining the relative importance of criteria and alternatives

An online *zoom* session was performed by inviting previous Bina Marga and Balai NTB officials who had participated in the interview session. However, only 5 out of 9 participated which the remaining 4 filled it on later. The session was meant to determine the relative importance of criteria and alternatives according to the AHP method (see Appendix C.1). When appraising the relative importance, the author used a google form. Four sections were divided within the session. The participants had to appraise the relative importance of criteria and alternatives against each criterion in each section.

4.2.3 MCDA calculation and result

The calculation is mainly divided into two parts, the <u>appraisal of criteria</u> and <u>appraisal of alternatives against each criterion</u>. The criteria part includes determining relative importance, aggregating individual judgment (AIJ), finding the criteria weight, and calculating the consistency ratio. For the alternatives, the initial calculation should include the items mentioned for the criteria appraisal (relative importance determination – consistency ratio calculation) and then determine the weighted score of alternatives and finally obtain the total weighted score (final selected package). Refer to Appendix C.5 for the detailed steps and computation of MCDAs.

The summary of four MCDAs where one alternative was selected as the packaged to recommend is discussed in the following Sub-Chapter. In addition, the most and least important criterion was also highlighted to give the impression of significance.

4.2.3.1 MCDA 1: Type of work in data collection

Package 2 – Inventory and condition data is opted, amounting to nearly 40%, see Table 4.2. All requirements for the consistency ratio of criteria and alternatives against each criterion have satisfied CR < 0.1; see the complete calculation in Table 8.4 in Appendix C.5. In a relatively small variation amongst four criteria (standard deviation 0.038), Both Cost and Time amounting to nearly 28%, which is considered the two highest criteria, where the least important criterion falls to “technological literacy”.

Table 4.2 MCDA 1 type of work in data collection

Type of work in data collection		Alternatives					
		Package 1		Package 2		Package 3	
Criteria	weight	Score	Weighted score	Score	Weighted score	Score	Weighted score
Cost	0.282	0.408	0.115	0.324	0.091	0.268	0.076
Time	0.276	0.334	0.092	0.466	0.129	0.200	0.055
Bridge literacy	0.257	0.260	0.067	0.412	0.106	0.328	0.084
Technological literacy	0.184	0.322	0.059	0.395	0.073	0.283	0.052
Total	1.000		0.334		0.399		0.267

4.2.3.2 MCDA 2: Type of work in routine maintenance

Package 1 – Cleaning debris and garbage, cutting the grass, and drainage cleaning is opted, amounting to 43%, see Table 4.3. All requirements for the consistency ratio of criteria and alternatives against each criterion have satisfied CR < 0.1; see Table 8.5 in Appendix C.5. In a relatively small variation amongst four criteria (standard deviation 0.066), the highest criterion falls to "Cost" with "labouring skill" becomes the least.

Table 4.3 MCDA 2 result type of work in routine maintenance

Type of work in routine maintenance		Alternatives					
		Package 1		Package 2		Package 3	
Criteria	weight	Score	Weighted score	Score	Weighted score	Score	Weighted score
Cost	0.363	0.546	0.199	0.233	0.085	0.220	0.080
Time	0.214	0.534	0.115	0.250	0.054	0.216	0.046
Labouring skill	0.191	0.357	0.068	0.290	0.056	0.352	0.067
Quality	0.231	0.211	0.049	0.301	0.069	0.489	0.113
Total	1.000		0.430		0.263		0.306

4.2.3.3 MCDA 3: Type of group in data collection

Package 2 – Local university (students and lecturers) and jobless graduates is opted, amounting to 49%, Table 4.4. All requirements for the consistency ratio of criteria and alternatives against each criterion have satisfied CR < 0.1; see Table 8.6 in Appendix C.5. In a relatively small variation amongst four criteria (standard deviation 0.048), the highest criterion falls to "Bridge literacy", with "technological literacy" becomes the least.

Table 4.4 MCDA 3 result type of group in data collection

Type of group in data collection		Alternatives					
		Package 1		Package 2		Package 3	
Criteria	weight	Score	Weighted score	Score	Weighted score	Score	Weighted score
Continuity	0.255	0.309	0.079	0.433	0.111	0.258	0.066
Level of education	0.266	0.231	0.061	0.491	0.130	0.278	0.074
Bridge literacy	0.306	0.227	0.070	0.523	0.160	0.250	0.077
Technological literacy	0.173	0.264	0.046	0.514	0.089	0.222	0.038
Total	1.000		0.256		0.490		0.255

4.2.3.4 MCDA 4: Type of group in routine maintenance

Package 1 – The municipality's list is opted, amounting to nearly 52%, Table 4.5. All requirements for the consistency ratio of criteria and alternatives against each criterion have satisfied CR < 0.1, see Table 8.7 in Appendix C.5 In a relatively small variation amongst four criteria (standard deviation 0.082), the highest criterion falls to "Cost" with "labouring skill" becomes the least.

Table 4.5 MCDA 4 result for the type of group in routine maintenance

Type of group in routine maintenance		Alternatives					
		Package 1		Package 2		Package 3	
Criteria	weight	Score	Weighted score	Score	Weighted score	Score	Weighted score
Cost	0.374	0.560	0.210	0.260	0.097	0.180	0.067
Time	0.244	0.491	0.120	0.351	0.086	0.158	0.039
Age	0.141	0.568	0.080	0.258	0.036	0.174	0.025
Labouring skill	0.240	0.450	0.108	0.344	0.083	0.206	0.049
Total	1.000		0.518		0.302		0.180

4.2.4 Remarks on MCDA

In obtaining a total of 4 MCDAs, the method was started by identifying the criteria and alternatives. Then, the synthesis process consisting of labelling and quotation transcripts and documents was conducted to formulate the final criteria and alternatives of MCDAs. There are nine criteria identified, four criteria including cost, time, bridge literacy, and technological literacy, are recurrent in some MCDAs. Each MCDA contains distinguished Package 1, Package 2, and Package 3, which resemble alternatives. Both alternatives and criteria described in Table 4.1 were determined by the government officials interview, complemented by literature (see Appendix C.2 and Appendix C.3). Following the formulation of MCDAs, the AHP method (using google form) to determine the relative importance were conducted through an online zoom session. The interviewed Bina Marga and Balai officials were involved.

Calculation-wise, it is performed by evaluating the criteria and alternatives against each criterion; the performed steps are explained in the initial part of Appendix C.5. The following are the results:

- MCDA 1: Package 2 – Inventory and condition data
- MCDA 2: Package 1 – Cleaning of debris and garbage, cutting of the grass, and drainage cleaning
- MCDA 3: Package 2 – Local university (students and lecturers) and jobless graduates
- MCDA 4: Package 1 – The municipality’s list.

4.3 SWOT and TOWS for BMS x Locals

This Sub-chapter presents the application of SWOT & TOWS for BMS x Locals. As explained in Sub-chapter 3.2.3, SWOT & TOWS is a combined method in planning a programme. SWOT serves as a means of identification and while TOWS acts as a strategy formulation tool. The method is mainly conducted by identifying internal (Strength & Weakness) and external (opportunity & threat) characteristics (Sub-chapter 4.3.1) of the proposed BMS x Locals programme, followed by an iterative pairing process to generate four situational strategies (Sub-chapter 4.2.2).

4.3.1 Identification of SWOT

In a large portion, the identification of SWOT was taken from the interview of public officials and locals, followed by the author's subjective synthesis. In the interview, although the specific question concerning to "SWOT element" was absent (as to avoid prolonged interview), the nature of the discussion and the formulated-open-questions appeared to generate insights against SWOT elements. It can also be generated when sure explicit BMS x Locals' questions were encountered, e.g., "Please explain about the certain groups in the local community that can be involved in BMS" and "What are the driving and hindering factors from the locals to be outsourced by Bina Marga in BMS x Locals". See the interview questions in Appendix B. Following the interview's transcription, the author conducted two steps to identify each SWOT element:

1. Four dedicated codes for each SWOT element were established in ATLAS.ti; see the definition of coding in Sub-chapter 3.2. In addition, the author conducted an extensive reading of interview transcripts to marking the text concerning the inclination of SWOT. The completion of coding is followed by the exporting of excel documents resulting in each SWOT element document. The summary of coding is presented in Table 4.6.

Table 4.6 Code labels for SWOT identification

No	Code (SWOT element)	The number of identified SWOT elements within code	The number of transcript(s) being coded out of 16 documents
1	BMS x Locals strength	9	7
2	BMS x Locals weakness	11	9
3	BMS x Locals opportunity	11	14
4	BMS x Locals threat	12	7

2. Based on the exported excel document. The item of SWOT is enumerated and grouped in a table according to its corresponding element. Besides, the ten categories[1] are added, allowing the author to formulate the later TOWS, including bridge inspector,

[1] The category denotes the kind of aspect concerning each SWOT element. It is important as the categorization allows the pairing process in TOWS more straightforward. It implies same aspect given a different "SWOT element" e.g., Strength-Opportunity in data quality aspect.

contract and financial, engagement of locals, engagement with an academic institution, Data platform (information system), cultural trait, job opportunity, and data quality safety and work package. See Table 4.7 for the summary.

Table 4.7 Summary of SWOT items and their category

No	Item	SWOT element	Category
1	Continuous yearly training	Opportunity	Bridge inspector
2	Option to commission the private sector for BMS x Locals	Opportunity	Contract and Financial
3	The interest from banking company to collaborate with Balai's BMS x Locals. The workers are given an ATM card	Opportunity	Contract and Financial
4	PPKs' relation with pre-identified locals	Opportunity	Engagement of locals
5	Existence of local public figures to influence the locals	Opportunity	Engagement of locals
6	Involvement of local university students to educate the locals while they are doing the live-in programme (KKN)	Opportunity	Engagement with the academic institution
7	Database of locals' specific ability provided by local government	Opportunity	Platform (information system)
8	User-friendly smartphone-based application and utilization of JAKI smartphone-based application for public reporting	Opportunity	Platform (information system)
9	Indonesian as a collective society	Opportunity	Cultural trait
10	Increasing job opportunities for the locals, minimizing the joblessness	Strength	Job opportunity
11	As for advice for Balai during the validation process, e.g., defect occurrence and discrepancies of empirical information	Strength	Data quality
12	An updated periodical bridge condition	Strength	Data quality
13	More stringent attention to safety aspect given local involvement	Strength	Data quality
14	A faster information update	Strength	Data quality
15	Less bureaucratic reporting (real-time)	Strength	Data quality
16	BMS x Locals as the prospective interactive Platform (information system) between government and society	Strength	Engagement of locals
17	Better fee received by the locals	Strength	Job opportunity
18	Easier transition from worker to data collector given the involvement of respective locals	Strength	Job opportunity
19	Online data input through a mobile-based app	Strength	Platform (information system)
20	Possession of a smartphone by the locals	Strength	Platform (information system)
21	Misperception on the condition mark	Threat	Bridge inspector
22	No detailed observation (negligence) by the inspector	Threat	Bridge inspector
23	Not being on target: people with a well-paid job join LIP	Threat	Contract and Financial
24	Workers not receiving a total amount of the prescribed fee	Threat	Contract and Financial
25	Worker mismatch: the registered list vs execution are not synchronized	Threat	Data quality
26	Foremen and workers request a higher bid than what already prescribed	Threat	Contract and Financial
27	The existence of the fake account	Threat	Platform (information system)
28	Safety concern: coming down under the bridge deck	Threat	Safety

No	Item	SWOT element	Category
29	Low productivity of locals and lousy work ethics due to culture	Threat	Cultural trait
30	Vandalism from irresponsible locals	Threat	Cultural trait
31	Lack of literacy on bridge elements	Weakness	Bridge inspector
32	BMS Inspection requires experts, not locals in general	Weakness	Bridge inspector
33	Requires more training	Weakness	Bridge inspector
34	Difficulties in training locals	Weakness	Engagement of locals
35	Monthly payment requires a significant budget allocation	Weakness	Contract and Financial
36	BMS Platform (information system) for the local is yet available	Weakness	Platform (information system)
37	The ability to control the quality of works	Weakness	Cultural trait
38	Difficulties in attracting workers in some regions	Weakness	Cultural trait
39	Contractors' readiness to employ workers in LIP	Weakness	Cultural trait
40	Dependent on a specific period (e.g., risk of not having workers given the farming period)	Weakness	Cultural trait
41	Limitation up to routine maintenance only	Weakness	work package
42	Higher effort to put than a road survey	Weakness	work package

4.3.2 Formulation of TOWS Matrix

After having identified the SWOT, the full TOWS matrix is established; see Table 4.8. The creation of such a matrix is an iterative process. Below are the steps followed to create TOWS matrix:

1. Substitute the SWOT group from Table 4.7 according to the TOWS matrix explained in Sub-chapter 3.2.3
2. Initially, SWOT categories were also indicated next to each item. But later, this would be deleted to make it more concise
3. Pair the items concerning Strength-Opportunity (Maxi-maxi), Strength-Threat (Maxi-mini), Weakness-Opportunity (Mini-maxi), Weakness-Threat (Mini-mini). Refer to Sub-chapter 3.2.3 for the definition of situational strategies
4. Eventually, the pairing process should generate a strategy that can be implemented on a situational basis by Bina Marga and Balai concerning BMS x Locals.

Table 4.8 TOWS Matrix for BMS x Locals

TOWS	Strength (S)	Weakness (W)
	1. Increasing job opportunities for the locals, minimizing the joblessness	1. Lack of literacy on bridge elements
	2. As for advice for Balai during the validation process, e.g., defect occurrence and discrepancies of empirical information	2. BMS Inspection requires experts, not locals in general
	3. An updated periodical bridge condition	3. Requires more training
	4. A more stringent attention to safety aspect given local involvement	4. Difficulties to train locals
	5. A faster information updates	5. Monthly payment requires a significant budget allocation
	6. Less bureaucratized reporting (real-time)	6. BMS platform for the local is yet available
	7. BMS x Locals as the prospective interactive platform between government and society	7. The ability to control the quality of works
	8. Better fee received by the locals	8. Difficulties to attract workers in some regions
	9. Easier transition from worker to data collector given the involvement of related locals	9. Contractors' readiness to employ workers in LIP
	10. Online data input through the mobile-based app	10. Dependent on certain period (e.g., risk of not having workers given the farming period)
	11. Possession of a smartphone by the locals	11. Limitation up to routine maintenance only
Opportunity (O)	**SO (Maxi-Maxi)**	**WO (Mini-Maxi)**
1. Continuous yearly training	O_1S_7: Conduct continuous yearly training to the locals to improve their ability and also the engagement between them and the government institution	$O_1W_1W_2W_3$: Plan the milestone and curriculum within the yearly training, especially for the data collection
2. Option to commission the private sector for BMS x Locals	O_2S_1: Collaborate with the private sectors (consultant and contractor) to employ the locals	O_2W_5: Commission the private sector to employ the locals; thus, the payment will be managed by another entity
3. PPKs' relation with pre-identified locals	$O_3S_5S_7$: PPK should maintain a continuous relation with the locals to get a faster information update	O_3W_4: Allowing PPK as the final decision maker for the local involvement by involving professionally capable locals
4. Existence of local public figures to influence the locals	O_4S_1: Embrace and maintain communication with the public figure to attract the willingness of locals	O_4W_8: Regional office to conduct a periodical meeting with the public figure
5. Involvement of local university students to educate the locals while they are doing the live-in programme (KKN)	O_5S_7: Regional office to embrace a relationship with the academic institution, i.e., local university	-
6. Database of locals' specific ability provided by local government	O_6S_1: The local government, i.e., the municipality, needs to have a good database of locals' occupations to improve the on-target employment	O_6W_7: Balai to perform a periodical screening to the locals' specific ability in the municipality
7. User-friendly smartphone-based application and utilization of JAKI smartphone-based application for public reporting	O_7S_{10}: Create a user-friendly app for online data inputting through the smartphone	O_7W_6: Bina Marga to embed a specific feature in JAKI for BMS x Locals
Threat (T)	**ST (Maxi-Mini)**	**WT (Mini-Mini)**
1. Misperception on the condition mark	T_1S_3: Control and monitor the periodical update of bridge condition	$T_1W_2W_3$: Only to employ professional bridge inspector for condition and inventory data collection
2. No detailed observation (negligence) by the bridge inspector	T_2S_2: Employ locals as the additional validation of the bridge's visual condition	T_2W_7: Withdraw from BMS x Locals
3. Not being on target: people with a well-paid job join LIP	-	$T_3T_4T_5W_9W_5$: Seek for more matured contractors outside of the related region
4. Workers not receiving a total amount of prescribed fee	T_4S_8: Balai should establish the legal standing of BMS x Local to protect the rights of the locals	-
5. Worker mismatch: the registered list vs execution is not synchronized	T_5S_{10}: PPK should recheck and validate the locals who participate in BMS x Locals to avoid mismatch of worker (routine maintenance) and fake accounts (data collection)	-
6. Foremen and workers request a higher bid than what has already been prescribed	T_6S_7: Balai needs to maintain communication and coordination with the locals, giving in the upfront information, especially the financial aspect	T_6W_5: To opt for an agreement between Balai and locals concerning the fixed remuneration
7. Safety concern: coming down under the bridge deck	T_7S_4: Balai needs to devise safety guidelines for those who participate in BMS x Locals	T_7W_2: Perform inspection supervised the professional bridge inspector
8. Low productivity of locals and lousy work ethics due to culture	T_8S_7: Balai needs to set up performance measurements in routine maintenance and data collection	T_8W_2: Consider labour and bridge inspectors from outside the region
9. Vandalism from irresponsible locals	-	T_9W_6: Reduce threat by utilization of JAKI mobile app to report any vandalism

4.3.3 Remarks on SWOT & TOWS and Chapter 4

The development of the situational strategy for BMS x Locals primarily consists of identifying SWOT and formulation of TOWS. In addition, the completion of SWOT & TOWS marks the end of the data analysis and synthesis.

The identification was mainly performed through interviews of public officials and locals, followed by the author's subjective synthesis. SWOT was identified by applying two steps: the coding of SWOT elements through extensive 16 transcript readings assisted by ATLAS.ti and the elements' categorisation. As a result, 42 elements were generated, including nine strengths, 12 weaknesses, 9 opportunities, and 10 threats. In addition, each SWOT element's item was categorized by attaching ten categories: bridge inspector, contract & financial, engagement of locals, engagement with the academic institution, platform (information system), cultural trait, job opportunity, data quality, safety, and work package. The result of the identification process can refer to in Table 4.7.

Formulation of the TOWS was conducted by pairing SWOT elements in the TOWS matrix. It requires four steps (substitution, indication of categorization, pairing of items, generation of strategies). As a result, four distinguished situational strategies were identified, consisting of 7 Maxi-maxi, 7 Maxi-mini, 6 Mini-maxi, 7 Mini-mini; see Table 4.8.

Given the completion of CLD, MCDA, and SWOT & TOWS analysis, the following part in Sub-chapter 5.1, 5.2, and 5.3 discusses three results combined. First, as we know, CLD has been used to highlight the current state of BMS in Bina Marga, Bina Marga's drivers in outsourcing locals, and the enabling and hindering factors for locals' willingness in BMS x Locals. Second, CLD manifests data quality represented in R1 and R2 loop, locals' participation in public reporting represented in loop R3, and expected design life in R4 and B1 loop (see Sub-chapter 4.1.3). Third, such manifestations are correlated with MCDA; for example, bridge data quality and locals' participation in public reporting is correlated with MCDA 1 and MCDA 3, i.e., Type of work and group for data collection, respectively; while preservation of expected design life is correlated with MCDA 2 MCDA 4, i.e., type of work and group for routine maintenance. Finally, it implies that three subjects of discussion refer to the issue presented earlier in Chapter 1, i.e., BMS data quality and routine maintenance.

Finally, the depiction from CLD and the chosen alternatives from MCDAs are discussed and validated with an expert from Bina Marga against strategies presented in the full TOWS matrix, which synthesises one to two realistic strategies in every four situational strategies.

5 Discussion of results

The discussion of results is divided into three aspects. Sub-chapter 5.1 explains the bridge data quality, Sub-chapter 5.2 discusses locals' participation in the public reporting, and Sub-chapter 5.3 deciphers the expected design life. Each discusses the three combined CLD, MCDA, and SWOT & TOWS results. The expert's validation has been embedded within Sub-chapters so that the solution against the empirical situation and challenges becomes relevant.

5.1 Bridge data quality

Bridge data quality is heavily influenced by proper inspection so that the bridge early warning responsiveness and quality of maintenance planning can be conducted. Therefore, a proper inspection is specified in MCDA 1 – Type of work in data collection and MCDA 3 – Type of group in data collection. As a result, MCDA 1: Package 2 - Inventory and condition data and MCDA 3: Package 2 – local university (students and lecturers) and jobless graduates.

The highest criteria play a significant contribution to the MCDA's result. For example, the selection of Package 2 amounting to nearly 40% for its total weighted score in MCDA 1 (See Table 4.2 and Table 8.4) is significantly determined by two criteria: cost and time. Both cost and time weigh nearly 28%, resulting in the weighted score of Package 2 by 12.9% and 9.1%, respectively. Also, the selection Package 2 in MCDA 3 (See Table 4.4 and Table 8.6) amounting to nearly 49% for its total weighted score, where bridge literacy weighs 30%, resulting in the weighted score by 16%. The highest criteria in MCDA 1 imply that the management aspect is preferred in deciding the working item, whereas the highest criterion in MCDA 3 inclines towards the technical aspect in determining the executor group.

In addition, technological literacy in MCDA 1 and MCDA 3 is surprisingly the lowest, contrary to what was expected to be one of the highest criteria by the author. In MCDA 1, dependency on bridge literacy occurs, implying that the literate person to bridges, e.g., the inspector, is likely to meet technological standards, as prescribed in BMS 1992 guideline. However, that leaves a trade-off upon public officials so that the other two aspects, e.g., cost and time, have the upper hand in MCDA 1. Proportionally to that regard, some officials argue "we have a limited budget for bridges because a considerable percentage goes to the preservation of roads compared to bridges, tunnel, and slope; also, the lesser the budget, the shorter time available dedicated for it". Hence in MCDA 1, the weight percentage difference (cost and time) is somewhat negligible.

Similarly, the dependency mentioned above occurs in MCDA 3. The bridge-literate-persons should have possessed an adequate engineering degree where technological stuff is part of their day-to-day encounter. It implies that being exposed to formal education and being technologically skilful do not necessarily bridge-literate. Trend-wise, the bridge-literate-persons are likely to continue supporting bridge affairs either on construction or maintenance as the resources are limited, and Bina Marga has always been putting "a grip" on them, especially experts in PUSJATAN (Institute of Road Engineering Indonesia).

Both MCDA results show a dependency. CLD loop R1 & R2 explain that the significance of data quality is heavily affected by the proper inspection; conducted by the reliable bridge inspector. The selection of inventory and condition data involving local universities is positively proportional because of the immense influence of bridge literacy, technological literacy, and level of education. However, it implies that locals are less suitable to be incorporated to perform such a complex data inspection.

As validated by an expert, the bridge data quality is prone to its adequacy. This issue has been alluded to within the problem demarcation (bridge quality) in CLD loop R3, specifically bridge safety issues. Furthermore, the metadata, including inventory and condition data stored in the SIMAJI, does not necessarily match on-site, e.g., the span lengths discrepancies, incorrect materials type, wrong expansion joint, drainage condition. As a result, low data quality leaves the road service provider unable to perform asset management to its max. As explained in Sub-chapter 4.1.3.1, The implication can be a misallocation of budget and incorrect maintenance treatment. As a solution, the synthesized TOWS strategies are presented in Table 5.1.

Table 5.1 Possible strategy to embrace from SWOT matrix for bridge data quality

Maxi-maxi	**O_5S_7:** Regional office to embrace the relationship with the academic institution, i.e., local university
Maxi-mini	**T_7S_4:** Balai needs to devise safety guidelines for those who participate in BMS x Locals
Mini-maxi	**$O_1W_1W_2W_3$:** Plan the milestone and curriculum within the yearly training, especially for the data collection
Mini-mini	**$T_1W_2W_3$:** Only to employ professional bridge inspector for condition and inventory data collection

5.2 Locals' participation in the public reporting

In the CLD, locals' participation in the public reporting is influenced by the sense of belonging and bridge condition mark (CM) to improve bridge data quality. As mentioned in CLD loop R3, Bina Marga's driving factors to employ locals are identified: up-to-date monitoring of bridge conditions and the needs of additional human resources. Furthermore, this study has been expected that locals "can contribute" to the public reporting; unfortunately, MCDA 1 and MCDA 3, i.e., concerning the type of data and its executor group, are less likely to favour such involvement. As discussed in Sub-chapter 5.1, the data collection is conducted for inventory and condition data by local university elements. For the opted locals' involvement, the later MCDA 2 and MCDA 4 are discussed in Sub-chapter 5.3, explaining locals' role in routine maintenance.

However, experts argue that Balai can still opt for locals' involvement in public reporting. In other instances, the reporting of roads using JAKI (Smartphone-based app - Public reporting for roads) has been significantly improved Bina Marga-Locals engagement. Most importantly, the received information through JAKI allows Balai to quickly applying corrective measures. In addition, the study also discovers the recurrence of some road service providers to exert locals and locals' willingness to participate, see CLD loop R3. It implies that Bina Marga can consider the embedment of bridge reporting within JAKI.

As validated by an expert, the absence of a "reporting platform" for bridges may undermine Bina Marga's reputation in providing road infrastructure service to society. Locals usually report poor bridge conditions on social media as currently there is no tailor-made platform dedicated for "bridges". The problem was explained in Sub-chapter 4.1.1 and depicted in Figure 4.2. Furthermore, the uploads made by the locals frequently can trigger virality on social media like Instagram or Facebook. Eventually, the unwanted virality, i.e., likely undermining Bina Marga/Balai's reputation, can be avoided, and most importantly, the bridge data are up-to-date concerning its current condition. Hence the presence of a dedicated public platform allows PPKs to apply faster corrective measures. As a solution, the synthesized TOWS strategies are presented in Table 5.2.

Table 5.2 Possible strategy to embrace from SWOT matrix for locals' participation public reporting

Maxi-maxi	**O_1S_7:** Conduct continuous yearly training to the locals to improve their ability and also the engagement between them and the government institution
Maxi-mini	**T_2S_2:** Employ locals as the additional validation of the bridge's visual condition
Mini-maxi	**O_3W_4:** Allowing PPK as the final decision maker for the local involvement, the professionally capable locals
Mini-mini	**T_2W_7:** Withdraw from BMS x Locals **$T_1W_2W_3$:** Only to employ professional bridge inspector for condition and inventory data collection

5.3 Expected design life

In the CLD, preservation of the expected design life of bridges can improve traffic safety and connectivity. In addition, preserving the bridge CM ≤ 2 (see Table 2.1) is influenced by one of the most critical variables, routine maintenance frequency. CLD loop R4 & B1 identifies the driving factors from Bina Marga to employ locals in routine maintenance: the economy, i.e., to improve regional's job opportunities and the pursuant of road service provider & locals engagement. From locals' perspective, drivers to participate are identified: the economy, i.e., additional income and the pursuant of knowledge and local pride. This finding implies the Creating Shared Value (CSV) between Bina Marga/Balai and locals. Therefore, in preserving the bridge, Bina Marga/Balai needs to improve the routine maintenance frequency (which increases the number of labours needed), and this can be intertwined by the willingness of locals for their subsistence and their existence utilization. In addition, proper routine maintenance is further specified in MCDA 2 – Type of work in routine maintenance, resulting in Package 1: cleaning of debris and garbage, cutting the grass, and drainage cleaning; and MCDA 4 – Type of group in routine maintenance, resulting Package 1: the municipality's list.

The highest criteria play a significant contribution to the MCDA's result. For example, the selection of Package 1 amounting to nearly 43% for its total weighted score in MCDA 2 (See Table 4.3 and Table 8.5) is significantly determined by the cost. The cost criterion weighs 30.6%, resulting in the weighted score for its criterion by nearly 20%. Also, the selection of Package 1 in MCDA 4 (See Table 4.5 and Table 8.7) amounting to nearly 52% for its total weighted score where cost weighs 37.4%, resulting in its weighted score by 21%. The occurrence of a similar highest criteria in both MCDA results implies that the budget austerity (management aspect) is prioritized in determining the working item and the executor group.

In addition, there are criteria in MCDA 2 and MCDA 4 which are low, yet they could have been higher. In MCDA 2, the labouring skill is the lowest amounting to 19.1%. It aligns with most experts, especially PPK, "a bare minimum labouring skill is fine, their willingness and commitment alone to work, are considered sufficient". Unsurprisingly, cost becomes the highest criterion, as the cheaper the labour-intensive work, the more locals can work. Furthermore, given the bridge complexity and the scattered location, more people employed can achieve better bridge preservation; hence, it is reasonable that the quality criterion becomes the second-highest amounting to 23%. In MCDA 4, the age criterion was an outlier, as experts mentioned multiple times that "we would prefer labours in routine maintenance to fall in the productive age preference (30 years ≤ Age ≤ 50 years) as they are likely to be communicative, directable, and swift". However, the willingness to work can trade it off. Some Balai officials said: "although such preference is uneasy to meet in some villages, the remuneration can make locals committed and cooperative though. Some physically fit youngsters, and older adults want to be employed because of college-absent/joblessness". It implies that routine maintenance can still carry on so long that the internal motivation exists; thus, age is a value-added criterion.

On average, bridges within national roads are designed for 50 years (Bina Marga, 1993a). An expert confirmed that the traffic load, improper maintenance plan, and the limited frequency of routine maintenance make it challenging to achieve the expected lifetime. Hence, preserving design life is imperative to maintain the reliability of the road network and its monetary value. The inability of the bridge to meet the expected design life can cause early replacement to take place. For instance, such a replacement, a collapse, can make the network vulnerable because construction needs to occur, and the traffic must be diverted or temporarily isolated. Bridge replacement before its expected design life is costly for Bina Marga, not only the value of investment but also the loss of traffic time and possible isolation of the two connected areas. As a solution, the synthesized TOWS strategies are presented in Table 5.3.

Table 5.3 Possible strategy to embrace from SWOT matrix for the expected design life

Maxi-maxi	**O_4S_1:** Embrace and maintain communication with a public figure to attract the willingness of locals **O_6S_1:** The local government, i.e., the municipality, needs to have a good database of locals' occupations to improve the on-target employment
Maxi-mini	**T_7S_4:** Balai needs to maintain communication and coordination with the locals, giving in the upfront information, especially the financial aspect
Mini-maxi	**O_3W_4:** Allowing PPK as the final decision maker for the local involvement by involving professionally capable locals
Mini-mini	**T_6W_5:** To opt for an agreement between Balai and locals about the fixed remuneration

5.4 Remarks on the discussion of results

Three CLD sub-systems combined with MCDA and SWOT & TOWS have been discussed, representing the socio-technical complexity in BMS. Generally, BMS' current state, including the regulation & practice, can be drawn: Bina Marga & Balai is struggling to achieve a high level of PIAM maturity.

Bridge data quality is influenced by proper inspection; proper inspection generates early warning responsiveness and quality of maintenance. The proper inspection in BMS x Locals is opted from MCDA 1 and MCDA 3 – resulting in Inventory and condition data (type of work) conducted by university elements (type of group). The final selection is heavily influenced by the highest criteria: cost & time (MCDA 1) and bridge literacy (MCDA 3). Meanwhile, both MCDA 1 and MCDA 3 have a similar lowest criterion, i.e., technological literacy. These MCDA analyses imply that "locals" are generally less likely to be employed to contribute to the bridge data quality. Empirically, bridge data quality is unreliably prone. The main problem faced by Bina Marga Marga and Balai is the mismatch on bridge metadata between the collected/stored data against the on-field. This problem can lead to a misallocation budget and incorrect maintenance treatment. As a solution, the synthesized TOWS strategy is presented in Table 5.1.

Locals' participation in public reporting is influenced by the sense of belonging and bridge condition mark, generating data quality. This variable unveils Bina Marga's driving factor to employ locals: up-to-date monitoring of bridge conditions and the needs of additional human resources. Although MCDA 1 and MCDA 3 are less likely to favour locals' data collection, public reporting can still be opted to improve local engagement and quickly apply corrective measures. By involving locals with a dedicated bridge reporting platform, Bina Marga can maintain their reputation and take faster action against defective bridges. Furthermore, the platform allows Bina Marga to minimize unwanted virality made by locals on social media, and PPKs can quickly apply corrective measures. The solution to strengthening this is presented in the synthesized TOWS strategy in Table 5.2.

The expected design life of bridges is influenced by routine maintenance frequency, which improves traffic safety and connectivity. However, intense routine maintenance requires more labour; hence Bina Marga's drivers to employ locals are identified: the economy and the pursuit of "road service provider-locals" engagement. In addition, locals' drivers to be employed are also identified: the economy and the pursuant of knowledge & local pride. Therefore, the proper routine maintenance is opted MCDA 2 and MCDA 4, resulting in cleaning works (type of work) and the municipality's list (type of group). The selection of that packages are heavily influenced by one highest criterion in both MCDAs, i.e., cost. In addition, the lowest criteria for MCDA 2 and MCDA 4 are labouring skill and age. Empirically, the bridge is prone to meet 50-year expected design life due to traffic load, improper maintenance plan, and limited frequency of routine maintenance. Frequently, an early replacement can occur, which is costly and impairing the road network. As a solution, Table 5.3 presents the synthesized TOWS strategy.

After having discussed the research results, the BMS x Locals guideline is presented in the following chapter. Such a practical guideline has been adapted based on the analyses performed and validated by a high-level Balai official.

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6 BMS x Locals guideline

BMS x Locals guideline is meant as a deliverable for the BMS Improvement. The diagram below summarizes the process of engaging locals in performing BMS in Indonesia. The diagram is adopted from Wattam (1998) and adjusted accordingly to this research (see Figure 6.1).

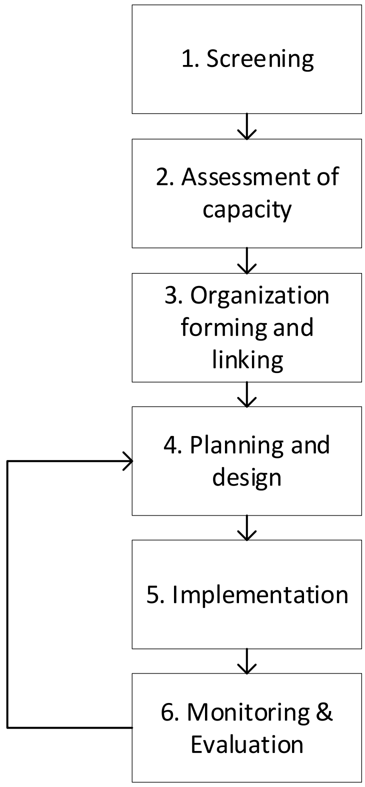


Figure 6.1 Process diagram for BMS x Locals

6.1 Screening

The screening aims to assess whether data collection and routine maintenance are the priority for the target group, i.e., local university elements and the municipality's list group. Then, a quantitative survey and competitive dialogue with the students, lecturers, jobless graduates, locals can be conducted.

6.2 Assessment of capacity

Capacity assessment serves to determine the organisation's ability (Bina Marga and Balai), particularly human resources-wise and budget-wise. Some approaches are advised in performing a capacity assessment. In human resources, HR analytics can analyze employee turnover, engagement, and performance. In the material and equipment aspect, inventory analysis and asset planning can help have a smooth fulfilment of orders, sufficient supply, and decision-making whether or not to scale the asset. Regarding budgeting, trend analysis could work (budgeting methods: incremental, activity-based, value proposition, zero-based). Later in BMS x Locals, such assessments allow the organization to adjust the "the extent of the engagement" to which educational institutions and the locals will provide.

6.3 Organization forming and linking

A dedicated BMS x Locals committee should be established. A committee is a group of people from Balai, educational institutions, and locals to serve specific BMS x Locals functions. The function can be diversified into data collection and routine maintenance sub-committee, where other sectors can be adjusted to the needs.

In routine maintenance work, the inclusive locals' representation is vital to avoid biased to a small population. Therefore, the propensity to employing "pre-identified locals", although they live far away from their residence, is likely to occur. Bina Marga is easier to find workers from a familiar neighbourhood than arranging the employment to other places to pursue inclusiveness.

To strengthen the targeting, in addition, there needs to be engagement with experienced parties. Therefore, it is recommended that the committee be active in liaising with the local government and NGOs. With their "first-hand" experience, substantive improvements by BMS x Locals in economic and social aspects can later be achieved.

6.4 Planning and design

The previous steps should be done accordingly to establish adequate planning and design. BMS x Locals planning and design include physical and management aspects.

6.4.1 Physical

Physical planning is distinguished into data collection and routine maintenance. Data collection can include inspection prioritization & sequence (based on accessibility, structural complexity, condition mark), equipment used, personnel deployment, and reporting & documentation protocols. Routine maintenance can include: tool & equipment used, amount of material used, the volume of work, coverage area. The planning can be derived from bridge conditions stored in the SIMAJI database. In addition, a discussion between the BMS x Locals committee and the nearby inhabitants/public figures living there can take place. Usually, they can explain the observable deterioration and unpleasant societal behaviours (e.g., illegal trash dumping and vandalism). The information gained can be used as secondary information that has not been covered yet historically in the SIMAJI databases.

The data collection and routine maintenance activity pose a safety risk. In addition, the people involved should be aware that their activity increases the human-vehicle mix (upper structure: bridge deck) and the danger of stepping down to the bridge (sub-structure: abutments and riverbank). Thus, the safety aspect must be carefully planned (implementable and supervise-able).

6.4.2 Management

As the bridge is varied within the national road network, its type (structural type, length, and material) serves a difference to the level of community involvement. For instance, short-span bridges or fewer complex structures are more feasible to involve locals because its accessibility. However still, the judgement falls to the bridge expert considering the complexity and safety

Balai is familiar with labour-intensive projects (LIP) where mass mobilisation entails. However, an overarching guideline, especially for PPK, must be established to achieve effective delivery. Therefore, BMS x Locals suggests that Balai liaise with the local municipality so that they can also provide that figure about how many people will be able to work, the best time of a year (e.g., farming and fishing period) to generate the best time to employ locals, and people who are responsible for coordinating the locals, e.g., foreman.

A well-formulated payment is necessary when involving locals in routine maintenance. For the fee, Balai has to comply with the region's minimum wage (UMR). In terms of the payment, it depends on how the type of contract to use. For self-management contract, PPK is currently responsible to give it directly to the employed locals. However, in commissioning contractors, the remuneration is managed by themselves and monitored by Balai.

6.5 Implementation

A large portion of the BMS x Locals part occurs during its implementation, whose predicated on careful planning. Contractually, the implementation can be categorized into two delivery models: Self-management (SWAKELOLA) and the commissioning of a contractor.

6.5.1 Self-management (SWAKELOLA)

SWAKELOLA is carried and managed independently by the organisation. In goods/service procurement, the implementation of this delivery model is planned, carried out, and supervised by Balai. Concerning the BMS x Locals, two types of SWAKELOLA can be adapted, prescribed in Presidential Decree No. 16 2018.

Type 1 – Selected if the work to be self-managed is the duty and function of corresponding authority, i.e., Balai. Balai uses employees of other Ministries/institutions/Regional Apparatuses and experts. The use experts should not exceed 50% of the total number of the implementing team. Inventory and condition data work is likely to favour Type 1 SWAKELOLA.

Type 4 - Selected if the work requires direct locals' involvement or for the direct interest of the locals who are considered capable of carrying it out. The implementation is based on the PPK contract with the locals' leader (public figure). Type 4 SWKELOLA is suitable for routine maintenance work.

6.5.2 Contractor

Balai has on option to commission a contractor. In general, maintenance works are conducted mainly by the small contractor were semi-skilled and unskilled labour. However, given the nature of routine maintenance, the locals can be hired in a semi-regular way. Practical details of routine maintenance can be referred to BMS 1992 guideline.

Many small contractors do not have a suitable financial condition because they are heavily dependent on the project. It implies that the continuation of BMS x Locals generally will help them to survive. Such a constraint often leaves them unable to continue working due to lack of funds, inadequate equipment, lack of status and ability to bid for projects. The following strategies have suggested a solution: Enactment of local law to adopt the issue of possession of resources (staff, machinery, stable financial condition)

- Enactment of local law to adopt the issue of possession of resources (staff, machinery, stable financial condition)
- Larger contractors to sub-contract smaller contractors
- Breaking down a large contract into smaller pieces of contract.

6.6 Monitoring and evaluation

Monitoring and evaluation conducted by the BMS x Locals committee are necessary for continuous improvement. Monitoring and evaluation can be divided into three aspects: physical, social and economic, and group participation; each aspect serves for data collection and routine maintenance where key performance indicators are suggested, see Table 6.1.

Table 6.1 Monitoring and evaluation BMS x Locals

Monitoring and Evaluation's aspect	Data collection KPIs	Routine maintenance KPIs
Physical	1. Data reliability improvement 2. Availability of historical data	1. Presence list 2. Performance of worker 3. The volume of work achieved, e.g. garbage and rubble collected, the volume of grass cleaned, area of drainage cleaned
Social & economy	1. Amount of people get paid 2. Contribution to regional's economy	1. Amount of people get paid 2. Contribution to regional's economy
Group participation	Recruitment rate in lectures, students, and jobless graduates	1. Recruitment rate in each LIP 2. Employment rate 3. Amount of JAKI app downloaded 4. Amount of public reports received

Achievements and concerns encountered during monitoring and evaluation must be openly discussed in the periodical meetings by the BMS x Locals committee and the parties involved. The meeting should be participated by PPK, contractors (if involved), educational institutions, and revered public figures. However, without waiting for a periodical meeting, the committee should be ready if the parties involved have an agenda to discuss; it allows openness and immediate settlement of concerns before it becomes too problematic. In addition, minutes of meetings should always be recorded and disseminated to participants most straightforwardly and inclusively. In that way, the meeting is controlled, and progress is checked.

7 Concluding remarks

7.1 Conclusion

In this section, the five-sub questions and primary questions of the research are answered.

SQ1 – What is the current state in terms of regulation and practice of Indonesian BMS?

BMS x Locals causal loop diagram (CLD) identifies the current state of BMS. Generally, Bina Marga and Balai are struggling to embrace the regulation and practice in BMS. The absence of specific quadrennial strategic planning (RENSTRA) for BMS leaves the data quality less significantly addressed – a prime factor in achieving a high Public Infrastructure Asset Management (PIAM) maturity level, specifically in the planning and implementation phase. In addition, the limited human resources making the road service provider unable to perform an adequate inspection and routine maintenance within a year.

SQ2 – What are the drivers enabling Bina Marga to outsource the local community?

Four drivers have been identified, which are mainly derived from CLD sub-systems. The first and second drivers are generated in Sub-system R3 concerning locals' participation in public reporting. Then, Sub-system R4 & B1 concerning the expected design life discovers the third and fourth drivers. The following drivers are:

1. The up-to-date monitoring of bridge conditions allows Bina Marga to improve the data quality inspected by the bridge inspector
2. The locals as an additional human resource
3. Economy, to improve the region's job opportunity
4. Engagement between road service providers and locals.

SQ3 – What type of works in BMS can be done by the locals?

In general, locals are less likely to be employed for data collection, yet bridge routine maintenance employment is suitable. Such a final selection is based upon MCDA 1 and MCDA 2. MCDA 1 – Type of work in data collection is influenced by criteria including cost, time, bridge literacy, and technological literacy, resulting in Package 2 – Inventory and condition data (final score: 39%). The selected Package 2 from MCDA 1 implies a low likelihood for locals involved in the bridge metadata collection. However, it is possible to employ locals in the public reporting as it can improve the engagement between road service providers and locals, have up-to-date bridge monitoring, and improve corrective measure responsiveness given defective bridge reports. Furthermore, MCDA 2 – Type of work in routine maintenance, influenced by criteria including cost, time, labouring skill and quality, generates Package 1 – Debris and garbage cleaning, grass cutting, drainage cleaning (final score: 43%). Ultimately, MCDA 2's result confirms that routine maintenance: cleaning works; is primarily the type of work the locals can do.

SQ4 – What type of group in the local community is eligible for Indonesian BMS in reporting and maintenance?

In general, the group from the local university elements is eligible for reporting, and locals from the municipality's list are suitable for maintenance. Such a final selection is determined by MCDA 3 and MCDA 4. MCDA 3 – Type of group in data collection, which comprises criteria including continuity, level of education, bridge literacy, and technological literacy, has opted for Package 2 – Local university (students and lecturers) and jobless graduates (final score: 49%). In addition, MCDA 4 – Type of group in routine maintenance, which is influenced by criteria consisting of cost, time, age, and labouring skill, has stipulated Package 1 – The municipality's list (final score: 51.8%). Thus, proportionally to the result stated in SQ3, MCDA 3 and MCDA 4 results imply that the group from the local university elements can perform reporting for bridge metadata collection, and the group from the municipality's list can perform maintenance in the form of cleaning works.

SQ5 – What are the factors which drive the community's willingness to be outsourced in Indonesian BMS?

Two factors influencing the locals' willingness have been identified, mainly derived from CLD Sub-systems. The first driver is generated in Sub-system R3 concerning locals' participation in public reporting. Then, Sub-system R4 & B1 concerning the expected design life discovers the second driver. Finally, the following are:

1. The economy, i.e., additional income
2. Pursuant of knowledge and local pride.

Given the opportunity of BMS x Locals employment, the first driver implies that locals, especially those who live in the village, are motivated to get paid to contribute income for their daily subsistence. Secondly, locals want to become technically capable of preserving bridges so that Balai can utilize their presence without taking additional skilled resources outside their region/province.

SQ6 – What is the Bina Marga and Balai strategy concerning the involvement of the local community in Indonesian BMS?

The strategies are derived from the iterative SWOT & TOWS analysis. SWOT identifies 42 elements, including 11 strengths, 12 weaknesses, 9 opportunities, and 10 threats. SWOT elements are categorized into ten categories comprising socio-technical aspects. The SWOT identification & categorisation manifests the full TOWS matrix generating four distinguished situational strategies amounting: seven maxi-maxi, seven maxi-mini, six mini-maxi, and seven mini-mini. Finally, the synthesized TOWS strategies have been adjusted against empirical situations concerning data quality, locals' participation in the public reporting, and expected design life. Finally, to adjust against empirical situations in data quality, locals' participation in the public reporting, and expected design life, the synthesized TOWS selects up to two realistic strategies in every four situational strategies.

MRQ: How can the local community be involved as the external resources to assist Bina Marga's in Indonesian Bridge Management Systems (BMS)?

The way locals can assist Bina Marga is prescribed in the proposed BMS x Locals guideline. In general, data collection is conducted by a local university elements group with a possible locals' public reporting assistance and routine maintenance is performed by the municipality's list group. The guideline recommends the following six activities to perform:

1. Screening can be done using quantitative analysis and competitive dialogue to local university elements group and locals.
2. Capacity assessment can be done using human resource analytics, inventory analysis, asset planning, and budgeting analysis.
3. Organizational forming & linking establishes BMS x Local committee comprising Balai, education institutions, and locals, then linked with local municipalities and NGOs.
4. Planning & design comprises physical and management aspects. The physical aspect plans for data collection activities: inspection & prioritization & sequence, equipment used, personnel deployment, reporting & documentation protocols, and safety. In addition, routine maintenance activities: tool & equipment used, amount of material used, work volumes, coverage area, and safety. In addition, the management aspect plans: locals involvement "level" against bridge complexity, mass mobilisation of workers, and payment.
5. The implementation phase selects the delivery model of data collection and maintenance execution with the possible option, i.e., Self-management (SWAKELOLA Type 1 and Type 4) or the commission of a contractor.
6. Monitoring & evaluation divides it into three aspects: physical, social & economic, and group participation. Each aspect covers key performance indicators (KPIs) on data collection and routine maintenance. All KPIs combined: presence list, workers' performance, the volume of works achieved, amount of people paid, contribution to the employment rate, and amount of public reporting app downloaded, i.e., JAKI and reports received. Ultimately, the measured performance is used better to improve the planning & design and implementation of BMS x Locals.

7.2 Limitation and future recommendation

Research

This research is conducted in a limited time, i.e., 28 weeks. Hence, the author can only conduct a single study at the regional level, i.e., Balai NTB. Therefore, it is challenging to thoroughly compare and generalize the results to all Balai across Indonesia. In addition, as some subjectivity exists in this qualitative study, the researcher's quality plays a significant role in influencing the excellent result. Hence, biases are inevitable despite the scientific approach that has been undertaken.

Given the time constraint, an initial meticulous formulation in literature studies must be conducted to avoid "complicated research", e.g., excessive research sub-questions entailing multiple methods. Furthermore, to improve the generalizability, multiple studies in Balai offices within Indonesia should be conducted so that the sample size can be more accurate. It can be started by dividing five major Indonesian islands concerning the regional offices (Sumatra, Java, Kalimantan, Sulawesi, and Papua). In addition, to improve the quality of the outcome, an alliance with related Bina Marga and Balai elements, e.g., Institute of Road Engineering (PUSJATAN), specialised bridge maintenance private entities, international development organizations, and NGOs, can be conducted.

Data Collection

Data collection is performed entirely remote because the author has limited mobility, mainly due to covid restriction and a significant time difference (6-7 hours). Most importantly, a "physical meeting" between locals could not be undertaken where intimate data collection and surprising insights could have been achieved much better.

If the covid situation in Indonesia gets well, then a site visit can be considered. If otherwise, an online setup can still be performed by reaching a broader typology of locals. As of now, only construction foremen and labours are involved.

Methods

In general, employing three methods: CLD, MCDA, SWOT & TOWS, is deemed too much and time-consuming. CLD is qualitative where variable's unit can easily be multi-interpreted if not carefully described. In addition, the simulation to measure the system's dependency amongst socio-technical variables cannot be performed due to the absence of quantifiable units. In MCDA, an official validation upon criteria and alternatives was not conducted before evaluating relative importance. Also, the low presence of officials in the online session is unfavourable as it can influence the subjective result of a pairwise comparison using the AHP tool. In addition, a limited number of participants for the overall appraisal resulting in narrow data. Hence, the sensitivity analysis for MCDA, which examines the deviation of the outcome, is considered negligible to be discussed statistically. Although situational strategies can be implemented as listed in the TOWS matrix, it is difficult to predict the empirical situation, especially when faced with different cultures and working styles within each Balai in Indonesia.

Research can be distinguished into several parts in the future, focusing only on one method analyzed profoundly for each. For CLD, variables can be re-assed into quantifiable units and validated by high-level officials. In addition, it can be further analyzed in the stock-flow diagram (SFD) using accompanying equations, i.e., CLD and SFD combined manifest System Dynamics (SD). Then SD can be used to visualise the complex system, perform quantitative simulation, and determine trade-offs of the proposed BMS x Locals. For a better decision-making process, criteria and alternatives should be thoroughly validated in MCDA. The number of participants also needs to be increased to obtain a broader range of data and perform sensitivity analysis. Finally, for the situational strategy, the matrix obtained from SWOT & TOWS analysis must be detailed further so that road service providers can embrace a high degree of adaptiveness.

7.3 Reflection

Towards the kick-off meeting

BMS x Locals was not the first topic the author would research. The author was supposed to research bridge reliability in Sweden, but the Covid-19 pandemic cancelled the project. Also, the travel restriction made the site inspections unfeasible. Luckily in early December 2020, the author came up with a novel BMS x Locals idea after watching Islands of Faith on Netflix.

In January 2021, establishing the graduation committee was cumbersome. From a total of 11 prospective first supervisors approached, none of them accepted the topic. Luckily, the first supervisor, who used to be the chairman, stepped in. Also, with the help of Marian Bosch-Rekveldt, the graduation chair and second supervisor could be set on board.

The thesis proposal was on time despite some issues. Formulating a connection between the practice and the scientific domain was challenging. Also, the literature study was too much, i.e., unnecessary theoretical backgrounds. Methods to use were unclear except SWOT & TOWS analysis. The author did not differentiate desk study into two categories for data collection, i.e., academic literature study and organizational document review. In addition, the interview was meant to be semi-structured turned to be structured to avoid complexity.

Towards the mid-term meeting

Two weeks after the kick-off, the author developed interview protocols for data collection and selected two remaining data analysis methods. Formulating the open-question for interviews was challenging. It took some time until the supervisor allowed him for interviews. Also, the selection of CLD and MCDA required the author to allocate more time to study such methods.

In general, data collection went well. The author managed to complete the online interview session amounting to 16 interviewees. One of the successes was because the author has a good connection with Bina Marga and Balai. However, data processing is very time-consuming. Transcribing interviews and coding them in ATLAS.ti was a very tedious job. Better planning could have made transcripts simple and avoided too many codes.

Data analysis took place with some issues following the completion of expert interviews. First, CLD variables were initially established without problem demarcation and objective tree. Also, MCDA criteria and alternatives were established unsystematically, and they were lack of clear definition. In addition, intensiveness on CLD and MCDA left the author unable to complete SWOT & TOWS analysis. Moreover, the BMS x Locals guideline had not been touched upon as the data analyses were incomplete.

Towards the green-light meeting

In addition to his sloppiness in English, the author experienced trouble in writing: the report structure was unclear, and the information put was overloaded. Moreover, the absence of an excellent flow made the report incomprehensible. In addition, the author tended to explain everything in the text, e.g., the recurrent MCDA criteria explanation were repetitive on each

MCDA type, and Data Analysis and Synthesis (Chapter 4) tediously explained the procedures of employed methods, which could have been attached in the appendix.

CLD had to be re-optimized. The author failed to understand the difference between system diagram/dynamics (SD) and CLD. In MCDA, he had to perform the criteria and alternative appraisal of relative importance. Devising a practical polling session was a big struggle; however, the zoom session assisted by google form did the trick. SWOT & TOWS was iterative because socio-technical aspects needed to be intertwined to generating strategies. It then became apparent when the identified SWOT elements were categorized. Finally, the three results were combined into three aspects; unfortunately, the discussion was not conducted profoundly.

BMS x Locals guideline could be developed after all analyses had been finished. However, the author did not allocate sufficient time to improve it more. As a result, the recommendation was too high level.

Towards the Final defence

The author barely passed the green light meeting. He had to revise many writing aspects and substantive matters. In terms of writing, structure, format, punctuation, and grammar required significant improvements. Furthermore, Hofstede's cultural dimension was removed in the literature background as it was not used. Data analysis and synthesis required text optimization as either repetitive information or incomplete explanation occurred. In addition, before entering the discussion of results (Chapter 5), the substantiation in dividing three aspects of Chapter 5 should have been included at the end of Chapter 4; the committee got confused about how it came into being and was not extensive enough. Also, the discussion in Chapter 5 was not extensive enough. Finally, the BMS x Locals guideline should be more straightforward and a feedback loop in the monitoring & evaluation to the planning & design must be linked.

By all those concerns, the author realized many works needed to be done, and he should have positioned himself as if a reader. He started working back on the thesis revision after having passed the and only last course he had, i.e., probabilistic design. The author combined all the comments and prioritized what to revise based on the degree of importance, which amounted to 80 critical comments. The author had spent three intensive weeks revising at TU Delft library. In addition, the peer review from the colleagues was also helpful. He learned to get perspectives that he had not thought about. Finally, the thesis report can be submitted in due time for the final defence after significant revisions have been implemented.

8 References

Adey, B. T. (2019). A road infrastructure asset management process: gains in efficiency and effectiveness. *Infrastructure Asset Management*. https://doi.org/10.1680/jinam.17.00018

Alatas, V., & Newhouse, D. (2010). *Indonesia jobs report: Toward better jobs and security for all*. https://openknowledge.worldbank.org/bitstream/handle/10986/27901/563480WP0Indon110Full0version0FINAL.pdf?sequence=1&isAllowed=y

Balai NTB. (2020). *Laporan Kinerja Instansi Pemerintah TA. 2019*. https://binamarga.pu.go.id/balai9/v2/assets/file/lkip_2019.pdf

Bina Marga. (1993a). *Bridge Management System: Bridge Inspection Manual*. Bina Marga. http://nspkjembatan.pu.go.id/public/uploads/TahapInspeksi/BM/151102028010.bridge_inspection_manual.pdf

Bina Marga. (1993b). *Bridge Management System: Bridge Investigation Manual*. Bina Marga. http://nspkjembatan.pu.go.id/public/uploads/TahapInspeksi/BM/151102039510.bridge_investigation_manual.pdf

Bina Marga. (2016). *BBPJN IV Handover Receives 283 National Road Land Certificates*. https://binamarga.pu.go.id/index.php/berita/bbpjn-iv-handover-receives-283-national-road-land-certificates

Bina Marga. (2019). *Bina Marga Task*. https://binamarga.pu.go.id/index.php/konten/profil/struktur-organisasi

Bina Marga. (2020). *Jumlah Jembatan Nasional*. https://data.pu.go.id/dataset/jumlah-jembatan-nasional

Boubaz, M., R, M., & W, H. (1990). Modelling and Predicting Bridge Repair and Maintenance Costs. In *Bridge Management Inspection, Maintenance, Assessment and Repair* (p. 187). Springer Science+Business Media. https://doi.org/10.1007/978-1-4899-7232-3_2

Calvert, S. C., & Snelder, M. (2018). A methodology for road traffic resilience analysis and review of related concepts. *Transportmetrica A: Transport Science*. https://doi.org/10.1080/23249935.2017.1363315

Claudio, David, C., Kremer, J., & Gul. (2008). AHP based borda count: A hybrid Multi-Person decision-making method for design concept selection. *IIE Annual Conference and Expo 2008*, 776–781.

Cnaan, R., Milofsky, C., & Hunter, A. (2008). *Handbook of Community Movements and Local Organizations*. Springer Science+Business Media. https://doi.org/10.1007/978-0-387-32933-8

Dembek, K., Singh, P., & Bhakoo, V. (2016). Literature Review of Shared Value: A Theoretical Concept or a Management Buzzword? *Journal of Business Ethics*. https://doi.org/10.1007/s10551-015-2554-z

Dubois, C. L. Z., & Dubois, D. A. (2012). Expanding the Vision of Industrial-Organizational Psychology Contributions to Environmental Sustainability. *Industrial and Organizational Psychology*. https://doi.org/10.1111/j.1754-9434.2012.01482.x

Dyson, R. G. (2004). Strategic development and SWOT analysis at the University of Warwick. *European Journal of Operational Research*, *152*, 631–640. https://www.elsevier.com/social-sciences-and-humanities/decision-sciences

Enserink, B., Hermans, L., Kwakkel, J., Thissen, W., Koppenjan, J., & Bots, P. (2010). *Policy Analysis of Multi-Actor Systems*. Lemma.

Faizal, N., & Suprayoga, G. B. (2014). *Sistem Pengadaan Untuk Pembangunan Jalan*. http://perpustakaan.pusjatan.pu.go.id/repositori/system/files/FA Isi Naskah Ilmiah Sistem Pengadaan untuk Pembangunan Jala.pdf

Forman, E., & Peniwati, K. (1998). Aggregating individual judgments and priorities with the Analytic

Hierarchy Process. *European Journal of Operational Research*, *108*(1), 165–169. https://doi.org/10.1016/S0377-2217(97)00244-0

Gebremedhin, E. T., Basco-Carrera, L., Jonoski, A., Iliffe, M., & Winsemius, H. (2020). Crowdsourcing and interactive modelling for urban flood management. *Journal of Flood Risk Management*. https://doi.org/10.1111/jfr3.12602

Halfawy, M., & Figueroa, R. (2006). Developing Enterprise Gis-Based Data Repositories for Municipal Infrastructure. *Joint International Conference on Computing and Decision Making in Civil and Building Engineering*.

Halfawy, M. M. R., Newton, L. A., & Vanier, D. J. (2006). Review of commercial municipal infrastructure asset management systems. In *Electronic Journal of Information Technology in Construction*.

Halse, W. ., & Stephens, R. L. C. (1990). Engineering Management of the Tamar Bridge. In M. J. Ryall, J. E. Harding, & G. A. R. Parke (Eds.), *Bridge Management Inspection, Maintenance, Assessment and Repair* (p. 173).

Harding, J. E., Parke, G. A. R., & Ryall, M. J. (1990). *Bridge Management: Inspection, Maintenance, Assessment and Repair*. Springer Science+Business Media. https://doi.org/10.1007/978-1-4899-7232-3

Honfi, D., Portal, N. Wi., Ivanov, O. L., Bjornsson, I., Ploss, M., Zandi, K., Carneiro, E., Lechner, T., Magnusson, J., & Gabrielsson, H. (2018). *Inspection and Monitoring of Bridges in Sweden*. http://ri.diva-portal.org/smash/record.jsf?pid=diva2%3A1206969&dswid=-3119

James, E. (Ted). (2016). Improving Indonesia's National Road Assets Maintenance Outcomes. *Journal of the Indonesia Infrastructure Initiative (PRAKARSA)*, *24*. https://media.neliti.com/media/publications/45309-EN-asset-management-in-infrastructure-in-indonesia.pdf

Jelen-Sanchez, A. (2017). Engagement in public relations discipline: Themes, theoretical perspectives and methodological approaches. *Public Relations Review*. https://doi.org/10.1016/j.pubrev.2017.04.002

Kementerian Pekerjaan Umum. (2017). *Modul 2 Sistem Manajemen Jembatan*. https://simantu.pu.go.id/epel/edok/1a2c1_MODUL-2_SISTEM_MANAJEMEN_JBT_FIX.docx.pdf

RENSTRA PUPR 2020-2024, (2020). https://binamarga.pu.go.id/assets/js/vendor/ckeditor/uploads/Renstra/Renstra PUPR 2020-2024.pdf

Khwaja, A. I. (2004). Is increasing community participation always a good thing? *Journal of the European Economic Association*. https://doi.org/10.1162/154247604323068113

Kopackova, H., & Libalova, P. (2018). Citizen Reporting Systems in the Global and Czech Specific View. *Globalization and Its Socio-Economic Consequences 2018*. https://www.researchgate.net/publication/328577820_CITIZEN_REPORTING_SYSTEMS_IN_THE_GLOBAL_AND_CZECH_SPECIFIC_VIEW

Kopackova, H., & Libalova, P. (2019). Quality of Citizen Reporting Tools at Municipal Level. *Journal of Information Systems Engineering & Management*. https://doi.org/10.29333/jisem/5891

Kwon, H. S., & Park, H. C. (2019). Creating sustainable and climate shared value in public institution: Lessons from a case of Korea Army Cadet Military School. *Sustainability (Switzerland)*. https://doi.org/10.3390/su11143796

Lee, D. (1990). Comparative Maintenance Costs of Different Bridge Type. In J. E. Harding, G. A. R. Parke, & M. J. Ryall (Eds.), *Bridge Management Inspection, Maintenance, Assessment and Repair* (p. 145). Springer Science+Business Media.

Lee, M.-H. (2018). A Study on Citizens' Public Report Application Usage. *Archives of Design Research*, *31*(3), 49–67.

Li, T. H. Y., Thomas Ng, S., & Skitmore, M. (2012). Public participation in infrastructure and construction projects in China: From an EIA-based to a whole-cycle process. *Habitat International*. https://doi.org/10.1016/j.habitatint.2011.05.006

Liu, W., Chen, S.-E., & Hauser, E. (2009). Remote sensing for bridge health monitoring. *Atmospheric and Environmental Remote Sensing Data Processing and Utilization V: Readiness for GEOSS III*, *7456*, 74560D. https://doi.org/10.1117/12.825528

Macharis, C. (2007). Multi-criteria analysis as a tool to include stakeholders in project evaluation: The MAMCA method. In *Transport Project Evaluation: Extending the Social Cost-Benefit Approach*.

Manning, D. G., & Masliwec, T. (1990). Application of Radar and Thermography to Bridge Deck Condition Surveys. In *Bridge Management Inspection, Maintenance, Assessment and Repair* (p. 305). Springer Science+Business Media. https://doi.org/10.1007/978-1-4899-7232-3_2

Meng, J., Yan, J., & Liu, B. (2016). An Exploratory Study of Relationships between National Culture and Infrastructure Sustainability. *Procedia Engineering*. https://doi.org/10.1016/j.proeng.2016.04.158

Mihani. (2019). Analisis Faktor-Faktor Yang Berpengaruh Terhadap Kinerja Pegawai Bidang Bina Marga Dinas Pekerjaan Ummum Kabupaten Kutai Timur. *Festival Riset Ilmiah Manajemen Dan Akuntansi*, 642–652. http://stembi.ac.id/file/FM-2019-L53 (Mihani - STIMI SAMARINDA).pdf

Moubray, J. (1997). *Reliability-Centered Maintenance* (2nd ed.). Industrial Press.

Ngowi, A. B. (1997). Community-managed infrastructure facilities. *Facilities*. https://doi.org/10.1108/02632779710188315

Porter, M. E., & Kramer, M. R. (2011). Creating shared value. *Harvard Business Review*. https://doi.org/10.32591/coas.ojss.0201.04037b

Putri, C. K., & Sastrawiria, R. P. P. (2018). Analisis Penerapan Aplikasi Inspeksi Visual Jembatan INVIJ (User Perspective). *Jurnal Protek Teknik Sipil*, *1*(1), 29–37. https://ejournal2.undip.ac.id/index.php/potensi

PwC. (2017). *Directorate General Bina Marga focuses on development and maintenance in 2018*. https://www.pwc.com/id/en/media-centre/infrastructure-news/infrastructure-news---archive/october-2017/directorate-general-bina-marga-focuses-on-development-and-mainte.html

Reel, R. ., & Muruganandan, C. (1990). Cost-effective Strategies in Bridge Management. In G. A. R. Parke & M. J. Ryall (Eds.), *Bridge Management Inspection, Maintenance, Assessment and Repair* (p. 715). Springer Science+Business Media.

Ruiz-Mallén, I., Schunko, C., Corbera, E., Rös, M., & Reyes-García, V. (2015). Meanings, drivers, and motivations for community-based conservation in Latin America. *Ecology and Society*. https://doi.org/10.5751/ES-07733-200333

Saaty, T. (1980). *Fundamentals of decision making and priority theory with analytical hierarchical process* (VI). RWS Publications, University of Pittsburgh.

Seixas, C. S., & Davy, B. (2007). Self-Organization in Integrated Conservation and Development Initiatives. *International Journal of the Commons*. https://doi.org/10.18352/ijc.24

Seto, T., Sekimoto, Y., Omata, H., Maeda, H., Kashiyama, T., Higashi, S., Fujii, M., & Seki, H. (2019). The Development of Open Source Based Citizen Collaboration Applications for Infrastructure Management: My City Report. *Proceedings of the ICA*. https://doi.org/10.5194/ica-proc-2-116-2019

Shah, R., McMann, O., & Borthwick, F. (2017). Challenges and prospects of applying asset management principles to highway maintenance: A case study of the UK. *Transportation Research Part A: Policy and Practice*. https://doi.org/10.1016/j.tra.2017.01.011

Slingerland, G., Lukosch, S., Comes, T., & Brazier, F. (2018). Exploring design guidelines for fostering citizen engagement through information sharing: Local playgrounds in The Hague. *EAI Endorsed Transactions on Game-Based Learning*. https://doi.org/10.4108/eai.13-7-2018.162636

Spatari, S., & Aktan, A. E. (2013). Asset management in civil engineering. In *Structure and Infrastructure Engineering* (Vol. 9, Issue 4, pp. 295–296). https://doi.org/10.1080/15732479.2012.654945

Sriskandan, K. (1990). Bridge Management - An Overview. In J. E. Harding, G. A. R. Parke, & M. J. Ryall (Eds.), *Bridge Management Inspection, Maintenance, Assessment and Repair* (p. 17). Springer Science+Business Media. https://doi.org/10.1007/978-1-4899-7232-3_2

Statista. (2020). *Smartphone users in Indonesia 2015-2025*. https://www.statista.com/statistics/266729/smartphone-users-in-indonesia/#:~:text=The number of smartphone users,India and the United States.&text=In 2018%2C the subscriber count,Telkomsel amounted to 163 million.

Sterman, J. D. (2000). *Business Dynamics: Systems Thinking and Modelling for a Complex World*. McGraw Hill.

Suthanaya, P. A., & Artamana, I. B. (2017). Multi-criteria Approach for Prioritizing Bridge Maintenance in Developing Country (Case Study of Bali Province, Indonesia). *Asian Journal of Applied Sciences*. https://doi.org/10.24203/ajas.v5i2.4688

Too, E. G., Betts, M., & Kumar, A. (2006). A strategic approach to infrastructure asset management. *BEE Postgraduate Research Conference, Infrastructure 2006: Sustainability & Innovation*.

Toorn, A. van Der, & Reij, A. W. F. (1990). A Systematic Approach to Future Maintenance. In J. E. Harding, G. A. R. Parke, & M. J. Ryall (Eds.), *Bridge Management Inspection, Maintenance, Assessment and Repair* (p. 215). Springer Science+Business Media. https://doi.org/10.1007/978-1-4899-7232-3_2

Utary, D., Agusdin, A., & Hermanto, H. (2018). Analisis Kebutuhan Pengembangan SDM Bidang Bina Marga Dinas PUPR Provinsi NTB. *JMM UNRAM - MASTER OF MANAGEMENT JOURNAL*. https://doi.org/10.29303/jmm.v7i2.316

Wattam, M. (1998). *Community Participation in Rural Transport Infrastructure*. https://www.ssatp.org/sites/ssatp/files/publications/HTML/Gender-RG/Source documents/Tool Kits & Guides/Participatory Project Approaches/TLPAR5 Community Participation in RT.pdf

Weihrich, H. (1982). The TOWS matrix-A tool for situational analysis. *Long Range Planning*, *15*(2), 54–66. https://doi.org/10.1016/0024-6301(82)90120-0

World Bank. (2004). World Development Report 2004: Making Services Work for Poor People. In *Banque mondiale, Washington, DC*.

Appendix A

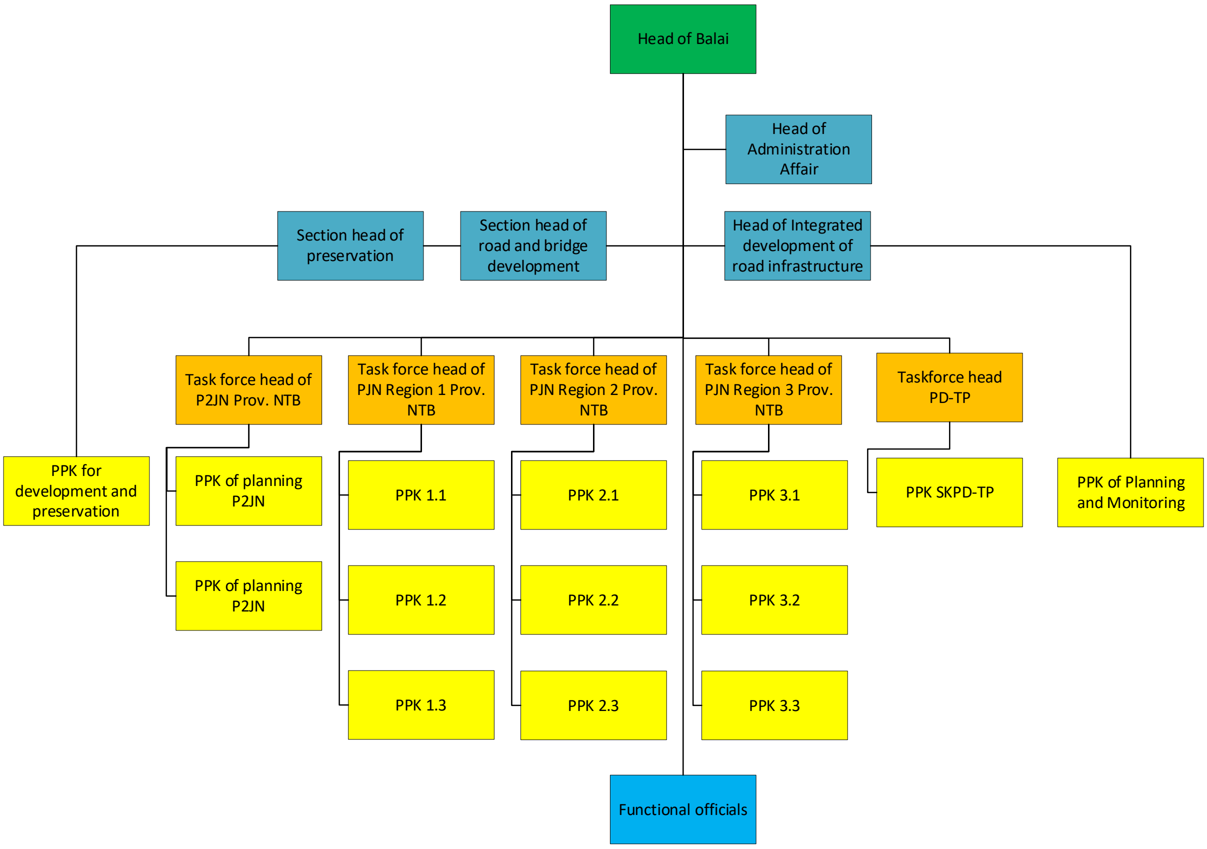


Figure 8.1 Balai NTB organizational chart (Balai NTB, 2020)

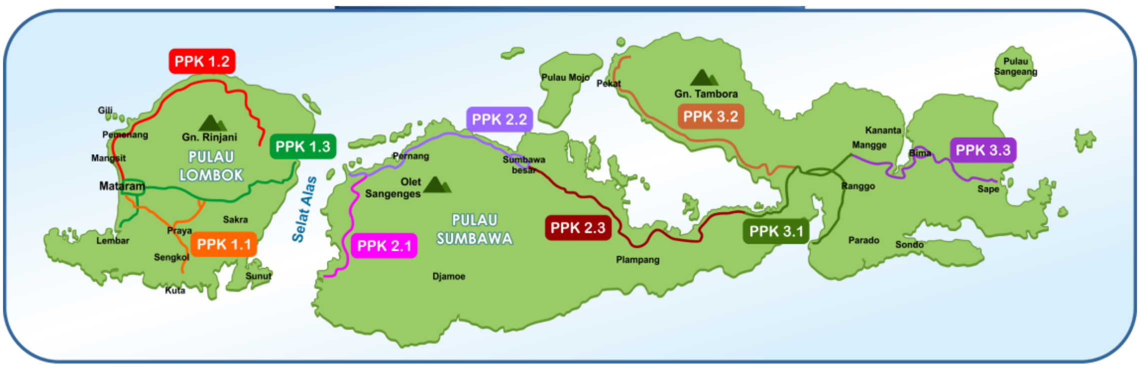


Figure 8.2 National Road network in West Nusa Tenggara managed by Balai NTB

Appendix B

Appendix B.1 Question for Bina Marga Officials

1. The current state, in terms of regulation and practice of Indonesian BMS
   A. What do you think about BMS practice in general? – Allude interviewee with data reliability and routine maintenance
   B. Describe the standard/target that Bina Marga wants to achieve now and the next five years
   C. Describe the life cycle of BMS practice from start to end on a yearly and five-yearly basis (e.g., special inspection or major repair), (planning, programming, the commencement of work packages) including the deployment of internal personnel and technology, and contract used if any (for procured works)
   D. Ideally, how many times does the bridge "condition data" needs to be updated?
   E. Describe the management and technical gaps between Bina Marga and Balai in implementing BMS.
2. The factors enabling Bina Marga to outsource the local community
   A. How do you see Bina Marga conducting labour intensive jobs (LIP) in the next five years?
   B. Could you explain the outsourcing process of locals in LIP?
   C. Could you explain the possibility of the outsourcing of locals for LIP for data collection? To what extent is the possibility?
   D. What factors (budget, technology, human resource, procurement, and policy) drive Bina Marga to outsource locals in the context of data collection?
   E. What value(s) that Bina Marga and Locals could share in each other? To what extent do you think the Creating Shared Value (CSV) can be embraced given the BMS x Locals?
3. The type of works that the locals can do
   A. How does Bina Marga foresee the involvement of the local community for BMS, particularly in data collection and routine maintenance works?
   B. What type of works, including its limitation, can the locals do in terms of furniture/architecture, super-structure, sub-structure, waterways/embankment?
4. The eligible type of groups and people for Indonesian BMS in terms of reporting and construction.
   A. Please explain the particular groups in the local community that can be involved in BMS!
   B. What are the skills required by the locals in performing data collection and routine maintenance for BMS?
5. Possible driving factors and hindering factors affecting the community's willingness to be involved in BMS.
   A. What are the driving and hindering factors from the locals to be outsourced by Bina Marga in BMS x Locals
      - Follow up question: do you have a suggestion for the payment system and its fee for the locals?
   B. What are the factors which can drive and hinder the success of BMS x Locals?

Appendix B.2 Question for Locals

1. Could you please introduce yourself?
    A. What is your background? (Name, occupation, age, marital status and family members)
    B. For how long have you been living in the community?
    C. Are you associated with any specific group or organization within the community?
    D. How is the significance of roads and bridges development within the area you live?
2. Could you please explain about your job(s)? How long and until when do you plan to do this? Motivation and expectation? How much money do you get from your job(s)?
3. If you have ever been outsourced in one of the labour-intensive works by Balai NTB, could you please explain the procedure of how they approach you or how to get into this?
4. How much fee do you get from Balai NTB for such works? Do you think it is worth it?
5. Are you accustomed to labour-intensive projects? If yes, please mention three significant skills that you possess concerning the construction
6. What values do you get from your involvement in such works?
7. Do you think the employment Balai can utilize your skills much better?
8. Do you have a smartphone? What applications do you usually use? Please rate your literacy of using a smartphone from 1 to 10!
9. Are you willing to be involved in the data collection for bridges and routine maintenance works?
10. What should Balai do so that locals are willing to be involved in BMS?
11. What are the driving and hindering factors that influence your willingness given the BMS x Locals?
12. What are the benefits that you could envision given the BMS – Local community?

Appendix C

Appendix C.1 Analytical Hierarchy Process (AHP) method

In AHP, pairwise comparisons of the relative importance of factors are the only inputs provided by the expert. Thus, the inputs in Figure 8.3 are taken two at a time; one follows the principle of "divide and rule".

1	Equal importance
3	Moderate importance
4	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values
1/3, 1/5, 1/7, 1/9	Values for inverse comparison

Figure 8.3 Value scale to fill in the pairwise comparison table

The ratio is considered the reciprocal judgement matrix and designated as A, where n is the number of factors for pairwise comparison, see Equation 8.1.

$$A = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \cdots & & & \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{bmatrix} = \begin{bmatrix} 1 & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & 1 & \cdots & \frac{w_2}{w_n} \\ \cdots & & & \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2n} \\ \cdots & & & \\ \cdots & & & \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{bmatrix}$$

Equation 8.1

There are many methods for aggregation; in this study, Aggregation of Individual judgements (AIJ) is selected, see Figure 8.3. An aggregating individual judgement does it for each pairwise comparison into an aggregate hierarchy. By using AIJ, each individual in the polling session should forgo their individual preferences. As this technique does not consider individual priorities, the Pareto principle is not violated. To satisfy the reciprocity requirement for judgements and consider the process's simplicity, AIJ uses the geometric mean (Claudio et al., 2008).

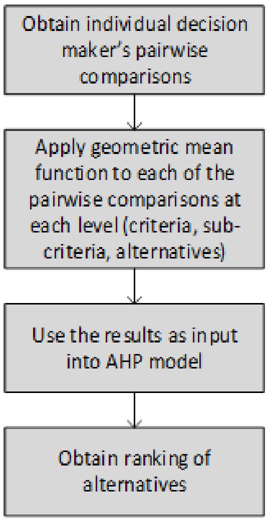


Figure 8.4 AIJ aggregation method flowchart (Claudio et al., 2008)

The following steps are conducted to obtain the respective criteria weight (calculation is done in excel):

1. Performing AHP online sessions with the interviewees. Once the values are obtained, the geometric mean will be applied to input criteria and alternatives.
2. Substituting pairwise values from the interviewees with regards to the relative importance results in a standard value. When comparing the relative importance between two different criteria, Equation 3.1 should be followed. The value for each criterion is vertically summed.
3. The vertical sum obtained is used to calculate the eigenvalue. Finally, the eigenvalue for each criterion is calculated to obtain the criteria weights (CW).
4. The eigenvalue is summed horizontally to obtain CW; the result represents the weighting for each criterion.
5. The next step is to calculate λ_{max}.

$$\lambda_{max} = \sum_{k=0}^{n} (\sum\nolimits_{criteria} \text{x}\, CW) \qquad \textit{Equation 8.2}$$

6. The next step is to calculate the consistency index (CI)

$$CI = \frac{\lambda_{max} - n_{criteria}}{n_{criteria} - 1} \qquad \textit{Equation 8.3}$$

7. The consistency ratio is the last step in AHP. The AHP is acceptable when CR < 0.1. CR is the ratio between CI and Random Index (RI); see Figure 8.5. For the random index to the n - criteria. The calculation is done by using the following formula:

$$CR = \frac{CI}{RI}$$ *Equation 8.4*

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Figure 8.5 Random index (RI) for calculation of consistency ratio

Appendix C.2 Criteria

Table 8.1 Specification and identification of MCDA criteria

No	Criteria	Description	Number of quotations	Example of the quotation from interviews	The existence concerning MCDA	Academic literature
1	Cost	The cheapest value of money to be allocated against a particular work package and type of group	16	1. The amount of fees is very tricky; sometimes we have to be aware of the fact that locals are well-paid on their current job, so they could be hesitant to work for BMS x Locals 2. We search locals who live in the vicinity of the bridge, and we pay them according to the regional minimum wage (UMR). The fee for an extensive bridge inspection is higher than UMR	MCDA 1; MCDA 2; MCDA 3.	(Boubaz et al., 1990; D. Lee, 1990; Reel & Muruganandan, 1990; Suthanaya & Artamana, 2017)
2	Time	The least amount of duration that is required against a particular data collection work package. The more complex set of data is collected, the longer it takes	7	1. There is a trade-off when counting on Farmers. For instance, natural rubber farmers who are in the farming season are unable to be employed. In this case, we have to search outside of the related region where the bridge at 2. As a foreman, If I am too involved in BMS x Locals, I am eager to allocate my time for 2-3 hours per day.	MCDA 1; MCDA 2; MCDA 4.	(Reel & Muruganandan, 1990; Toorn & Reij, 1990)
3	Age	The required productive age required against a particular type of group in performing routine maintenance, which entails 30 years ≤ ideal age ≤ 50 years	3	1. To employ locals in routine maintenance it requires their age to be 30 years old ≤ participant's age ≤ 50 years old 2. For sure, those who are mature and able to distinguish normality and abnormality on bridges. The youth does not have that good sense, I assume, perhaps people who are above 30 years old	MCDA 4	-
4	Labouring skill	Labouring skill is defined as the technical capability required against a particular routine maintenance work package and a particular type of group package in performing routine maintenance	22	1. The labour-intensive project is routine maintenance. The items are cleaning jobs (garbage and drainage), painting jobs. For sure, any non-extensive skill-required jobs 2. Routine maintenance such as tightening bolts, structural painting, blasting of steel members could involve locals. Those are the response-treatment for condition mark 2 on bridges	MCDA 2; MCDA 4.	(Halse & Stephens, 1990; Harding et al., 1990)

No	Criteria	Description	Number of quotations	Example of the quotation from interviews	The existence concerning MCDA	Academic literature
5	Bridge literacy	The knowledge of bridge component required against a particular data collection work package and against a particular type of group package in performing data collection	5	1. a critical criterion for data collection is literacy in civil engineering, i.e., bridge elements 2. Trend-wise, locals living in the vicinity of the bridge are more aware; perhaps their participation could be done by identifying the type of defects with their version	MCDA 1; MCDA 3.	(Halse & Stephens, 1990; Harding et al., 1990; Honfi et al., 2018)
6	Techno-logical literacy	The extent of required technical skill to operate devices such as laptops or phones or tablets, etc., against a particular data collection work package and against a particular type of group in performing data collection	20	1. Criteria for data collection: technological literacy, i.e., an ability to use PC and smartphone 2. Sometimes there are reliable locals that we can utilize, which means they can take photographs concerning bridge condition	MCDA 1; MCDA3.	(M. M. R. Halfawy et al., 2006; Harding et al., 1990; Liu et al., 2009; Manning & Masliwec, 1990)
7	Quality	The extent to which a particular routine maintenance package can relatively bring improvement to the bridge condition	2	1. During Covid-19 government promotes labour intensive projects as a stimulus package for economic recovery. On the other hand, PPK is worried about the quality of the structure. Capital purchasing contributes to the remaining life of the structure while the goods purchasing does not 2. For work items that fall below the goods purchase scheme, it is OK. The thing is, PPK concerns with the delivered quality of labour intensive for capital purchase scheme	MCDA 2	(Harding et al., 1990)
8	Level of education	Level of education is the extent of locals concerning the required degree of education in performing data collection. This criterion allows Bina Marga better to choose the package as the level of education	4	1. For data collection, we need to employ experienced locals, not those who just recently graduated from university or let alone high school graduates 2. The concern when employing locals in data collection is that their low education level	MCDA 3	(Harding et al., 1990)

No	Criteria	Description	Number of quotations	Example of the quotation from interviews	The existence concerning MCDA	Academic literature
		can commit the locals much easier				
9	Continuity	The extent of the continuation of a particular type of group package in performing data collection	10	1. As a foreman, I am ready to be employed as a bridge watcher. I am eager to allocate my time 2. As a worker, I can allocate 4-5 hours per day to monitor the bridge 3. I have been working in construction for 5 years. In the future, it depends on my productivity as for to continue or not	MCDA 3	(D. Lee, 1990; Sriskandan, 1990)

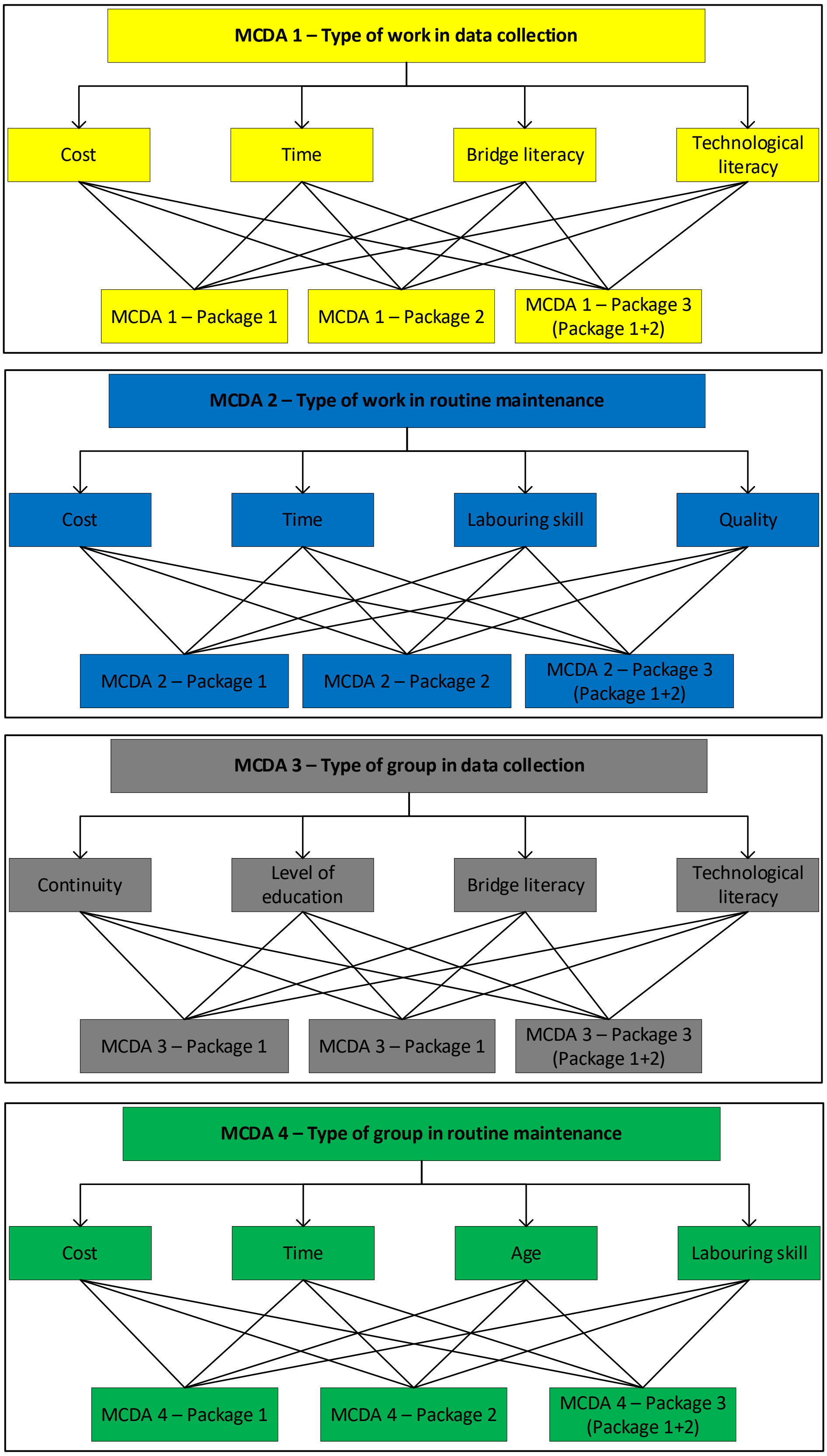
Appendix C.3 Alternative

Table 8.2 Specification and Identification of MCDA alternatives

Alternative	**MCDA 1**		**MCDA 2**		**MCDA 3**		**MCDA 4**	
	Description	**Number of quotations**	**Description**	**Number of quotations**	**Description**	**Number of quotations**	**Description**	**Number of quotations**
Package 1	Periodical public reporting Incidental public reporting	13	Cleaning of debris and garbage Cutting of grass Drainage cleaning	20	Locals in general non-governmental organization	16	Municipality's list	11
Package 2	Inventory and condition data	11	Non-structural patching Cosmetic painting Stonework	15	Local university students Local university lecturers Graduate locals who have no jobs	7	The specific group including farmers, fishermen, foremen, workers, and youth organization	10
Package 3	Package 1 and Package 2 combined	-	Package 1 and Package 2 combined	-	Combination of Package 1 and Package 2	-	Jobless people Semi-jobless people	6

Appendix C.4 BMS x Locals AHP Diagram

Table 8.3 BMS x Locals AHP diagram



Appendix C.5 Calculation

Appraisal of criteria:

1. 8 participants determine the relative importance value by using pairwise comparison, see Equation 8.1
2. The geometrical mean will be performed for the whole participants, complying with the aggregation of individual judgement (AIJ) so that the Pareto principle will not be violated (Forman & Peniwati, 1998)
3. The values generated from the geometrical mean act as the input for the MCDA table
4. The eigenvalue for each criterion is calculated. It is obtained by dividing the relative importance value of the criterion over the sum value of all criteria.
5. The sum of eigenvalue resulting criteria weight. The sum value of the criteria must be 1
6. Consistency ratio (CR) is calculated, where CR < 0.1 should be met:
    a. λmax is calculated by using Equation 8.2
    b. Consistency Index (CI) is calculated by using Equation 8.3
    c. Finally, CR is calculated by using Equation 8.4

Appraisal of alternative against each criterion:

1. Perform the step 1-6 explained above to obtain the score of alternatives against each criterion. From this step, a score of each package against each criterion in each MCDA can be obtained
2. Multiply criterion weight with the alternative score to obtain the weighted score of alternatives for each criterion.
3. The total weighted score represents which alternative (package) to choose. It is obtained by summing the weighted scores concerning the criteria.

Table 8.4 MCDA 1 – Type of work in data collection calculation

Criteria-work-DC	Cost	Time	Bridge literacy	Technological literacy	Eigen value				Mean/Criteria Weight (CW)
Cost	1	1.251033	1.0762	1.2574	0.284	0.338	0.276	0.2302	0.282
Time	0.7993	1	1.1624	1.6904	0.227	0.27	0.298	0.3094	0.2761
Bridge literacy	0.9292	0.860281	1	1.5152	0.264	0.232	0.256	0.2774	0.2575
Technological literacy	0.7953	0.591577	0.66	1	0.226	0.16	0.169	0.183	0.1844
sum	3.5238	3.702891	3.8986	5.463					1
λmax	4.0274								
CI	0.0091								
CR	0.0102								
CR <0.1 is OK	TRUE								

Cost	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	1.605295	1.2068	0.4079	0.493	0.323	0.408
Package 2	0.6229	1	1.5352	0.2541	0.307	0.41	0.324
Package 3	0.8286	0.651374	1	0.338	0.2	0.267	0.268
sum	2.4515	3.256669	3.7421				1
λmax	3.0586						
CI	0.0293						
CR	0.0506						
CR <0.1 is OK	TRUE						

Time	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	0.703508	1.7067	0.3325	0.329	0.342	0.334
Package 2	1.4214	1	2.2899	0.4727	0.467	0.458	0.466
Package 3	0.5859	0.436702	1	0.1948	0.204	0.2	0.2
sum	3.0074	2.140209	4.9966				1
λmax	3.0004						
CI	0.0002						
CR	0.0004						
CR <0.1 is OK	TRUE						

Bridge literacy	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	0.64842	0.7711	0.2605	0.268	0.252	0.26
Package 2	1.5422	1	1.2943	0.4017	0.413	0.422	0.412
Package 3	1.2968	0.772625	1	0.3378	0.319	0.326	0.328
sum	3.8391	2.421045	3.0654				1
λmax	3.0008						
CI	0.0004						
CR	0.0007						
CR <0.1 is OK	TRUE						

Technological literacy	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	0.964679	0.9647	0.3254	0.376	0.267	0.322
Package 2	1.0366	1	1.6549	0.3373	0.389	0.457	0.395
Package 3	1.0366	0.604275	1	0.3373	0.235	0.276	0.283
sum	3.0732	2.568954	3.6196				1
λmax	3.0288						
CI	0.0144						
CR	0.0248						
CR <0.1 is OK	TRUE						

Table 8.5 MCDA 2 – Type of work in routine maintenance calculation

Criteria-work-RM	Cost	Time	Labouring skill	Quality	Eigen value				Mean/Criteria Weight (CW)
Cost	1	2.903	1.706737	1.02305	0.344	0.532	0.3357	0.242	0.36337
Time	0.345	1	1.364262	1.21662	0.118	0.183	0.2683	0.288	0.21447
Labouring skill	0.586	0.733	1	0.98692	0.201	0.134	0.1967	0.234	0.1915
Quality	0.977	0.822	1.013257	1	0.336	0.151	0.1993	0.237	0.23066
sum	2.908	5.458	5.084256	4.22659					1
λmax	4.176								
CI	0.059								
CR	0.065								
CR <0.1 is OK	TRUE								

Cost	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	3.266	1.885884	0.54454	0.658	0.436	0.5464
Package 2	0.306	1	1.435189	0.16671	0.201	0.332	0.2334
Package 3	0.53	0.697	1	0.28875	0.14	0.231	0.2202
sum	1.836	4.963	4.321073				1
λmax	3.113						
CI	0.057						
CR	0.098						
CR <0.1 is OK	TRUE						

Time	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	2.903	1.913855	0.53562	0.638	0.43	0.5343
Package 2	0.345	1	1.539178	0.18452	0.22	0.346	0.2499
Package 3	0.523	0.65	1	0.27986	0.143	0.225	0.2157
sum	1.867	4.552	4.453033				1
λmax	3.096						
CI	0.048						
CR	0.083						
CR <0.1 is OK	TRUE						

Labouring skill	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	1.373	0.909636	0.35362	0.396	0.322	0.3573
Package 2	0.729	1	0.917004	0.25763	0.289	0.324	0.2903
Package 3	1.099	1.091	1	0.38875	0.315	0.354	0.3525
sum	2.828	3.463	2.82664				1
λmax	3.012						
CI	0.006						
CR	0.01						
CR <0.1 is OK	TRUE						

Quality	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	0.611	0.492692	0.21431	0.176	0.243	0.211
Package 2	1.636	1	0.53455	0.35071	0.287	0.264	0.3005
Package 3	2.03	1.871	1	0.43498	0.537	0.493	0.4885
sum	4.666	3.482	2.027243				1
λmax	3.021						
CI	0.011						
CR	0.018						
CR <0.1 is OK	TRUE						

Table 8.6 MCDA 3 – Type of group in data collection calculation

Criteria-group-DC	Continuity	Level of education	Bridge literacy	Technological literacy	Eigen value				Mean/Criteria Weight (CW)
Continuity	1	1.275373	0.98345	0.888644774	0.2547	0.336	0.2923	0.138	0.25534
Level of education	0.784084	1	0.99648	1.951090489	0.1997	0.264	0.2962	0.3029	0.26564
Bridge literacy	1.016832	1.003528	1	2.601820983	0.259	0.265	0.2972	0.4039	0.3062
Technological literacy	1.125309	0.512534	0.38435	1	0.2866	0.135	0.1142	0.1552	0.17282
sum	3.926225	3.791435	3.36428	6.441556246					1
λmax	4.153049								
CI	0.051016								
CR	0.056685								
CR <0.1 is OK	TRUE								

Continuity	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	0.94388	0.9036	0.316	0.396	0.216	0.3094
Package 2	1.0595	1	2.276	0.335	0.4196	0.545	0.4329
Package 3	1.1067	0.43937	1	0.35	0.1844	0.239	0.2577
sum	3.1661	2.38325	4.1796				1
λmax	3.0884						
CI	0.0442						
CR	0.0762						
CR <0.1 is OK	TRUE						

Level of education	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	0.58088	0.6647	0.237	0.2861	0.171	0.2312
Package 2	1.7215	1	2.2247	0.407	0.4925	0.572	0.4906
Package 3	1.5045	0.4495	1	0.356	0.2214	0.257	0.2782
sum	4.226	2.03038	3.8894				1
λmax	3.0551						
CI	0.0276						
CR	0.0475						
CR <0.1 is OK	TRUE						

Bridge literacy	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	0.54525	0.7128	0.236	0.2848	0.161	0.2274
Package 2	1.834	1	2.7066	0.433	0.5223	0.612	0.5225
Package 3	1.4029	0.36947	1	0.331	0.193	0.226	0.2501
sum	4.2369	1.91472	4.4194				1
λmax	3.0692						
CI	0.0346						
CR	0.0596						
CR <0.1 is OK	TRUE						

Technological literacy	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	0.67043	0.8995	0.278	0.3375	0.178	0.2642
Package 2	1.4916	1	3.1654	0.414	0.5034	0.625	0.5141
Package 3	1.1117	0.31591	1	0.309	0.159	0.197	0.2217
sum	3.6033	1.98634	5.0649				1
λmax	3.096						
CI	0.048						
CR	0.0828						
CR <0.1 is OK	TRUE						

Table 8.7 MCDA 4 – Type of group in routine maintenance calculation

Criteria-group-RM	Cost	Time	Age	Labouring skill	Eigen value				Mean/Criteria Weight (CW)
Cost	1	1.58	2.482	1.6094	0.376	0.382	0.3528	0.3851	0.3739
Time	0.634	1	1.8369	0.9869	0.238	0.242	0.2611	0.2361	0.2444
Age	0.403	0.54	1	0.5829	0.152	0.132	0.1422	0.1395	0.1412
Labouring skill	0.621	1.01	1.7155	1	0.234	0.245	0.2439	0.2393	0.2405
sum	2.658	4.14	7.0343	4.1792					1
λmax	4.003								
CI	1E-03								
CR	0.001								
CR <0.1 is OK	TRUE								

Cost	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	2.25	2.9848	0.5622	0.575	0.544	0.5604
Package 2	0.444	1	1.5045	0.2494	0.255	0.274	0.2596
Package 3	0.335	0.66	1	0.1884	0.17	0.182	0.18
sum	1.779	3.92	5.4893				1
λmax	3.002						
CI	0.001						
CR	0.002						
CR <0.1 is OK	TRUE						

Time	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	1.54	2.8373	0.4993	0.522	0.452	0.491
Package 2	0.65	1	2.4409	0.3247	0.339	0.389	0.3509
Package 3	0.352	0.41	1	0.176	0.139	0.159	0.1581
sum	2.003	2.95	6.2782				1
λmax	3.01						
CI	0.005						
CR	0.009						
CR <0.1 is OK	TRUE						

Age	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	2.72	2.7066	0.5757	0.637	0.49	0.5675
Package 2	0.368	1	1.8193	0.2116	0.234	0.329	0.2583
Package 3	0.369	0.55	1	0.2127	0.129	0.181	0.1741
sum	1.737	4.27	5.5259				1
λmax	3.051						
CI	0.026						
CR	0.044						
CR <0.1 is OK	TRUE						

Labouring skill	Package 1	Package 2	Package 3	Eigen value			Mean/Criteria Weight (CW)
Package 1	1	1.16	2.4884	0.4415	0.409	0.501	0.4503
Package 2	0.863	1	1.4833	0.3811	0.353	0.298	0.3442
Package 3	0.402	0.67	1	0.1774	0.238	0.201	0.2055
sum	2.265	2.83	4.9717				1
λmax	3.017						
CI	0.008						
CR	0.014						
CR <0.1 is OK	TRUE						