Proceeding

SCESCM 2016

Sustainable Civil Engineering Structures and Construction Materials

Special Topics in Public Works Research and Technology

Bali, September 5-6 , 2016

Editors :
Dadang Karmen, Fitri Riandini, Suharyanto

Guest Editors :
Suprapto, Henricus Priyosulistyo, Ali Awaludin, Han Ay Lie

Publisher :

Department of Civil and Environmental Engineering
Gadjah Mada University
Yogyakarta

Conference Editors

Published by:
Department of Civil and Environmental Engineering
Gadjah Mada University, Yogyakarta, INDONESIA
Website: http://tsipil.ugm.ac.id
Tel: +62-274-545675
Fax: +62-274-545676

ISBN 978-602-71762-3-2

Conference Organization

ORGANIZING INSTITUTIONS

Departement of Civil and Environmental Engineering
Faculty of Engineering
Gadjah Mada University, Indonesia

The Ministry of Public Works and Housing (PUPR)
Republic of Indonesia

Division of Engineering and Policy for Sustainable Environment
Faculty of Engineering
Hokkaido University, Japan

Institute of Concrete Structures and Building Materials (IMB) Faculty of Civil Engineering, Geo, and Environmental Sciences Karlsruhe Institute of Technology, Germany

SCIENTIFIC COMMITTEE

Han Ay Lie (Chair), Indonesia
Anita Firmanti, Indonesia
Suprapto, Indonesia
Andreas Triwiyono, Indonesia
Wawan Rusmana, Indonesia
Sugianto, Indonesia
Zaidir, Indonesia
Edy Anto Soentoro, Indonesia
Anton Soekiman, Indonesia
Syafi'I, Indonesia
Istiarto, Indonesia
Ery Suhartanto, Indonesia
Suharyanto, Indonesia
Barry Jones, United States
Masahiro Yoshimura, Japan
Salman Azhar, United States
Stephen Pessiki, United States
Benny Suryanto, United Kingdom
Adrian J. M. Leijten, The Netherlands
Anastasia Yunika, The Netherlands
K. van Breugel, The Netherlands
H. M. Jonkers, The Netherlands
B. H. W. Hadikusumo, Thailand
Djoen San Santoso, Thailand
Teerapong Senjuntichai, Thailand
Wen-Hsiang Hsieh, Taiwan
Abraham Christian, Singapore
Lado Riannevo Chandra, Singapore
Ong Khim Chye, Singapore
Tam Chat Tim. Singapore
Tor Arne Martius-Hammer, Norway
Buntara Sthenly Gan, Japan
Mitsuyasu Iwanami, Japan
Takashi Matsumoto, Japan
Tamon Ueda, Japan
Shunji Kanie, Japan
Ehsan Noroozinejad, Iran
Ade Lisantono, Indonesia
Agus Maryoto, Indonesia
Ali Awaludin, Indonesia
Aine Kusumawati, Indonesia
Aloysius Tjan, Indonesia
Djwantoro Hardjito, Indonesia
Ediansjah Zulkifli, Indonesia
Endah Wahyuni, Indonesia
Harijanto Setiawan, Indonesia
Henricus Priyosulistyo, Indonesia
Ilham Nurhuda, Indonesia
Ima Muljati, Indonesia
Iman Satyarno, Indonesia
Intan Supraba, Indonesia
Suripin, Indonesia
S. A. Kristiawan, Indonesia
Wong Foek Tjong, Indonesia
Senot Sangadji, Indonesia
Sholihin As'ad, Indonesia
Januarti Jaya Ekaputri, Indonesia
Jati Utomo Dwi Hatmoko, Indonesia
Jimmy Chandra, Indonesia
Johannes Adhijoso Tjondro, Indonesia
Made Sukrawa, Indonesia
Mochamad Teguh, Indonesia
M. Agung Wibowo, Indonesia
Patria Kusumaningrum, Indonesia
Prabowo Setiyawan, Indonesia
Pungky Pramesti, Indonesia
Purwanto Bekti Santoso, Indonesia
Sofia Mavridou, Greece
Frank Dehn, Germany
Franz-Hermann Schlueter, Germany
Harald S. Mueller, Germany
Petr Hájek, Czech Republic
Bagus Haryo Setiadji, Indonesia
Bambang Suhendro, Indonesia
Bambang Suryoatmono, Indonesia
Benjamin Lumantarna, Indonesia
Buan Anshari, Indonesia
Dina Rubiana Widarda, Indonesia
Robby Permata, Indonesia
Kefei Li, China
R. Sony Sulaksono W, Indonesia
Andi Arham Adam, Indonesia
Antoni, Indonesia
Antonius, Indonesia
Arya Thanaya, Indonesia
Anastasia Caroline Sutandi, Indonesia
Ary Setyawan, Indonesia

ORGANIZING COMMITTEE

Henricus Priyosulistyo, Indonesia (Chair)
Ali Awaludin, Indonesia (Vice)
Dadang Karmen, Indonesia
Wawan Rusmana, Indonesia
Hasan Basri, Indonesia
Arif Hidayat, Indonesia
Nynke Verhulst, The Netherlands
Arief Setiawan Budi Nugroho, Indonesia
Akhmad Aminullah, Indonesia
Inggar Septhia Irawati, Indonesia
Arya Thanaya, Indonesia
Suharyanto, Indonesia
Tatang Listyawan, Indonesia
Ade Lisantono, Indonesia
Luky Handoko, Indonesia
Eko Siswoyo, Indonesia
Prima J. Romadhona, Indonesia
Hariadi Yulianto, Indonesia
IGL Bagus Eratodi, Indonesia
S.A. Kristiawan, Indonesia
Antonius, Indonesia
Ima Muljati, Indonesia
Antoni, Indonesia
Harijanto Setiawan, Indonesia
Dina Rubiana Widarda, Indonesia
Paulus Kartawijaya, Indonesia

SUPPORTING INSTITUTIONS

UNDIP, Diponegoro University, Semarang
UNPAR, Parahyangan Catholic University, Bandung
UNS, Sebelas Maret University, Surakarta
UGM, Gadjah Mada University, Yogyakarta
UNSYIAH, Syiah Kuala University, Banda Aceh
UNAND, Andalas University, Padang
ITB, Institute Technology of Bandung, Bandung
UNIBRAW, Brawijaya University, Malang
UAJY, Atma Jaya University of Yogyakarta
UII, Islamic University of Indonesia, Yogyakarta
TU DELFT, Delft University of Technology, The Netherland
Lehigh University, United States
UNISSULA, Sultan Agung Islamic University, Semarang
Petra Christian University, Surabaya
Nihon University, Japan
TU/e , Eindhoven University of Technology, The Netherland

SUPPORTING ORGANIZATION

HAKI, Indonesian Society of Civil and Structural Engineering
ACF, Asian Concrete Federation
JSCE, Japan Society of Civil Engineers
FIB, International Federation for Structural Concrete
IABSE, International Association for Bridge and Structural Engineering

Preface

Dear participants and distinguished readers,

This International Conference on Sustainable Civil Engineering Structures and Construction Materials (SCESCM) is the 3rd in the series of a two-yearly event. The first and second conferences were conducted in Yogyakarta-Indonesia, and ever since this organization has grown, both in size, quality and performance. Initiated in 2012 by the Gadjah Mada University, the Karlsruhe Institute of Technology in Germany, and Hokkaido University in Japan, this organization is now supported by eleven major universities from Indonesia, The Netherlands and the United States. This 2016 conference has received over 400 papers originating from 27 countries. Professional organizations supporting the 3rd SCESCM are the Indonesian Society of Civil and Structural Engineers (HAKI), the Asian Concrete Federation (ACF), the Japan Society of Civil Engineers (JSCE), the International Federation for Structural Concrete (*fib*-CEB), and the International Association for Bridge and Structural Engineering (IABSE).

This 3rd SCESCM conference is also distinguished by the existence of a special session conducted in cooperation with the *Ministry of Public Works and Housing*, Indonesia. This special session is designated as *Special Topics in Public Works Research and Technology*. The Sustainability issue has been of major concern for the past decades, and its awareness became a primary subject and source for conservation and preservation of natural earth resources. The Ministry of Public Works and Housing is one of the largest ministrials in Indonesia, and it fulfills a foremost role in the physical and intellectual development of the country. All key-constructions and infrastructures in Indonesia are accommodated, and fall under the responsibility of this ministry. A constant improvement in human resource quality by means of research and continuing education stands frontline for this ministry, enabling to keep up with the ever emerging fast global progress in technology.

Main concentrations for creating sustainable structures and systems are contemplated on the use of non – regeneration - able materials, while further attention has to be paid on material production and structural systems that generate hazardous waste, both directly or indirectly. The methodology behind the solution to these issues is a complex and ever emerging combination of variables, where research and technology stand central. This special session will host the research publications and research products of researchers, policy makers, educators and Department of Public Work and Housing Officials that were conducted over a period of two years. The majority of the publications are based on state-of-the-art development of structural systems and constructions of existing projects.

This event was made possible by the contributions and hard work of all supporting institutions and is hoped to that its outcome serves as a contribution to the future development in sustainable technology for constructions and structures.

Conference Chairman,

Prof. Ir. Henricus Priyosulistyo M.Sc, Ph.D.

Welcoming Speech

Dear Distinguish Guests, Guest Speakers, Ministry of Public Work and Housing Officials, Colleagues, Participants, Members of the supporting Universities, Committee Members, Ladies and Gentlemen,

Welcome to Bali, and welcome to this Special Topics in Public Works Research and Technology session that is conducted in cooperation with the 3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials (SCESCM). This event will be held from today till the 6th of September 2016 at the Sanur Paradise Hotel in Bali, Indonesia.

This event marks a big milestone in the field of collaboration between the scientific community represented by the academic institutions, and the professional sector represented by among others the Indonesian Society of Civil and Structural Engineers (HAKI), the Asian Concrete Federation (ACF), the Japan Society of Civil Engineers (JSCE), the International Federation for Structural Concrete (*fib*-CEB), and the International Association for Bridge and Structural Engineering (IABSE), and foremost the government institutions hereby represented by the Department of Public Work and Housing Officials.

The participation of the Ministry of Public Works and Housing is of great importance, since this cooperation has major benefits for both parties. It is hoped that this conference will lead to a continuing long-time collaboration between the SCESCM and the Ministry of Public Works and Housing. The SCESCM has marked itself as one of the leading conferences in Indonesia, and the papers resulted from the past conferences were internationally recognized. The Ministry of Public Works and Housing on the other hand, has long been working together with academic institutions all over the country in improving the scientific quality and knowledge of its official through training and education. This merging through the conference resulted in a special session as part of the SCESCM 2016 conference.

It is hoped that the work, discussions, research disseminations and conclusions will be a valuable contribution to the civil engineering community generally, and the academic institutions and the Department of Public Works and Housing in particular.

I wish you a very pleasant stay in Bali while at the same time enjoying the conference and I thank to all supporting organizations and persons for their hard work to make this event a success and beneficial.
Thanks you very much.

Head of Education and Training Center
For Water Resources and Construction
The Ministry of Public Works and Housing

Dr. Ir. Suprapto, M.Eng

Table of Content

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

Special Topics in Public Works Research and Technology

Public Private Initiatives (PPI) facilitated through Integrated Project Delivery (IPD) for Maximizing Design and Construction Value.

Barry Jones *

College of Architecture & Environmental Design, Cal Poly, San Luis Obispo, California

Abstract

The paper and presentation will discuss PFIs (Public Private Initiatives) also called public-private partnerships (PPP's or P3) delivered through Integrated Project Delivery (IPD).

Keywords: PPI; PPP; BIM; IPD; Computer Agents; Infrastructure Projects

1. Objectives

The research objective was to find ways to better deliver Public Finance Initiatives (PFIs) and Public Private Partnerships (PPPs) by exploring Integrated Project Delivery and applying this delivery method to PPP Infrastructure Projects. A secondary objective was to build on the author's research in Intelligent Computer Agent and find how this technology could be used to assist the IPD process in identifying and analyzing alternative solutions to issues such as sustainable construction and the environmental impact of infrastructure projects.

2. Research Method

Conducted through interviews, and monitoring IPD projects in California and determining how this delivery process could be applied to PPP's then reviewing reports on the success or failure of past PPP strategies.

The research (first phase) built on earlier work that measured the processes and interactions that Architects, Engineers and Construction Managers (AEC) use when making key project decisions (Jones 1998). In that study research data was collected from 54 companies in the USA and 39 in the United Kingdom. Scenarios of typical design and production problems were used to measure the differences in making key decisions in the traditional method of project delivery (design-bid-build) compared to a system where there was a high incidence of collaborative decision making; such as Design-Build. Results were compared between the three participating groups (AEC) so that the consensus view could be obtained.

The second phase of this investigation measures the current state of AEC collaboration that is in progress on various projects in California through IPD strategies.

The third ongoing stage is to determine whether large infrastructure projects using PPP or PFI strategies might benefit from using IPD.

* Tel.: +1 805 756 6265;
E-mail address: bkjones@calpoly.edu

3. Integrated Project Delivery (IPD)

IPD is a contract delivery system that helps create an integrating partnership for decision making at design and pre-construction stages through to the final project handover to the facility management team. (Ashcraft 2011) defines IPD as the framework that defines the relationships among the project participants and the processes that guide their actions. It embodies the project goals and creates consequences for success or failure tied to their achievement. It puts control in the hands of the project participants and makes them responsible for total project outcome, not just their individual performance. Correctly designed, it stimulates behaviors that increase creativity, improve productivity, and reduce waste. A strong IPD Framework leads to better outcomes, whether measured in value, aesthetics, and sustainability or other project criteria.

4. Virtual Design and Construction (VDC) and Building Information Modelling (BIM)

VDC is a process that integrates the design and construction professionals into a collaborating team that build a BIM model of the project using 3D, 4D(cost), 5D(time), 6D (carbon footprint) CAD visualization. A virtual object is created before construction starts so that much of the criteria and constraints associated with the project under design are analyzed at an early stages of project development. As such, it serves as a shared knowledge resource for information about a facility thereby forming a reliable basis for decisions during its lifecycle from project inception onwards. For best results it is essential that VDC are implemented from the beginning of a construction project in order to increase the quality of the object, the organization, and the process, during the building life cycle (GSA.2011). In particular, the criteria and constraints of the various contributors need to be articulated and discussed as the model builds. For the approach to work effectively it is essential to include the experience of construction managers and specialist sub-contractors to maximize project benefits from the execution experience.

5. VDC used in the IPD environment

It was found that using VDC in an Integrated Project Delivery (IPD) environment becomes the key to effective project delivery with the IPD team offering a solution-oriented approach. At a very early stage (project development, pre-draft phase) the entire planning (design) is carried out by a team that involves not only an architect and a structural engineer, but also specialists in the areas of construction management, MEP engineering, energy technology, environmental engineers, building physics, acoustics, façade construction and depending on the type of project further specialists. This work method leads to a collaborative, integrated and transparent construction process. All communication goes back to the central model. The model is shared among all project team members and it serves as a common, rich database where all information is structured managed and maintained. Therefore, the amount of redundant data is reduced and repetitive data that already resides in the model can be used by all participants. It also acts as an excellent team building tool. A shared, visual model to externalize and share project issues is a valuable team-building tool. This rich data model on the completion of the project can be handed over to the Facilities Management team who provides the experience for operating and ensuring economic building performance.

Research indicated that the “Big Room” concept can be used to facilitate the process, where all the key project participants, including the client, collaboratively work in the same room to define the methods, schedule, quality, performance and cost goals for the project. They then evaluate how to satisfy these goals often using ‘lean’ construction techniques. Multi-domain intelligent computer agents could be used here to search for alternative solutions (Jones, 2003). For instance a goal might be use of local material resources by assessing the opportunities presented by the site itself, and selecting materials that are minimal polluters, sustainable and recyclable, etc. or the sustainability aspects can be analyzed with the goal to eliminate, reduce and change the use of materials and components that increase environmental inefficiencies. Similarly, the cost and time to build aspects are driven down by the collaborative team through many iterations of considering alternative materials, methods, layouts, component analysis, etc. Next, the functional requirements of the structure are reviewed to see if it is possible to reduce the demand from that standpoint, i.e. efficient envelope design, solar and efficient lighting, construction systems required to build, energy requirements, life-cycle maintenance costs, air quality health impact, design for safety, etc.

Within the “Big Room” collaborative design environment it can be supported by responsive decision analysis support tools such as intelligent search computer agents as discussed next that are used to refine the design by searching out suitable alternatives that add value to the project while satisfying the many criteria and constraints. The resulting design will bear a high degree of confidence that in regard to material and component efficiencies, sustainability, cost and time to build, it will achieve its objectives. Throughout the process, and during future use of the structure, continuous efforts will be made to reduce waste, improve health, use economical recycled and environmentally benign materials, and reduce the generation of pollutants.

6. Intelligent Computer Search Agents

Earlier research (Pohl, 2000) found that the advances in the concept of an object as a high-level information source led to the paradigm of object-oriented modeling and the development of object-oriented computer languages. The premise is that a crucial element in the decision making process that human designers utilize to solve problems is the reliance they place on their ability

to identify, understand and manipulate objects, e.g. architects develop solutions by reasoning about location, sites, buildings, floors, spaces, walls, windows, doors, and so on; the contractor does likewise. Each of these objects encapsulate knowledge about its own nature, its relationships with other objects, its behavior within a given environment, what it requires to meet its own performance objectives and how it might be manipulated by the designer within a given design problem scenario.

Within the computer agent environment proposed, problem solving is seen as a co-operative process with mutual sharing of information to produce a solution. Objects are information entities only whereas computer agents are active and have knowledge of their own nature, needs and global goals. Objects are accessible by agents but cannot take action. Within the computer environment agents also have the ability to communicate and take action. Typically, each agent is represented at the level of detail to which the collaborative team wishes to reason about the designed system in the building project. A coordinator should be capable of invoking a procedure for resolving conflict conditions based on consultation. The agents use their specialized expertise and available resources to work in parallel on different or coordinating tasks to arrive at a solution concurrently. They assist in searching out alternative solutions.

Complete families of computer-agents that represent a particular domain can be built e.g. architect, interior designer, civil engineer, landscape architect, safety manager, quality manager, environmental manager, mechanical and electrical engineer, construction manager, project manager, etc. and within each family specific agents would monitor and offer assistance regarding criteria and constraints imposed in the areas of environmental, quality, safety, cost, production time, etc. For instance there could be a 'Sustainability' agent residing in a number of domains i.e. Architect, Construction manager, Project Manager, Quality manager, each would be representing the criteria and constraints of that domain. It must be stressed that this design assistance using computer agent is not intended to automate the design process. Agents would assist the designer or collaborative partnership by acting as co-operative search agents having the ability to liaise with knowledge bases in the search for alternative solutions. They exist to express opinions about the current state of the construction solution. The intention is to change incrementally the current state of the design through the interaction among the various agents within the environment. This interaction enriches the environment with information about the current design state and how it relates to the design requirements. Each agent would provide two kinds of support; intermittent foreground responsiveness to requests for information initiated directly by the designer, and continuous background monitoring and evaluation of the evolving design solution.

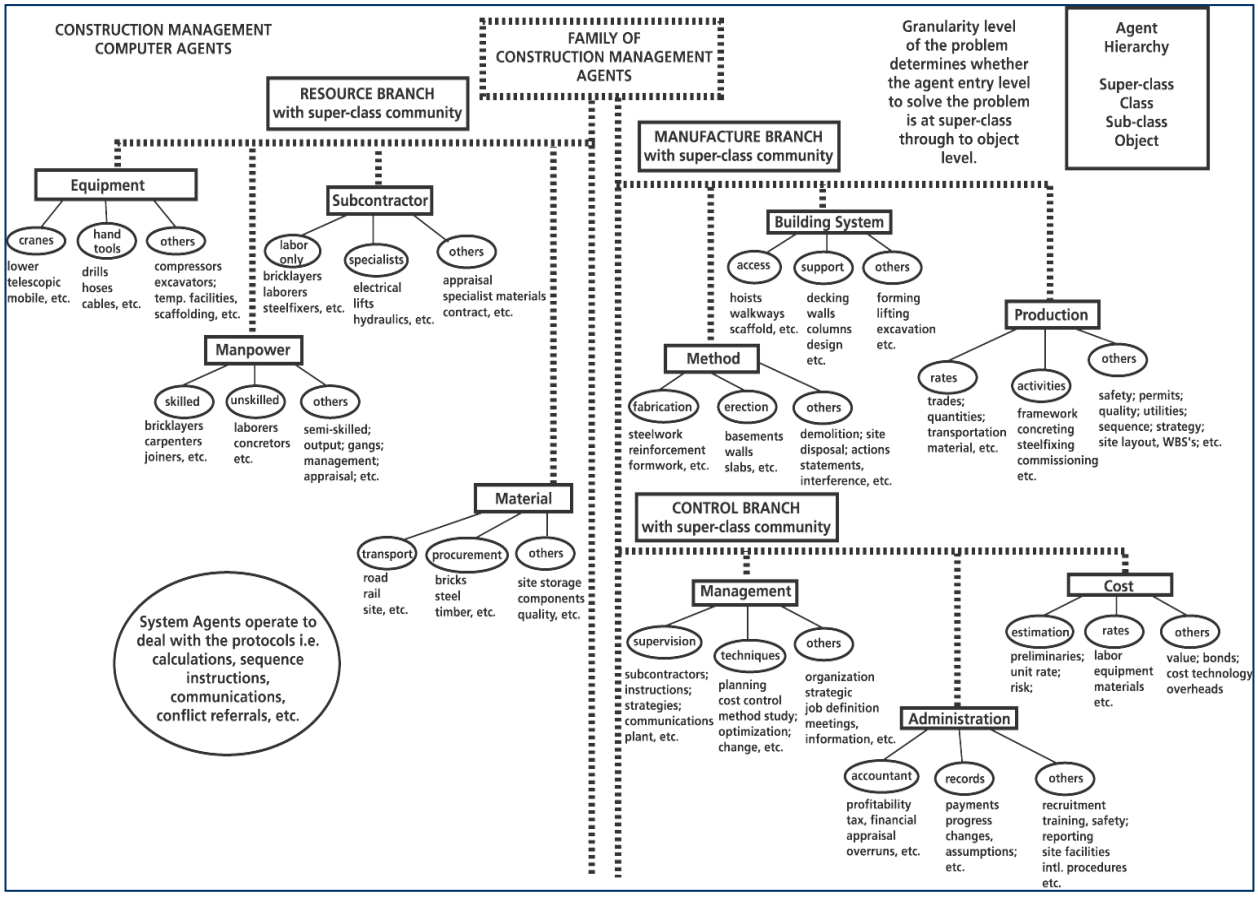

Fig 1. Family of Construction Management Search Computer Agents

7. PFIs and PPPs

PFI's are a method of providing funds for major capital investments where private firms are contracted to complete and manage public projects. It is as a legally binding contract between a public sector entity and a private company where the partners agree to share some portion of the risks and rewards inherent in an infrastructure project. It is a long term contract between government entities, private investors, construction firms, and asset and operations managers. The project is delivered by a consortium and the risks involved are transferred to the party most qualified to manage it. Thoughtful allocation of project rewards and risks are the basis of a successful PPP. (Brooking 2014) states that political dysfunction, a challenging fiscal environment, greater project complexity, and the sheer size of the need across different sectors are forcing leaders to explore new ways to finance the investments and operations that will grow their economies over the next decade. Part of this exploration means new kinds of agreements between governments at all levels and the private sector to deliver, finance, and maintain a range of projects. In particular, PPPs for infrastructure are complicated; they require robust economic analysis, complex negotiations, intense public scrutiny, long-term commitments, political leadership, and force public sector employees and policymakers to hone a relatively new skill set.

In the most advanced PPP markets, such as the United Kingdom, this risk and reward sharing structure more narrowly refers to agreements where the private sector designs, builds, finances, operates, and maintains (also known as DBFOM) an infrastructure asset for a pre-determined period of time. In exchange, the public sector provides a recurring payment based on the condition of the asset (known as an availability payment) or allows the private sector to collect tolls or fees generated from the project.

Four arrangements are recognized (i) Bid/Build; (ii) Design/Build; (iii) Design/Build/Finance; (iv) Design/Build/Finance/Operate/Maintain. Public and private sector collaboration from the outset of an infrastructure project, whether green-field or brown-field, can lead to a number of innovations. These may come in the form of new materials, faster project delivery, increased use of technology, operational efficiencies, or enhanced building techniques. One major advantage of the private sector is that it is often less tolerant of cost overruns and project delays than the public sector. Therefore, transferring construction, operational, and/or demand risk to the private sector can result in quantifiable savings for the public sector. These might not be the cheapest options in the short term, but have the potential to drive savings over the long term through decreased energy usage, lower maintenance costs, or enhanced resiliency

The U.S. Department of Transportation, as well as international leaders like Her Majesty's Treasury in the United Kingdom, recommends using a VFM (also referred to as a public sector comparator) analysis to econometrically evaluate the true costs and benefits of a PPP project. Private consultants or financially savvy internal review teams are capable of running these types of models, which can incorporate a number of different scenarios. Importantly, VFM analysis is predicated on quantifiable inputs and outputs in the project. These considerations often look at the cost of capital, demand projections, tax implications, social gains, risk transfer pricing, environmental externalities, and a range of other factors. Using a VFM, policymakers can start making informed decisions about entering into a PPP by comparing the costs and risks associated with different proposals and procurement models. It is so important to map out the full process before moving a project forward.

In the United Nations report ESCAP "A New Vision of PPPs in Asia Pacific" it stated that above all, infrastructure bottlenecks have still prevented many countries from realizing their full potential, and are major obstacles to development and achieving real social equity. But for more than three decades, PPP's have mostly proven, that they can be effective tools to complement the efforts of Asia-Pacific governments in developing infrastructure and providing related services.

8. PPP's linked to IPD

Assembling a group with the right mix of finance, technical, managerial, legal, policy, and communications knowledge and experience is critical to the success of any PPP project. In the research this was found to be similar to the requirement of a successful IPD projects. In both cases creating this environment requires transparency, collaborative engagement strategies, and some form of profit and risk sharing linked to project success. Therefore PPPs and IPD share many of the benefits and are complementary to each other. Collaboration, teamwork, focus on delivering to time and budget, overall quality and performance, risk sharing built to profit all operating in a transparent system are the requirements of both.

9. Results and Conclusion

The environment proposed from the first phase of research (Jones 1998) is one that fully utilizes the strengths of intelligent collaborative computer agents that interact with the multi-discipline pre-construction team to interrogate and refine the design solution before construction commences. In the second phase of this research using families of domain specific intelligent agents linked to Virtual Design and Construction tools allows alternative design and construction solutions to be rapidly generated. Linking this model to IPD operating in the "Big Room" opens up new ways of exploring client solutions that satisfy the many criteria and constraints that are sought by the key stakeholders of the project. Further, the integrated model based approach will positively impact construction in the 21st century. Many positive experiences and case studies are beginning to exist and many of

these new collaborative practices are becoming standard for some clients. . In this way a collaborative team has the tools and information to interrogate and solve many of the cost, constructability, time, quality, sustainability, environmental, safety, etc. issues before construction commences, and continue that monitoring throughout the construction process. Also, at the end of the project all captured information can be organized and passed to the facility operations team.

In the third ongoing phase of this research linking IPD to deliver PPP projects was found to be a two-way complementary model that benefit each other; similar issues exist to be resolved in both systems. Faster delivery times, increased certainty and accountability for the operational condition of the asset, process transparency, increased value, engagement of key stakeholders, diminished downside financial risk, budgetary certainty over a long period of time, lower lifecycle costs, and the use of innovative materials or technologies are all achievable through a well-structured PPP linked to IPD.

References

AIA C191 3 Party Integrated Project Delivery Contract and AIA C195

American Bar Association (2012) Integrated Project Delivery: The Game Changer, Joseph Cleves and Lisa Dal Gallo, 2012 annual meeting, April 26-28, Bellagio Hotel, Las Vegas.

Ashcraft, H.W. "The IPD Framework 2011" report H.W. Ashcraft is a partner in the San Francisco office of Hanson Bridgett LLP where he leads the Construction Group and its collaborative project delivery practice.

Brooking Institute; Sabol, P and Puentes, R. Report, "Private Capital, Public Good: Drivers of Successful Infrastructure Public Private Partnerships", The Brookings Institute, 2014.

Damon Socha; Virtual Building Systems Coordination – using Navisworks Manager; 2014

Digital Built Britain; Level 3 Building Information Modelling - Strategic Plan; HM Government (UK) Feb 2015

Egan, Sir John, (1998). Rethinking Construction, Report of the Construction Task Force, DOE, UK.

GSA National 3D-4D BIM Program (2011) BIM Guide for 4D Phasing. Office of Design and Construction Public Building Service U.S. General Service Administration, Washington DC.

Hanson Bridgett (2012) Comparison of Integrated Project Delivery Agreements, Lisa Dal Gallo et al, San Francisco, California Jones, Barry K (1998). A Model for Collaborative Engineering in the Construction Industry, PhD Thesis, University of Southampton, UK

Heyzer, Noeleen. Ministerial Conference on Public Private Partnerships for Infrastructure Development, Third Session Iran, 14 Nov 2012

Jones, B.K (2003). "Human-Machine Collaboration to bring essential Knowledge to the Inter-disciplinary construction team", International Conference– Construction Project Management Systems: The Challenge of Integration (CIB W99), San Paulo, Brazil 25-28 March 2003.

Latham, Sir M (1994). Construction the Team, Final report of the government/industry reviews of procurement and contractual arrangements in the UK construction industry, HMSO

Martin, Joe, UK Government Building Information Modelling (BIM) Strategy, BCIS Executive Director, Paper for CEEC meeting Oct 2011

Martin, Joe, UK Government Building Information Modelling (BIM) Strategy, BCIS Executive Director, Paper for CEEC meeting Oct 2011

National BIM Standard - United States™ Version 2- A Strategy for Classifying the Built Environment – OmniClass and Building SMART alliance – National Institute of Building Sciences 2014.

Pohl,J., A Chapman,. K Pohl (2000) Computer-Aided Design Systems for the 21st Century: Some Design Guidelines, Collaborative Agent Design (CAD) Research Center, San Luis Obispo, CA.

United Nations ESCAP "A New Vision of PPPs in Asia Pacific". Nov 2012

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

The 3rd SCESCM

Special Topics in Public Works Research and Technology

Post-tsunami coastal structures performances around Meulaboh City, Indonesia

Aminullah Hidayat[a], Syamsidik[b], Masimin[b]

[a]*Master of Civil Engineering Graduate Program of Syiah Kuala University Banda Aceh, Indonesia*
[b]*Faculty of Engineering, Syiah Kuala University Banda Aceh, Indonesia*

Abstract

The great Indian Ocean Tsunami in 2004 hit several Asian countries including Indonesia. The tsunami severely affected the morphological and induced changed around the west coast of Aceh province, Indonesia, especially Meulaboh city. Post tsunami, the shoreline around Meulaboh City had shifted 20-60 m ashore. For the last ten years several observations and mitigation plannings has been conducted to protect and preserve the shoreline, among these are the construction of protection structures. This paper presents the stages of tsunami-caused morphology changes on coastal lines and evaluates the performance of coastal structures around Meulaboh city, West Aceh district. In this study, the shoreline position is obtained from the aerial photographs provided by Google Earth time series for four years include 2004, 2008, 2011, and 2014. One decade of shoreline position changing stage is digitized to determine which location was severely affected by the coastal process. In this period the coastal structures performance based on closing inventory in the studied area, is also observed. Most structures along the coast were constructed after the 2004 tsunami. Some of these exhibited severe damaged originated from the coastal process, such as longshore sediment transport rates and wave impact. This study showed that the coastal structure which were constructed during this period have significant influence to the coastal morphological change.

Keywords: tsunami; coastal recovery; coastal structures performance; longshore sediment transport

1. Introduction

One of the areas in Aceh province most severely hit was the coastal around Meulaboh, West Aceh district. The coastline around Meulaboh city occupies around ± 10 km of the total length of West Aceh's shoreline that measures ± 55 km totally. The coastal area facing the Indian Ocean is the most vulnerable to wave impact during the monsoon period, which potentially eroding shoreline.

The tsunami waves that reached heights up to 5 m affected geographical coastline changes. Hydrodynamic factor causing erosion and accretion processes that are influenced by the process of longshore sediment transport (LST) on the coastal area have continued since the tsunami until now. One of the objects of this study is protective coastal structures built after the Tsunami of 2004. The structure of the structure includes the hexapod, sand container, seawall that undergoes structural changes due to scouring by waves. Coastal structures that placed on shoreline has obstructed distribution of sediments from littoral drift activities, the consequences of structure of coastal protection is causing diminished its aesthetic value of the coastal because of the construction built would be difficult to be dismantled or relocated.

1.1 Study issues

This study prepared on some major issues based on field inspection, so that there are some questions: how far morphological changes in the coastline that has occurred and the return phase of the coastline around Meulaboh city, where the direction and how much amount of sediment budget and how well coastal structures work on the location where they were constructed.

1.2 Research purpose

The purpose and objectives of this study are as follows:

- Review morphoplogy of shoreline around Meulaboh city caused by tsunami waves from 2004 to 2014;
- Review the process of longshore sediment transport;
- Review the changes and coastal protection performance of structures built after the tsunami of 2004 and compared with the last condition of the structure structure.

The benefits of this research are the availability of information on stages of shoreline change for reference in spatial planning, especially in the coastal areas of Meulaboh city. The research may be useful in the process of construction planning includes coastal protection such as revetment, breakwater, seawall and jetty, furthermore it can also help in determining the type of construction that is suitable to be built in the location.

1.3 The Scope of Research

The boundaries of research as below:

- Coastline morphological changes around the Meulaboh city from 2004 to 2014;
- The direction and average annual sediment budget rate;
- Coastal structures performance which built between 2004 and 2014.

2. Literature Review

2.1 Coastal Morphology

Sutikno (1993) explains that the coastal is an area that extends from the lowest point of sea water at low tide to inland until it reaches the effective boundary of the wave. While the coastline is the line where the sea to the mainland whose position varies according to the position at the time of the tides, waves and ocean currents influence. Some of factor are: hydro-oceanographic, factors referred to include the wave, fetch, currents, and tides and anthropogenic, factor is a process that is caused by human activity. Human activity on the coastal can destabilize coastal environments.

2.2 Shape Coastal, Littoral process, Abrasion, and Sedimentation

Coastal profile shape is strongly influenced by the wave of attacks, the properties of sediments such as density and resistance to erosion, the size and shape of the particles, wave and current conditions, as well as shore bathymetry by Triatmodjo (2002). Sorensen (2006) explains that the littoral process is a process that occurs in coastal areas due to the interaction of wind, waves, currents, tides, sediment, and other such human activity.

2.3 Longshore Sediment Transport (LST) and Actual Alongshore Sediment Transport Rate

Shore sediment transport is the movement of sediment in coastal areas caused by waves and currents raised. Sediment transport along the coast consists of two main components, namely the transport of sediment in the form of a saw blade on the shoreline and transport along the coastal in the surf zone. The actual number of sediment transport calculated by testing various inflows (inflows) outflows (outflows) surplus region, and the region eroded sand. This calculation is also known as the sediment budget.

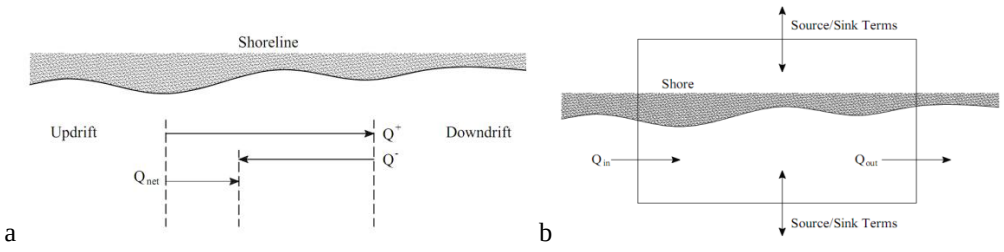

Fig. 1. (a) Sediment Transport Rate; (b) Sediment Transport Control Volume at Littoral Cell. (Source: Kamphuis, 2002)

2.4 Formula CERC

CERC (1984) publish an equation that is most commonly used in the calculation of sediment transport. The amount of sediment transport calculated with regard to the amount of energy flux or force of the waves in every reach perpendicular coastal (wave rays) are described as follows:

$$Is = 0.39\, Pab \quad (1)$$

Where I_s is coastal sediment rate.

$$P_{ab} = \frac{1}{16}\frac{\rho g^{\frac{3}{2}}}{\gamma_b^{\frac{1}{2}}} H_b^{\frac{5}{2}} \sin 2\alpha_b \quad (2)$$

By assuming the density of sand, ρs = 1.800kg /m^3 and the porosity, n = 0:32, then the formula (2.4) can be converted into:

$$Q_c = 2.2.10^6 . \frac{H_b^{5/2}}{\gamma_b^{1/2}} sin2\alpha_b \ (m^3/year) \quad (3)$$

$$Q_c = 250 . \frac{H_b^{5/2}}{\gamma_b^{1/2}} sin2\alpha_b \ (m^3/day) \quad (4)$$

Where H_b is a function of breaking wave and Q_c are only influenced by the wave height (H) and the angle of incidence wave (α).

2.5 Littoral Cell

Littoral cell is defined as a margin of an area of coastline that has been linked pattern of sediment movement in it. In theory, this region has a zero sediment inflow from the total process up drift and down drift. The district includes a forward area (surplus sediment) and there is a retreat due to scour by Kamphuis (2002) as shown in Fig. 2.

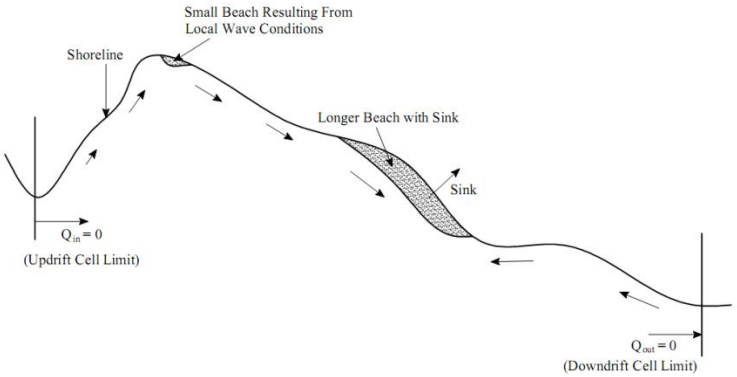

Fig. 2. Littoral Cell in a coastal area. (Source: Kamphuis, 2002)

2.6 Coastal Structures Performance

Each coastal structure is planned has several requirements that deserves to be built. Some of these requirements are loaded with conditions where the planned structure could withstand the load even in the most extreme conditions so that they function properly. Some of the variables that should be considered include the sea water level, wave height, wave period, wave direction, height and slope of the coastal surface by Kamphuis (2002).

2.7 The parameters of Coastal Damage Assessment

Structure damage parameter assessment as outlined in the Minister of Public Works and of Republic of Indonesia No. 07/PRT/M/2015 about Coastal Protection Structure.

3. Methodology

The stage of this research will be described in sub-chapter on research methods below.

3.1 Orientation Location Overview

According to coastal cell the area is divided into 4 (four) parts, namely: Zone I in western part (Gampong Pasir and Suak Ribee), Zone II and III in the middle (Gampong Ujung Kareung), and Zone IV in eastern part (Gampong Padang Seurahet) as shown in Fig. 3.

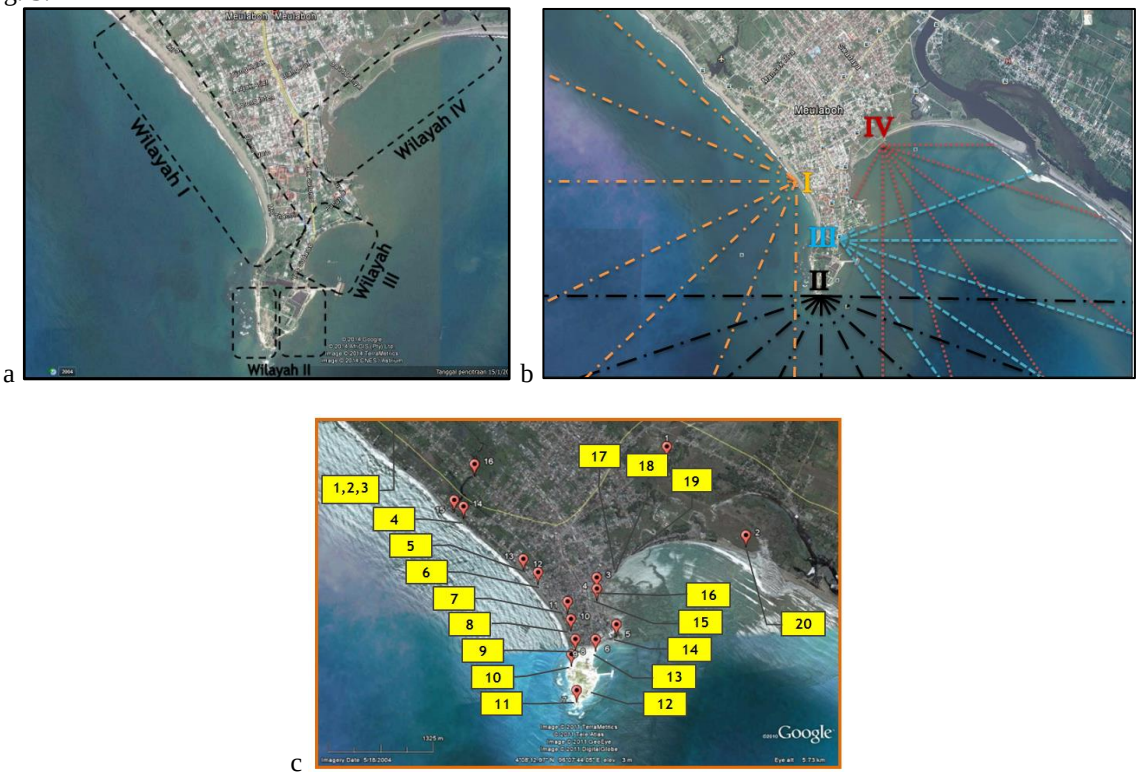

Fig. 3. (a) Zoning of the study area; (b) Fetch in each study area; (c) Coastal structure index along the coast around Meulaboh city.

3.2 List of data

Table 1. The data related to the study.

No	Data Item	Use of Data	Source	Year	Data Specifications
1.	Map of Topography and Bathymetry	Views contours of the land and sea, and structure layout	BWSS-I Aceh Bakosurtanal	2011	Elevation contours per 2 m and the structures coordinates
2.	Map of Google Earth Time Series	Determination of shoreline change every year	BWSS-I Aceh	2011	Google Earth Time Series.
3.	Wave Data	Forecasting waves and wind direction	Google Earth	2004-2014	Maximum Monthly Data.
4.	Tidal Data	Water surface elevation	BWSS-I Aceh	2011	Main Component of Tidal.
5.	Current Data	Forecasting LST	BWSS-I Aceh	2011	Velocity and Direction data
6.	Sediment Data	Estimation LST	BWSS-I Aceh	2011	Grain size D50
7.	Coastal Protection Structures	Structure performance analysis and inventory of type of structure ever built	BWSS-I Aceh Contractor	2005- 2014	Project documentation

3.3 Stage of research

The research phase is done by dividing the study area into four (4) sections, perform digitization on a Google Earth time series map, perform calculations waves and sediment transport, and conduct an inventory and analysis of coastal structure's performance, and hold meetings and interview.

3.4 In-depth interview

Interviews were conducted to obtain detailed information about the condition of the coastal around Meulaboh city covering the scope and area studies. Some questions prepared by following some basic problems, are: process of shoreline change in the location of reviews, planning and structure of coastal protection, construction, benefits and effects of coastal structures.

4. Results and Discussion

4.1 Coastline morphology

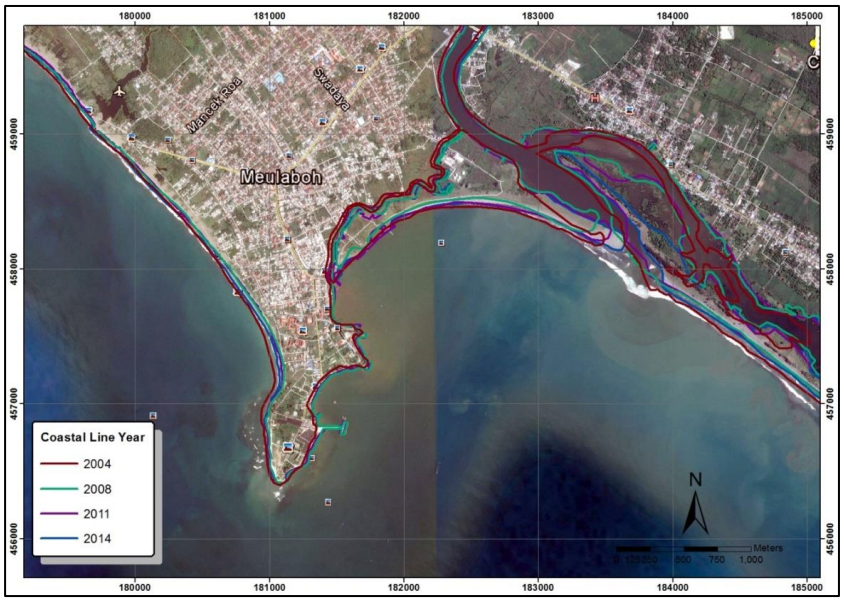

Fig. 4. Coastline morphology around Meulaboh city after the tsunami (2004-2014).

Result of this study showed shoreline morphology described below:

- Shoreline in Zone I with black sand material decline of ± 20 m ~ 50 m landward;
- Shoreline in the Zone II did not undergo significant changes due to land forming material made from coral. Shoreline position is progressing due to the subsidence of land due to earthquake and tsunami 2004;
- Shoreline in the Zone III is a slight change in morphology, because the location of the shoreline is protected against the dominant wave coming from the west were hindered by the position of the tip of peninsula. The formation of the coastline here is also affected by hexaleg;
- Shoreline in Zone IV moving about ± 30-60 m landward since the tsunami and did not much change until now. Coastal material composed of black sand to be altered by the hydro-dynamics.

4.2 Sediment transport

The amount of sediment budget obtained from the calculation of longshore sediment transport outlined in the following table and the illustration of sediment transport direction can be seen in Fig. 5.

Tabel 2. Sediment budget around coastal of Meulaboh city.

Zone	Sediment Budget (m^3/year)	Direction	Mainland Material	Description
I	7.660.705	South to North West	Sand	The position of the coastal faces Indian Ocean. There are several structures to hinder the process of erosion and wave run-up. LST is affected by the wave of a direction perpendicular to the coastal.
II	387.227	South to North	Coral	Located on peninsula and face western coast, vulnerable to wave attack from all directions.
	6.595.532	South West to North East	Coral	Located on peninsula and face eastern coast, the shoreline protected by headland. LST is affected by the waves from the southwest and south.
III	3.687.980	South West to North East	Sand and Coral	The position of the coastal is relatively safe from attack waves from the west because it is located in a bay and sheltered by the headland position. LST is affected by the waves from the southwest and south.
IV	3.687.980	South West to North East	Sand	The position is relatively safe coastal sheltered by the headland position are estuary Kr. Cangkoi and estuary Kr. Meureubo are supplying sediment to the coast. LST is affected by the waves of the south and refraction waves from the west.

Fig. 5. Illustration directions of sediment transport that occurs along the coast.

4.3 Coastal structures performance

Coastal structures performance that located on each zone of this study will be described in the Table 3.

Tabel 3. The condition of the structure performance around the coastal Meulaboh city.

Zone	Structure Material	Function	Application	Structures Performance
I	Concrete wall	Retaining wave of tidal	4 storey structures arranged as a fence settlement	The structure is still function properly. There is a pile of sand in front of the structure by tidal wave.
	Concrete hexaleg / hexapod	Sediment trap to form the mainland	Construction arranged along the coastal as the bottom and top resulting in interlocking between units of hexaleg	Most of the structures sink below MSL because of overtopping waves and scouring on the front / leg, causing structures down from its original elevation. The dimensions and arrangement of construction can not withstand the pressure wave from the front.
	Sand container (geotextile sacks sand filled by local sand)	Reducing the rate of tidal waves	7 layers arranged trapezoidal	Some point decline due to damage materials sand bags. The damage caused by service periode of structure, the tidal wave attack, human activities, as well as due to animal activity.
	Radial steel flood gate	Restrain the rate of entry into estuary that caused rob, and to drain flood to the sea	Constructed with steel gate installed sequentially in 5 parts	The gate was broken and could not be operated again due to sediment in the area of the front gate. Sedimentation process influenced by waves and currents.
II	Concrete seawall	Restrain the wave that caused inundation on mainland and roads	The concrete walls are installed parallel to the coastline	In part that is often exposed to the tidal wave occurred fracture, causing flanking, or scouring slowly rose to the land and make the body construction became weakened.
	Tetrapod revetment with rubble mound	Restrain the wave that caused inundation on mainland and roads	Constructed by rubble mound to be core material, then placed tetrapod composed as the armor layer and for wave breaker. Breech of construction is protected by concrete cubes	The structure was built in 2014 and continued in 2015 are still work and function normally.
III	Concrete hexaleg / hexapod	Sediment trap to form the mainland	Construction arranged along the coastal as the bottom and top resulting in interlocking between units of hexaleg	The structure was built in 2005 purposing for shoreline protection in Zone III is still function properly.
IV	Jetty with rubble mound	Restrain the rate of erosion at the mouth of the estuary Kr. Cangkoi	Stones arranged to form a trapezoid with a certain slope with a core made of stone 5-60 kg and a protective layer of stone 1-2 tons	The structure is still function normally.
	Sheet pile (concrete sheet pile)	Retaining river walls of Kr. Cangkoi	Sheet Pile made of concrete slabs are put up along the margin of the river	The structure is still function normally.
	Concrete seawall-I	Restrain the rate of erosion on the left side of the mouth of the estuary jetty of Kr. Cangkoy.	The concrete walls are installed parallel to the coastline in the upright position the end of the jetty	Edge of structure is already eroded to the rear of the structure.
	Concrete seawall-II with shoe protection	Maintaining the position of the shoreline in the area of Padang Seurahet.	The concrete walls are installed parallel to the shoreline behind the rubble of the old seawall	Seepage occurs on some points and seawater flow through the slit.

5. Conclusion

Some conclusions based on the results and discussions are described as follows:

- Zone I
  The shoreline morphology is influenced by longshore sediment transport in the direction from south to northwest. In this location structures such as hexaleg, concrete ring seawall, sand container, and flood gate exist. It is observed that at some construction changes occur, and there also was a function decrease when compared to the initial conditions.
- Zone II

The shoreline morphology is greatly affected by wave attacks from the direction of the sea towards the peninsula. The wave coming from all directions and this point changed, because of the subsidence by earthquake in 2004. The longshore sediment transport process in this location is relatively small, due to the fact that the mainland is composed of coral. The t western area dominant sediment occurs from the south to the north, the east area is dominated by the sediment movement from the southwest to northeast. There are seawall and revetment structures with cover protection of tetrapod and concrete cube in this area.

- Zone III
  The shoreline morphology is relatively small due to the location of the shoreline that is protected against the dominant waves from the west by the position of the tip of the peninsula. The formation of the coastline here is also influenced by the hexaleg coastal protection structure. The longshore sediment transport is influenced by the wave of southwest to northeast. The low sediment rate is originated form the fact that most of the land in this location consists of coral material.
- Zone IV
  The shoreline morphology tends to be linear in pattern influenced by its relatively safe location sheltered from wave attack to the west, by the position of the estuary. The embouchure of Kr. Meureubo changed the mainland significant over the past 10 years originated by the wave direction that carries sand spit sediment in the mouth area of the estuary. The longshore sediment transport is influenced by wave loads from eastern to northwestern. In this location, seawalls, jetties, and sheet concrete piles exist for holding the side wall of the river against erosion. Additional structures are a combined type revetment seawall on the left side of the estuary Kr. Cangkoy which serve to hold the rate of erosion at the mouth of the estuary under normal conditions.

6. Recommmendation

Some suggestions to do next research activities such as the following:

- Continuing research work should be focused on the implementation of a numerical model to simulate the behavior
- Accurate field measurement using theodolites to obtain elevation values, dimensions, coordinates, and final condition of the structure, to compare to the initial condition due to stages of coastal structure change should be conducted
- The sediment transport direction can be used to determine the type of construction, and support the planning of structures' position precisely on the shoreline.

References

CERC, 1984. Shore Protection Manual, US Army Coastal Engineering Research Center, Washington.

Essen, M., 2007. An Implicit One-Line Numerical Model On Longshore Sediment Transport. Graduate School's Thesis, Natural And Applied Sciences of Civil Engineering Department, Middle East Technical University, Ankara, Turkey.

Kamphuis, J. William, 2002. Introduction to Coastal Engineering and Management, Allied Published Limited, Queen's University, Canada.

Lubis, I.R.(ed), 2008. Kajian Kondisi Biofisik dan Sosial Ekonomi di lokasi-lokasi Proyek Green Coast Fase II, Green Coast Project, Wetlands International - Indonesia Programme, Bogor.

Meilianda, E., 2009. Past, Present And Future Morphological Development Of A Tsunami-Affected Coast: A Case Study Of Banda Aceh, PhD Dissertation, University of Twente, The Netherlands.

Rais, J. et al, 2004. Menata Ruang Laut Terpadu, Percetakan Penebar Swadaya, Jakarta.

Reeve D., Chadwick A., & Fleming C., 2004. Coastal Engineering: Processes, Theory and Design Practice, Spon Press, Oxon, United Kingdom.

Sorensen, R.M., 2006. Basic Coastal Engineering, 3rd edition, Department of Civil and Environmental Engineering of Lehigh University, Bethlehem, Pennsylvania.

Supriyatno, A., 2003. Analisis Abrasi Pantai dan Alternatif Penanggulangan di Perairan Pesisir Perbatasan Kabupaten Kendal Kota Semarang, Tesis Program Magister Ilmu Lingkungan Undip, Semarang.

Sutikno, 1993. Karakteristik Bentuk dan Geologi di Indonesia, Diklat PU Wil. III. Dirjen Pengairan DPU, Yogyakarta.

Syamsidik, Iskandar, A., & Rasyif, T.M., 2014. Progress Of Coastal Line Rehabilitation After The Indian Ocean Tsunami Around Banda Aceh Coasts, Recovery from Indian Ocean Tsunami., Editor Shaw, Springer, Tokyo, pp175-189.

Tanaka, H. et al, 2012. Coastal And Estuarine Morphology Changes Induced By The 2011 Great East Japan Earthquake Tsunami, Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering), Vol. 54 No.1, 125001.The Overseas Coastal Area Development Institute of Japan (OCDI), 2002, Technical Standards For Port And Harbour Facilities in Japan. Japan Ports and Harbours Association.

Triatmodjo, B., 1999. Teknik Pantai, Beta Offset, Yogyakarta.

Van Rijn, L.C., 2002. Longshore Sediment Transport, Report Z3054.20, Delft Hydraulics, Delft, The Netherlands.

Yuwono, N., 1986. Teknik Pantai, Volume I, Biro Penerbit Keluarga Mahasiswa Teknik Sipil Fakultas Teknik, Universitas Gajah Mada, Yogyakarta.

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

The 3rd SCESCM

Special Topics in Public Works Research and Technology

Application of condition index of buildings (case study Sragen Technopark building)

Agus Fitriyanto[a,*], SA. Kristiawan[a], Syafi'i[a]

[a] *Post Graduate Civil Engineering Programs Sebelas Maret University, Jl. Ir. Sutami 36A, Surakarta 57126; Telp. 0271-634524*

Abstract

One of the problems in the maintenance of the building is the unavailability of database on the value of the condition of a building. The need for a data value of building conditions for the management of the building is very important to decide the appropriate maintenance actions. The problems faced by many local governments in managing state buildings are limited human resources and knowledge of the appropriate methods in the assessment of the condition of the building into its own obstacles in maintenance activities. This study will make an assessment of the value of the condition of buildings in Sragen Techno Park. Sragen Techno Park is one of state building in Sragen. The method used in the assessment of building conditions using the Condition Composite Index (CCI). The index value on the condition of the building is a merger of two or more values multiplied by the weight conditions. Weight calculation function components were analyzed using Analytical Hierarchy Process (AHP). The results showed that the assessment of the physical condition of the building Sragen Technopark in the main building "A" has a value of 92.922% thus included in good condition. There is some damage that needs to be improved, especially in structural damage. If the damage is directly addressed it will not lead to a wider impact on the system of the existing structure.

Keywords: sragen technopark; composite condition index; AHP

1. Introduction

Maintenance is one activity that is very important for a building. Maintenance will increase the service life of the age of the building. According to Supriyatna (2009) Building maintenance activities that are less well cause the function of a building degraded. According to *Permen PU no.24 / PRT / M / 2008* year 2008 on guidelines for the maintenance of the building, maintenance building is activity to maintain the reliability of the building along with the ingredients so that the building is always worth function. In reality maintenance activities are less noticed by the owner of the building. According to Labombang (2006) maintenance activities obtain less attention due to several factors. These factors, among others, (a) not deemed urgent maintenance activities compared with development activities, (b) improper maintenance organization structure, (c) the facility manager assume that the maintenance of the building is a technical matter which is not associated with the goal of building functions corresponding user desires.

Data is very important in the maintenance activity is the value of the condition of the building. Data availability will facilitate the building condition value budget users to perform building maintenance priorities by looking at the available budget. Therefore, this study aimed to get an assessment of the physical condition of the building.

2. Theory of composite condition index

2.1. Building condition value

To assess the condition of the building at a time, can be done by setting the index value of building condition is a merger of two or more component state value multiplied by the weight of each component. Composite Condition Index was formulated as follows (Hudson et.al., 1997):

* Corresponding author. Tel.: 0271-634524
E-mail address: gusfitoke@gmail.com

$$CCI = W_1*C_1+W_2*C_2+\ldots..+\ldots..+W_n*C_n \quad (1)$$

where:
CCI = Composite condition index
W = Component weight
n = Component number
C = Value of component condition

The weights of components obtained using the analytical hierarchy process (AHP). Building conditions index has a scale between 0 (zero) to 100 (one hundred) as can be seen in Table 1.

Table 1. Condition Index Scale (McKay et al., 1999)

Zone	Condition Index	Condition description	Recommended action
1	85-100	Excellent: No noticeable defects. Some aging or wear may be visible.	Immediate action is not required.
	70-84	Good: Only minor deterioration or defects are evident.	
2	55-69	Fair: Some deterioration or defects are evident, but function is not significantly affected.	Economic analysis of repair alternatives is Recommended to determine appropriate action.
	40-54	Marginal: Moderate deterioration. Function is still adequate	
3	25-39	Poor: Serious deterioration in at least some portions of the structure. Function is inadequate.	Detailed evaluation is required to determine the need
	10-24	Very Poor: Extensive deterioration. Barely functional.	For repair, rehabilitation, or reconstruction. Safety
	0-9	Failed: No longer functions. General failure or complete failure of a major structural component.	Evaluation is recommended.

The composite condition index calculation is done gradually, starting from sub condition index calculating element to obtain a composite index like the following conditions (Uzarski et al., 1999):

- Step I: Sub Elements Condition Index (IKSE)

To calculate the value of IKSE, using the following equation:

$$IKSE = 100 - \sum_{i=1}^{p}\sum_{j=1}^{m} a(Tj, Sj, Dij) * F(t, d) \quad (2)$$

where:
a (..) = Deduct value depends on the type of damage *Tj*, *Sj* damage level and quantity of damage *Dij*
p = Number of types of damage to subgroups of elements to be reviewed
m = Number of levels of damage to the type of damage to.... -i
F(t,d) = Correction factor for damage with multiple different

In calculating IKSE based above formula, the value of 100 (one hundred) is the maximum value judgments. While the value of a deduction of between 0 (zero) to 100 (one hundred), depending on the type of damage (Tj), the degree of damage (Sj), and the quantity of damage (Dij). Factor correction factors depending on the danger level of each type of damage, the amount of the correction factor is one, as can be seen in Table 2.

Table. 2. Factor Correction To Combination Damage (Uzarski, 1997)

No	Number Combination of Damage	Priority damage	Factor Correction F (t,d)
1	2	I	0,8 - 0,7 -0,6
		II	0,2 - 0,3 - 0,4
2	3	I	0,5 – 0,6
		II	0,3 – 0,4
		III	0,1 – 0,2

- Step 2: Element condition index (IKE)

$$IKE = IKSE_1*BSE_1+IKSE_2*BSE_2+\ldots\ldots+IKSE_n*BSE_n \quad (3)$$

where:
IKE = Element Condition Index
IKSE = Sub Element Condition Index
BSE = Weight of Sub Element
n = Number of Sub Element

- Step 3: Sub component condition index (IKSK)

$$IKSK = IKE_1*BE_1+IKE_2*BE_2+\ldots\ldots+IKE_n*BE_n \quad (4)$$

where:
IKSK = Sub Component Condition Index
IKE = Element Condition Index
BE = Weight of Element
n = Number of Element

- Step 4: Component condition index (IKK)

$$IKK = IKSK_1*BSK_1+IKSK_2*BSK_2+\ldots\ldots IKSK_n*BSK_n \quad (5)$$

where:
IKK = Component Condition Index
IKSK = Sub Component Condition Index
BSK = Weight of Sub Component
n = Number of Sub Component

- Step 5: building condition index (IKB)

$$IKB = IKK_1*BK_1+IKK_2*BK_2+\ldots.+IKK_n*BK_n \quad (6)$$

where:
IKB = Building Condition Index
IKK = Component Condition Index
BK = Weight of Component
n = Number of Component

2.2. Analytical hierarchy process (AHP)

To determine the weight of a building component functions used AHP. AHP is a method used in the decision making process a complex issues such as the problems of planning, determination of alternative, prioritization, selection wisdom, resource allocation, determining needs, forecasting needs planning performance, optimization, and conflict resolution (Saaty, 1991). A problem is said to be complex if those issues are not clearly structured, if there is a lack of data and if the statistical information

is accurate, thus human intuition is used to solve this problem. This intuition must come from people who are experts in the field. Saaty (1991) set a quantitative scale of 1 (one) to 9 (nine) to assess the interest rate comparison against the other element, as shown in Table 3.

Table 3. The fundamental scale of absolute numbers (Saaty, 1991)

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Values between two values adjacent considerations	This value is given when two compromise between the two options
Reciprocal	If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	

Basically AHP can be used to process data from the respondents. Additionally, application assessments to the criteria were developed by some respondents. Further, the geometric mean from the assessment given by all respondents was used in the analysis (Wijayanti, 2015). The average value of the geometric formulated with:

$$GM = \sqrt[n]{X_1 \; x \; X_2 \; x \; \dots \dots X_n} \quad (7)$$

where:
- GM = Geometric mean
- X_1 = Respondent assessment 1
- X_n = Respondent assessment n
- n = Number of respondents

The values of the geometric mean for all ratings interest are arranged in a matrix of pairwise comparisons and then do multiplication elements in one line and the square root of n. As the following equation:

$$W_i = \sqrt[n]{a_{11} x \, a_{12} x \ldots x a_{1n}} \quad (8)$$

The next priority vector is calculated by the following equation:

$$X_i = \frac{W_i}{\sum W_i} \quad (9)$$

The results obtained are eigenvector (X1) as weight of elements. To get the maximum eigenvalues (λ_{max}) matrix multiplication is carried out with weights derived from the sum of the operating results of the matrix is the maximum eigenvalues (λ_{max}) with the following equation:

$$\lambda_{max} = \sum a_{ij} \; x \; X_i \quad (10)$$

where :
- λ_{max} = Maximum eigen value
- a_{ij} = Value pairwise comparison matrix
- X_i = Eigen vector (weight)

Furthermore, the consistency index calculation to determine the consistency of the answers that will affect the truth of the results. Consistency index calculation can be done using the following equation:

$$CI = \frac{\lambda_{maks} - n}{n-1} \quad (11)$$

where :
CI = Consistency Index
λ_{max} = Maximum eigen value
n = The size of the matrix

To determine the CI is good enough or not, one needs to know Consistency Ratio (CR). Consistency ratio is a parameter to check whether the pairwise comparisons have been conducted with consistency by using the following equation:

$$CR = \frac{CI}{RI} \quad (12)$$

Value of Random Index (RI) depending on the size of the matrix as shown in Table 4.

Table 4. Relationship Between Matrix Size and Value RI (Saaty,1991)

Matrix size	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56	1,57	1,59

Terms comparison matrix formulation can be accepted if the value of CR <0.1. When CR ≥ 0.1 then the assessment of importance of the criteria must be started again.

3. Methodology

The research location used for the case study is Sragen Techno Park Building, Dr. Sutomo Street No. 05 Sragen. Data collection methods are:

- Primary data, to get the type and extent of damage building components obtained from direct observations in the field using. Weighting the criteria for the purposes of weighting functions obtained through a questionnaire. Sampling using purposive sampling method sampling technique with a certain considerations. Respondents at this research are the experts of the building.
- Secondary data, obtained through the technical specifications of the building and through the technical drawings from agencies from Sragen Techno Park. Analysis of the data for the assessment of the condition of the building is done in stages following the hierarchy of the office building. Valuation method using the physical condition of the building condition assessment model developed by (Uzarski et al., 1999). Started by calculating Sub Elements Conditions Index (IKSE) to calculate value of Building Condition Index (IKB). To calculate the value of the index weighting conditions necessary sub elements, elements, sub-components and components of the building was done by the AHP method. Weight calculation begins with the assessment of interest between the sub-elements in one element to obtain a comparison matrix. Weighting acceptable when done consistently comparison matrix, which is measured by the value of CR. Acceptable if the comparison matrix CR < 0.1 If CR = 0.1, the ratio changed to meet the criteria for CR < 0.1.

4. Result and discussion

4.1. Weight of Building Components

The building is composed of structural components, architectural and utility. Each component is described again into the elements and sub-elements, e.g. architectural components are divided into components wall, ceiling, doors, windows and floors. For the calculation of the condition of the building, each of the components, elements and sub-elements must be known to the condition and the weight of each. The calculation of weight in this study using Analytical Hierarchy Process (AHP), while the weight calculation step, namely:

- Establish a hierarchy of the office building.
- Determine the criteria used to provide an assessment of the building between components.
- Provide an assessment of interest between building components based on each criteria.
- Perform weight calculation component of the building and see the consistency of assessment.

In this study a questionnaire of 20 (twenty) respondents consisting of teams TABG District, the Public Works Department officials, Supervisors and Planning Building of the Department of Public Works, Consultants and Contractors. Example calculation results from questionnaires with a review of the building as can be seen in Table 5.

Table 5. Rate of Interest and Geometric Mean.

	Building		
Respondent	**Structural**	**Structural**	**Architectural**
	Architectural	**ME**	**ME**
1	1,000	5,000	5,000
2	1,000	1,000	1,000
3	9,000	7,000	1,000
4	9,000	5,000	1,000
5	9,000	7,000	1,000
6	9,000	7,000	7,000
7	9,000	1,000	1,000
8	0,333	0,333	1,000
9	7,000	1,000	1,000
10	1,000	5,000	5,000
11	9,000	5,000	0,200
12	7,000	5,000	0,200
13	1,000	1,000	1,000
14	9,000	7,000	5,000
15	9,000	5,000	3,000
16	1,000	3,000	3,000
17	1,000	1,000	1,000
18	1,000	3,000	3,000
19	3,000	3,000	3,000
20	3,000	3,000	1,000
Geometric mean	**3,091**	**2,820**	**1,488**

Furthermore, the geometric mean results are arranged in pairwise comparison matrix as can be seen in Table 6.

Table 6. Pairwise Comparison Matrix

	Structure	Architecture	ME
Structure	1,000	3,091	2,820
Architecture	0,324	1,000	1,488
ME	0,355	0,672	1,000

By using Equation (8), then the value Wi :

Row I : $W_1 = \sqrt[3]{1x3{,}091x2{,}820}$ = 2,058

Row II : $W_2 = \sqrt[3]{0{,}324x1x1{,}488}$ = 0,784

Row III : $W_3 = \sqrt[3]{0{,}355x0{,}672x1}$ = 0,620

Wi = 3,462

X_i (Eigen vector) value using equation (9):

Structural weight $X_1 = \frac{2{,}058}{3{,}462}$ = 0,595

Architectural weight $X_2 = \frac{0{,}784}{3{,}462}$ = 0,226

ME weight $X_3 = \frac{0{,}620}{3{,}462}$ = 0,179

λ_{max} *(Eigen Maximum)* value calculation using equation (10):

$$\lambda_{max} = \begin{bmatrix} 1 & 3{,}091 & 2{,}820 \\ 0{,}324 & 1 & 1{,}488 \\ 0{,}355 & 0{,}672 & 1 \end{bmatrix} \text{ x } \begin{bmatrix} 0{,}595 \\ 0{,}226 \\ 0{,}179 \end{bmatrix} = \begin{bmatrix} 1{,}799 \\ 0{,}685 \\ 0{,}542 \end{bmatrix}$$

λ_{max} = 3,027

CI value using equation (11) :

$CI = \frac{3{,}027-3}{3-1}$ = 0,013

CR value using equation (12). In this example the matrix size n = 3, then based on Table 4, the value RI = 0,58.

$CR = \frac{0{,}013}{0{,}58}$ = 0,023

Conditions comparison matrix can be accepted if the value of CR <0,1, so the above assessment results are acceptable CR = 0,023 <0,1. Full results of the weighting function of building components as can be seen in Table 7.

Table 7. The Weights of Building Components

COMPONENT	SUB COMPONENT		ELEMENT	SUB ELEMENT	
Architectural (B) 0,226	Public 0,460		Ceilings (A) 0,136	Plafond frame (F)	0,343
				Plafond cover (G)	0,474
				Plafond paint (H)	0,183
			Walls (B) 0,311	Brick (I)	0,371
				Plaster (J)	0,382
				Wall paint (K)	0,246
			Doors (C) 0,216	Door sills (L)	0,301
				Door panel (M)	0,363
				Door hinges (N)	0,179
				Door key (O)	0,157
			Windows (D) 0,183	Window sills (P)	0,212
				Window panel (Q)	0,321
				Window hinges (R)	0,135
				Window key (S)	0,106
				Glass (T)	0,226
			Floors (E) 0,155	Ceramic (U)	0,822
				Floor (V)	0,178
	Semipublic 0,194		(A),(B),(C),(D),(E)	(F) - (V)	
	Private 0,223				
	Service 0,122				
Structural 0,595	Roof stucture 0,166	Slab roof 0,530	Roof beam 0,631	Main beam	0,828
				Supporting beam	0,172
			Roof slab	0,369	
		Light weight roof frame 0,470	Main truss	0,521	
			Roof cover 0,168	Tile	0,680
				Nok	0,320
			Roof frame	0,311	
	Top structure 0,293		Coloumn	0,519	
			Beam 0,326	Main beam	0,828
				Supporting beam	0,172
			Slab 0,155	Floor slab	0,778
				Stair slab	0,222
	Base Structure 0,540		Sloof	0,339	
			Foundation	0,661	
ME 0,179	Fire System Installation 0,145		Fire extinguisher 1,000		
	Electrical installation 0,320		Cable installation	0,478	
			Socket	0,170	
			Switch	0,125	
			Lighting	0,227	
	Plumbing installation 0,276	Water supply installation 0,469	Water pump	0,262	
			Water tank	0,163	
			Clean water pipe	0,353	
			Water storage	0,120	
			Faucet	0,102	
		Waste water installation 0,370	Water closet	0,205	
			Waste water pipe	0,282	
			Septictank	0,234	
			Absorption	0,207	
			Sink	0,072	
		Rain water installation 0,161	Rain water pipe	0,418	
			Drainage channel	0,582	
	HVAC 0,096		AC	0,542	
			Fan	0,146	
			Exhaust fan	0,312	
	Communication and networks 0,163		Phone	0,504	
			Phone network	0,496	

4.2. Building Condition Assessment Calculation

Building conditions index is calculated using data type of damage, the extent of damage and the damage volume obtained by direct observation in the field. For example in the hierarchy weighting function, the component architecture is divided into sub-

components of the spaces. Component architecture is divided into four sub-components: a public zone, semi-public zone, private zone and service zone (Pynkyawati et.al., 2014). Each sub-component consists of a ceiling, doors, windows, walls and floors. Examples of the types of damage to architectural components, public sub-components, wall elements, the wall paint is chipped (Correction Factor/FK = 0.7) and faded wall paint (Correction Factor/FK = 0.3). It is widely known on the walls of a public zone amounted to 779.28 m^2. Paint chipped walls measuring 311.9 m^2, faded wall paint area of 239.78 m^2, using equation (2), then the calculation Sub Element Condition Index (IKSE) are as follows:

Percentage chipped paint $= \frac{311,9}{779,28}$ x 100 = 39,02%

NP = 75

Percentage paint faded $= \frac{239,78}{779,28}$ x 100 = 30,00%

NP = 50

$IKSE_{\text{wall paint}}$ = 100-((75x0,7)+(50x0,3))

$IKSE_{\text{wall paint}}$ = 32,5%

Fig. 1. Paint chipped walls.

Based on the calculation of IKSE above, the element conditions index (IKE) can be calculated using Equation (3). Examples of wall elements on public component based on Table 7 provides weight sub element (BSE) masonry 0.371, stucco 0.382 and wall paint 0.246 then the calculation is as follows:

IKE wall = (IKSE masonry x BSE masonry) + (IKSE stucco x BSE stucco) + (IKSE wall paint x BSE wall paint)

= (92.5x0.371)+(92.5x0.382)+(32.5x0.246)

=77.72%

Based on the calculation of IKE above, sub components conditions index (IKSK) can be found using Equation (4). Examples for sub public component based on Table 7 weight element (BE) for ceiling 0.136, wall 0.311, doors 0.216, windows 0.183 and floor 0.155 then calculated as follows:

$IKSK_{\text{publik}}$ = (IKSK ceiling x BSK ceiling)+(IKSK wall x BSK wall)+(IKSK door x BSE door)+(IKSK window x BSK window)+((IKSK floor x BSK floor)

= (90.85x0.136)+(77.72x0.311)+(100x0.216)+(100x0.183)+(98.66x0.155)

= 91.63%

Based on the calculation of IKSK above, component conditions index (IKK) can be found using Equation (5). Based on table 7 weight sub components (BSK) to the public 0.460, semi-public 0.194, private 0.223 and service 0.122, then calculated as follows:

$IKK_{architectural}$ = (IKSK public x BSK public) + (IKSK semipublic x BSK semipublic) + (IKSK private x BSK private) + (IKSK service x BSK service)

= (91.63x0.460) + (87.55x0.194) + (93.16x0.223) + (98.13 x 0.122)

= 92.03%

Model calculations above were also performed on the component structure and ME. From the calculation of IKK architecture, structures and ME are used to determine building conditions index (IKB) with Equation (6). Based on Table 7, known weighting function architecture components 0.226, structural 0.595 and ME 0.179, then the calculation is as follows:

$IKB_{Main\ Building\ A}$ = (IKK architectural x BK architectural) + (IKK structural x BK structural) + (IKK ME x BK ME)

= (92.03x0.226) + (95.88x0.595) + (84.24x0.179)

= 92.992%

5. Conclusions

Building physical condition assessment Sragen Techno Park especially in the Main Building "A" using the Composite Condition Index (CCI), assess the condition of the building with the scale of 92.992% so that the building is in good condition. There is some damage, which needs to be improved, especially in structural damage. If the damage is not directly addressed a broader impact on the system of the existing structure can be expected. This research is still to be developed further to prioritize the maintenance of building components with fuzzy AHP method which is still in the process of completion.

References

Hudson,W.R., Haas,R.C.G., Uddin,W., 1997, *Infrastructure Management*, New York : McGraw Hill Companies Inc.

Labombang,M., 2008, Manajemen Pemeliharaan Fasilitas Dalam Pengelolaan Gedung, Majalah Ilmiah Mektek, Tahun 10, No.1, Januari 2008, hlm.44-48.

McKay, D.T., Rens, K.L., Stecker, J.H., Greimann, L.F., 1999, Condition Index Assesment for U.S. Army Corps of Engineers Civil Works, Journal of Infrastructure Systems. ASCE, 5(2) : 52-60.

Pynkyawati,T., Aripin.S, Iliyasa,E., Ningsih,L.Y., Amri., 2014, Kajian Efisiensi Desain Sirkulasi pada Fungsi Bangunan Mall Dan Hotel BTC, Jurnal Reka Karsa, Jurnal Online Institut Teknologi Nasional No.1 Vol.2, hlm.1-8.

Saaty,T.L.,1991, Pengambilan Keputusan: Proses Hirarki untuk Pengambilan Keputusan dalam Situasi Kompleks, Jakarta : Pustaka Binaman Pressindo.

Supriyatna,Y. 2008, Estimasi Biaya Pemeliharaan Gedung, Majalah Ilmiah Unikom, Vol.9,No.2, hlm. 199-206.

Uzarski,D.R., dan Burley,L.A., 1997, Assesing Building Condition by the Use of Condition Indexes, Proceeding Infrastructure Condition Assesment: Art, Science, Practice, ASCE, Boston, MA.

Wijayanti,A.R.,2015, Skala Prioritas Pemeliharaan Gedung Kantor Balai Pelatihan Konstruksi Wilayah V Jayapura, Tesis, Magister Teknik Sipil :Universitas Sebelas Maret.

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

The 3rd SCESCM

Special Topics in Public Works Research and Technology

Damage analysis for coastal protection structure at Batu Berhanti Island (the outer islands) in Batam

Tommy Afrialdi[a], M. Cahyono[b], Fitri Riandini[c]

[a]*Master Program in Water Resources Management, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia*
[b]*Advisor at Master Program in Water Resources Management, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia*
[c]*Co Advisor at Master Program in Water Resources Management, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia*

Abstract

Batu Berhanti Island is the basis outermost island for measuring state border for *Negara Kesatuan Republik Indonesia*. The status of the outermost island is based on *Keputusan Presiden RI Nomor : 78 Tahun 2005* about Outermost Island Management. The characteristic of outermost island is *Nomor Titik Dasar (TD*) and *Nomor Titik Referensi (TR),* which is a marker of law area. TD and TR Batu Berhanti Island is 192 with coordinates 01 ° 11'06 "N, 103 ° 52'57" E. In 2014, existing coastal protection structure that was built in 2012 suffered damage from the blow of sea waves which will threaten the existence of Batu Berhanti Island as the outer islands. From data analysis with 25-year period, the maximum wave coming from the east is 3.2 m of height and a period of 9.4 seconds, HHWL = 3.59 m, MSL = 1.83 m. The alternative is an additional form of protective armor structure by forming three alternatives, the structure of natural stone, tetrapod and a- jack. The dimension of heavy armor natural stone = 3.6 Ton, tetrapod = 2.9 and armor jack Ton Ton = 1.2. Peak elevation of the building for the alternative rock material is +7.6 m, alternative tetrapod material is +6.79 m and a jack-alternative material is +7.29 m. Construction costs are the lowest, using a material-jack that requires a fee of Rp. 15,445,282,663.00 (Fifteen Billion Four Hundred Forty Five Million Two Hundred Eighty Two Thousand Six Hundred Sixty Three Rupiah).

Keywords: Outermost Island; Pulau Batu Berhanti; crushed stone; tetrapod; a-jack

1. Introduction

1.1. Background

Batu Berhanti island is the basis outermost island for measuring state border for *Negara Kesatuan Republik Indonesia*. The status of the outermost island is based on *Keputusan Presiden RI Nomor : 78 Tahun 2005* about Outermost Island Management. The characteristic of outermost island is *Nomor Titik Dasar (TD)* and *Nomor Titik Referensi (TR),* which is a marker of law area. TD and TR Batu Berhanti Island is 192 with coordinates 01 ° 11'06 "N, 103 ° 52'57" E.

Batu Berhanti island is located in *Desa Pemping, Kecamatan Belakang Padang, Batam city, Kepulauan Riau* Province. The island is the outermost island which border with Singapore. The island is a coral group which is crowded by passing ships because it is in international waters zone.

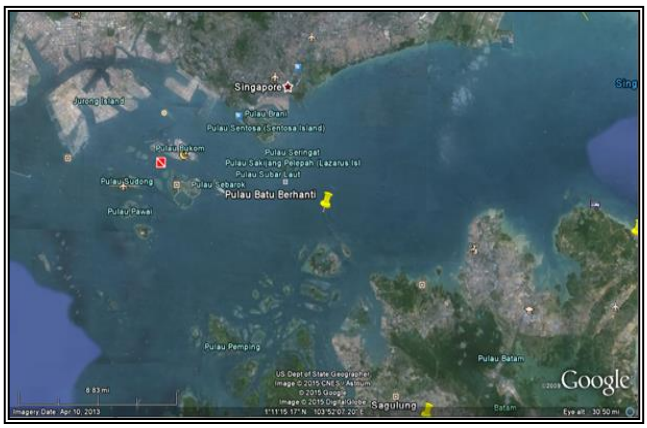

Fig. 1. Location of Batu Berhanti Island. (From : Google Earth, 2015)

In 2012 the government in this case *Balai Wilayah Sungai Sumatera IV Direktorat Jenderal Sumber Daya Air Kementerian Pekerjaan Umum* has made efforts to secure the island by building a revetment around the island made of Sand Bag (KPG) coated with Bronjong HDPE stone filled. However, in 2014 there has been damage severe enough in the protection structure. Revetment made of KPG and gabion material HDPE (High Density Poly Ethylene) is damaged and results in the release of sand and the gabion material HDPE is carried over by currents and waves. The condition of the building at the time of the crash as in Fig. 2 and Fig. 3.

Fig. 2. Damage Point Batu Berhanti Island Coastal Protection.

Given the importance of this island, the existence and stability of the island must be maintained. Based on it the study will be conducted to review Detail Design planning of Batu Berhanti Island coast security, a review of constructions method and determination of alternative solutions.

1.2. Research Purpose

This study intent to conduct a technical analysis of the Batu Berhanti Island protection structure detailed design and assess the existing condition of the building.

The purpose of this study is:

- Aspects reviewing in the cause of the damage Batu Berhanti Island protection structure;
- Giving an appropriate alternative protection structure recommendation for the problem that occur so that there would be anticipation for similar problem in the future

2. Methodology

2.1. Research Mindset

Stages of the study was structured so that a systematic arrangement continue to seek resolution of problems that occur. The following is the line of thinking on the implementation of this study:

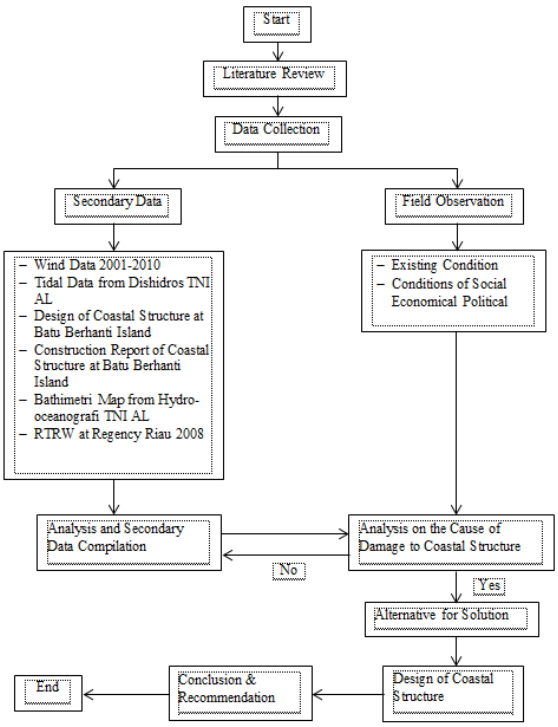

Fig. 3. Research Mindset.

3. Analysis and Discussion

3.1. Data Analysis

3.1.1. Wind Data Analysis

Wind is one of the dominant element of generating waves in deep water. Thus, forecasting waves in the deep ocean requires wind data near the surface (approximately the elevation of 10m above sea level). Data that is needed is a variation of wind speed and direction continuously from time to time with intervals of one hour. Hourly wind data (hourly wind data) is usually sufficient for forecasting assuming that the wind blows at a constant speed and direction within one hour. Wind data is collected hourly from Hang Nadim Batam station with recording period from 2001 to 2010.

Table 1. Wind Speed Data From Hang Nadim Batam Station in 2001-2010.

Wind Direction	Wind Speed (%)				
	< 5 knot	5 up to 10 knot	10 up to 15 knot	> 15 knot	Total
North	2.86	5.49	0.44	0.05	8.84
Northeast	0.84	7.32	3.96	1.25	13.37
East	1.28	2.55	0.25	0.03	4.11
Southeast	1.68	5.44	0.80	0.04	7.96
South	2.26	5.99	0.79	0.04	9.09
Southwest	1.28	2.80	0.30	0.03	4.40
West	1.20	2.26	0.13	0.02	3.61
Northwest	1.14	1.55	0.04	0.01	2.74
Windy	54.12				
Not recorded	15.69				
Windless	30.20				
TOTAL	100.00				

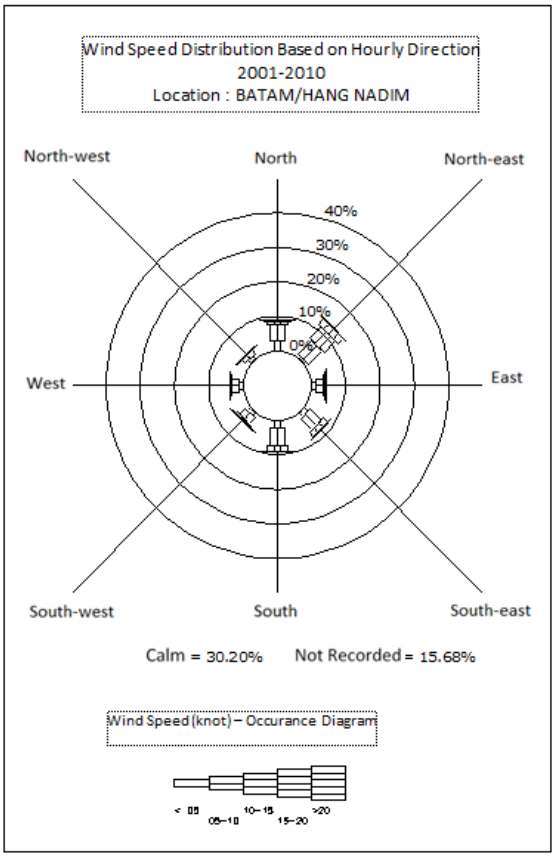

Fig. 4. The distribution of wind speed and direction hourly total.

3.1.2. Hindcasting

Long-term wind data, a minimum of 10 years, gives more reassuring statistics for this hindcasting method. Calculation of the effective fetch is as follows:

North direction

Fetch angle : 0^o ; long fetch (f) : 6037 m ; α (alpha) : 0^i cos α : 1
f x cos α = 1 x 6037 = 6037 m
Then the angle is calculated for up to -20^o - 20^o fetch, then:

Table 2. Results of analysis of Pulau Batu Berhanti Island fetch.

Direction	Angle	Distance, F (m)	α (alpha)	cosα	Fcosα
	340	7487	-20	0.939693	7035
	345	6843	-15	0.965926	6610
	350	6435	-10	0.984808	6337
	355	6181	-5	0.996195	6157
North	0	6037	0	1	6037
	5	5989	5	0.996195	5966
	10	6028	10	0.984808	5937
	15	6147	15	0.965926	5938
	20	6354	20	0.939693	5971

Fetch length is calculated for 8 (eight) point directions

$$Lf_i = \frac{\sum Lf_i.\cos\alpha_i}{\sum \cos\alpha_i} = \frac{7035+6610+6337+6157+6037+5966+5937+59385971}{0{,}939+0{,}965+0{,}984+0{,}996+1+0{,}996+0{,}984+0{,}965+0{,}939} = 6238 \text{ m}$$

For effective fetch analysis results for more 7 point directions is attached in the following table:

Table 3. Effective fetch calculation of Batu Berhanti Island.

No	Wind Direction	Fetch Effective
1	North	6382
2	Northeast	19629
3	East	314123
4	Southeast	16060
5	South	24742
6	Southwest	49658
7	West	118935
8	Northwest	17229

Example of hindcasting calculation:

Known:

Wind speed : 5 Knot = 2,572 m/s
Coming direction : 10^o (North direction)
Effective fetch : 6382 m
R_L : 1,6
Correction : $U_w = U_L R_L$ = 2,572 x 1,6 = 4.1349 m/s
Stability Correction : $U = R_T U(10)$ = 1,1 x 4,134 = 4.5484 m/s

After correction and conversion speeds above is done, the next step is to convert the wind speed into Wind Stress Factor.
U_A = 0.71 $U^{1.23}$ = 0,71 x 4,5484 ^{1,23} = 4.5754
Duration of observation result = 2 hours

$$t_d = \frac{68{,}8\ x\ (UA/g)\ x\ (g\ x\ Feff\ /\ UA^2)^{2/3}}{3600} = 1{,}85 \text{ s}$$

Because observation result t > t_d, then it is classified as Fetch limited, value of effective fetch is = 6382 m.

$$Hm_0 = 0.0016 \times \frac{{U_A}^2}{g} \times \left(g \times \frac{F_{eff}}{{U_A}^2}\right)^{\frac{1}{2}} = 0.1177\ m$$

$$T_p = 0.2857 \times \left(\frac{U_A}{g}\right) \times \left(\frac{g \times F_{eff}}{{U_A}^2}\right)^{\frac{1}{3}} = 1.4114\ s$$

Then data is calculated using Microsoft excel, the put into wave rose graphic.

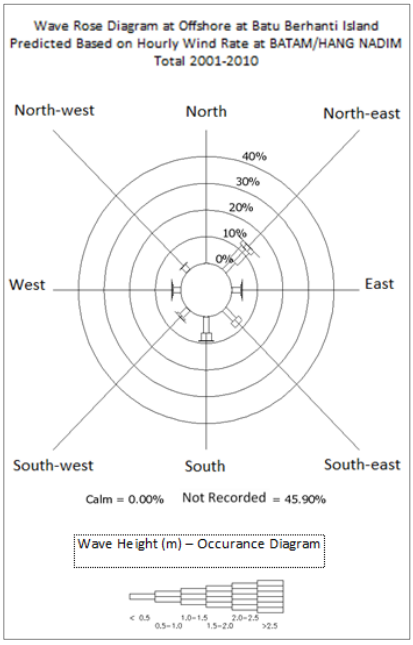

Fig. 5. Waverose Batu Berhanti Island

Table 4. Hmax each direction per year (meters) in the Batu Berhanti Island.

Years	Hmax at Direction :								Max
	N	NE	E	SE	S	SW	W	NW	
2001	0.609	1.041	1.927	0.967	0.961	1.669	1.388	0.853	1.927
2002	0.667	1.129	1.620	0.824	1.082	1.186	1.388	0.591	1.620
2003	0.724	1.041	1.319	0.872	1.022	1.448	1.262	0.591	1.448
2004	1.300	1.041	2.296	0.967	1.035	2.173	1.024	0.802	2.296
2005	0.935	1.129	3.426	0.967	1.370	1.362	1.553	0.903	3.426
2006	0.609	1.129	0.838	0.824	1.035	1.100	0.921	0.591	1.129
2007	0.550	1.257	0.893	0.872	1.082	1.186	1.862	0.536	1.862
2008	0.580	1.041	0.989	0.920	1.177	0.931	1.418	0.645	1.418
2009	0.609	2.185	1.204	0.824	1.742	1.100	1.620	0.751	2.185
2010	0.516	1.172	1.614	0.824	1.106	1.100	1.553	0.591	1.614

3.1.3. Extreme Wave Plan Analysis

Extreme waves plans are required as input data in the next wave analysis is derived as:

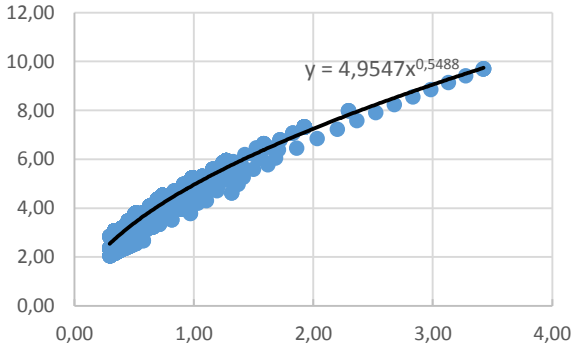

Fig. 6. Graph of wave height and wave period in Batu Berhanti Island.

Table 5. Used distribution function to calculate wave plan in Batu Berhanti Island.

Direction	Distribution Function
North	Gumbel
Northeast	Gumbel
East	Gumbel
Southeast	Gumbel
South	Gumbel
Southwest	Gumbel
West	Gumbel
Northwest	Gumbel

Table 6. Maximum Wave in Batu Berhanti Island.

No	Reset Period	Hmax (meter)	N	NE	E	SE	S	SW	B	NW	Max	Unit
1	5	Hmax	0.9	1.5	2.2	0.9	1.3	1.6	1.6	0.8	2.2	m
		Tmax	4.6	6.1	7.6	4.8	5.8	6.4	6.4	4.3	7.6	s
2	10	Hmax	1.0	1.7	2.6	1.0	1.5	1.8	1.8	0.9	2.6	m
		Tmax	5.0	6.6	8.4	4.9	6.1	6.8	6.8	4.5	8.4	s
3	25	Hmax	1.2	1.9	3.2	1.0	1.6	2.1	2.0	1.0	3.2	m
		Tmax	5.5	7.1	9.4	5.0	6.5	7.4	7.2	4.8	9.4	s
4	50	Hmax	1.3	2.1	3.7	1.1	1.8	2.3	2.1	1.0	3.7	m
		Tmax	5.8	7.5	10.1	5.1	6.8	7.8	7.5	5.0	10.1	s
5	100	Hmax	1.5	2.3	4.1	1.1	1.9	2.5	2.3	1.1	4.1	m
		Tmax	6.1	7.8	10.7	5.2	7.0	8.1	7.8	5.2	10.7	s

As a result of changes in sea surface contour, then at Batu Berhanti Island refraction and shoaling processes is happened that affect the value of high waves plan. High waves due to the influence of refraction process is influenced by the amount of refraction coefficient (Kr) and shoaling coefficient (Ks). High waves can be calculated using the equation:

$H'_0 = H_0$ Ks Kr

The result of the above calculation is shown in Table 7.

Table 7. Refraction Wave Height Calculation Results.

Coefficient	Value	Unit
Lo	138.577	m
Co	14.703	m/s
d/Lo	0.025	
d/L (Table)	0.066	
L	54.278	m
C	5.759	
sin α	0.277	
α	15.481	
Kr	0.857	
n	0.947	
Ks	1.161	
H_{ref}	3.210	m

Then the wave height obtained after a process of refraction and shoaling is 3.21 m.

3.1.4. Tidal Data Analysis

The data were then analyzed using a tidal ERGTide software and produce:

Table 8. Tide constituents.

No.	Tide Constituents	Period (hour)	Amplitude (cm)	Phase (^{o})
1	M_2	12.24	78.80	187.92
2	S_2	12.00	39.25	314.66
3	N_2	12.66	13.95	210.87
4	K_2	11.97	28.61	14.09
5	K_1	23.93	22.36	22.12
6	O_1	25.82	28.32	30.34
7	P_1	24.07	9.46	213.96
8	M_4	6.21	2.12	339.25
9	MS_4	6.10	2.21	204.26
	S_0		183.01	

Table 9. List of important tidal elevation.

No	Important tidal elevation		Elevation (cm)
			Level on Batu Berhanti
1	HHWL	Highest high water level	359
2	MHWS	Mean high water spring	329
3	MHWL	Mean high water level	274
4	MSL	Mean sea level	183
5	MLWL	Mean low water level	96
6	MLWS	Mean low water spring	29
7	LLWL	Lowest low water level	0

From tidal analysis above, HHWL is 3.59 meter against LLWL.

3.2. Planning Coastal Protection

In calculating the dimensions of protection structure, there are a few things into consideration, including the determination of breaking wave depth. The breaking wave calculation at the building site that is:

High Wave Equivalent: $H'_0 = Kr \times H_{shallow\ sea} = 0.8565 \times 3.21 = 2,75$

$$\frac{H'_0}{gT^2} = \frac{2,75}{9.81\ x\ 9.43^2} = 0,00309$$

From the graph obtained value $\frac{H_b}{H'_0} = 1,3$ Then, $H_b = 1,3 \times 2,75 = 3,575$

$$\frac{H_b}{gT^2} = 0,004$$

From the graph obtained value $\frac{d_b}{H_b} = 0,75$; Then, $d_b = 2,6$ m

So breaking wave will occur at a depth of 2.6 meters. Because db <dHHWL, it means the location of the building at a depth of 3.59 meters waves do not break.

3.2.1. Alternative Armor Coating Material Crushed Stone

From dimension analysis of the building and plans obtained the following results:

Table 10. Crushed Stone alternative.

No	Parameter	Minimum weight		Minimum Dimension		Minimum Elevation	
		Analysis (kg)	Plan (kg)	Analysis (m)	Plan (m)	Analysis (m)	Plan (m)
1	Weight of layer 1	3566	3600				
2	Weight of layer 2	240 - 360	360				
3	Weight of layer 3	0,6 - 18	Average 10				
4	Top elevation					+ 7,59	+ 7,60
5	Thickness Layer 1			2,59	2,75		
6	Top elevation of layer 2						+ 4,85
7	Thickness Layer 2			1,20	1,28		
8	Top elevation of layer 3						+3,57

Refer to the results of existing and plans above, comparison of the two conditions can be done to assess the needs in implementation of construction plan. Comparison between the plan and existing conditions such as in the following table:

Table 11. Dimensions crushed stone plan.

No	Parameter	Plan			Existing			Information
		weight (kg)	Dimension (m)	Elevation (m)	weight (kg)	Dimension (m)	Elevation (m)	
1	Weight of layer 1	3600			-			
2	Weight of layer 2	360			1411			
3	Weight of layer 3	10			1411			
4	Top elevation			+ 7,60			-	
5	Thickness Layer 1		2,75		-			
6	Top elevation of layer 2			+ 4,85			+4,59	lower 26 cm
7	Thickness Layer 2		1,28		1,20			
8	Top elevation of layer 3			+3,57			+3,30	

From the comparison, it can be seen that the elevation of top layer 2 to the existing condition is lower than planned (0.26 meters). Under these conditions adding sandbags as much as 1 layer to achieve elevation +4.85 meters can be done, or existing sandbags is pulled up to achieve elevation +4.85 meters with consequences core layer material plus is added or adding material as an additional second layer of crushed stone, to reach the elevation of +4.85.

Based on these two alternatives, to avoid damage to existing sandbags and ease of implementation, add a layer of crushed stone material is chosen

3.2.2. Tetrapod armor

From dimensions analysis of the building and plans obtained the following results.

Table 12. Tetrapod Alternative.

No	Parameter	Minimum weight		Minimum Dimension		Minimum Elevation	
		Analysis (kg)	Plan (kg)	Analysis (m)	Plan (m)	Analysis (m)	Plan (m)
1	Weight of layer 1	2741	2900				
2	Weight of layer 2	27,41	28				
3	Weight of layer 3	14,5	15				
4	Top elevation					+ 6,65	+ 6,79
5	Thickness Layer 1			2,20	2,20		
6	Top elevation of layer 2						+ 4,59
7	Thickness Layer 2			1,00	1,00		
8	Top elevation of layer 3						+3,59

Refer to the results of existing and plans above, comparison of the two conditions can be done to assess the needs in implementation of construction plan. Comparison between the plan and existing conditions such as in the following table.

Table 13. Tetrapod Dimension Plan.

No	Parameter	Plan			Existing			NB
		weight (kg)	Dimension (m)	Elevation (m)	weight (kg)	Dimension (m)	Elevation (m)	
1	Weight of layer 1	2900			-			
2	Weight of layer 2	28			1411			
3	Weight of layer 3	15			1411			
4	Top elevation			+ 6,79			-	
5	Thickness Layer 1		2,20		-			
6	Top elevation of layer 2			+ 4,59			+4,59	
7	Thickness Layer 2		1,00		1,20			
8	Top elevation of layer 3			+4,07			+3,39	

From the comparison, for the use of tetrapod armor types require only the addition of armor because of the elevation of the existing building and the weight of the existing material has been qualified to serve as second and third layer of protection structure.

3.2.3. Alternative Armor Coating Material A-jack

From dimensions analysis of the building and plans obtained the following results:

Table 14. A-jack Alternative.

No	Parameter	Minimum weight		Minimum Dimension		Minimum Elevation	
		Analysis (kg)	Plan (kg)	Analysis (m)	Plan (m)	Analysis (m)	Plan (m)
1	Weight of layer 1	876,91	1200				
2	Weight of layer 2	120	28				
3	Weight of layer 3	6	6				
4	Top elevation					+ 7,29	+ 7,29
5	Thickness Layer 1			1,57	3,00		
6	Top elevation of layer 2						+ 4,29
7	Thickness Layer 2			0,73	1,00		
8	Top elevation of layer 3						+3,29

Refer to the results of existing and plans above, a comparison of two conditions to assess the needs in the implementation of the construction plan can be done. Comparison between the plan and existing conditions such as in the following table:

Table 15. Dimension a-jack plan.

No	Parameter	Plan			Existing			NB
		Weight (kg)	Dimension (m)	Elevation (m)	Weight (kg)	Dimension (m)	Elevation (m)	
1	Weight of layer 1	1200			-			
2	Weight of layer 2	28			1411			
3	Weight of layer 3	6			1411			
4	Top elevation			+ 7,29			-	
5	Thickness Layer 1		3,00		-			
6	Top elevation of layer 2			+ 4,29			+4,59	
7	Thickness Layer 2		1,00		1,20			
8	Top elevation of layer 3			+3,29			+3,39	

From the comparison, the use of armor-jack type only requires the addition of armor because the elevation of the existing building and the weight of the existing material have been qualified to serve as second and third layer of protection structure.

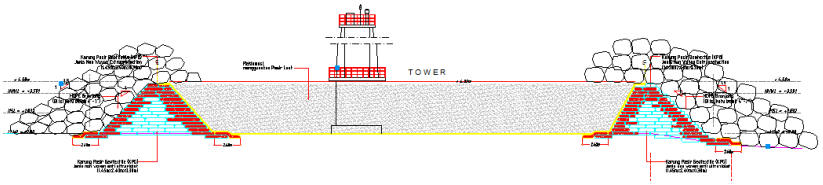

Fig. 7. Cross-section of the compilation of planning protection structure with crushed stone armor.

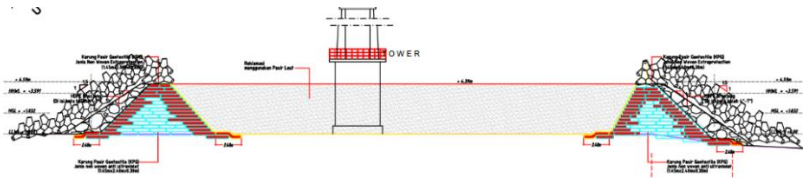

Fig. 8. Cross-section of the compilation of planning protection structure with tetrapod armor.

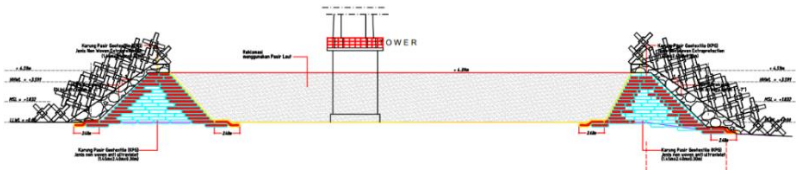

Fig. 9. Cross-section of the compilation of planning protection structure with a-jack armor.

3.3. Armor Material Comparison

In the selection of alternative materials to be selected as armor material for safety structure in Batu Berhanti Island is reviewed from several aspects between the availability of material factors, economic factors and the environment. Here we present some advantages and lack of alternative material 3 armor.

Table 16 Comparison between 3 types of armor layer.

No	**Evaluated Item**	**Rubble Mound**	**Tetrapod**	***A-Jack***
1	Availability of Materials	Ready from Karimun island	manufacturing	manufacturing
2	Durability	ok	ok	ok
3	Durability to corrosion	ok	ok	ok
4	Ease of implementation	easy	More difficult	More difficult
5	Environment impact	nothing	nothing	nothing
6	Aesthetics	good	good	good
7	Maintenance	More difficult	easy	More difficult

3.3.1. Budget Plan

When viewed in terms of economics, each material alternatives forming structure has a material prices and details vary according to the needs assessment of armor weight, material and dimensions of armor protectors. *Rencana Anggaran Biaya* (RAB) for three alternative material cost protection armor Batu Berhanti Island (unit price analysis attached) is:

No	Activities	Unit Price (Rp)	Rubble Mound Alternative			Tetrapod Alternative			A-jack Alternative		
			Volume	Unit	Total Price (Rp)	Volume	Unit	Total Price (Rp)	Volume	Unit	Total Price (Rp)
I	PREPARATION				Rp 20,000,000.00			Rp 20,000,000.00			Rp 20,000,000.00
1	Preparation	Rp 20,000,000.00	1.00	Ls	Rp 20,000,000.00	1.00	Ls	Rp 20,000,000.00	1.00	Ls	Rp 20,000,000.00
II	MOBILIZATION AND DEMOBILIZATION				Rp 80,000,000.00			Rp 80,000,000.00			Rp 80,000,000.00
1	Mobilization and Demobilization of Equipment and Personnel	Rp 80,000,000.00	1.00	Ls	Rp 80,000,000.00	1.00	Ls	Rp 80,000,000.00	1.00	Ls	Rp 80,000,000.00
III	MAIN WORKS				Rp 15,019,172,495.73			Rp 13,984,457,822.16			Rp 13,723,641,761.38
1	Procurement and Placement of A-jack	Rp 2,947,101.57	0.00	Unit	Rp -	0.00	Unit	Rp -	3913.00	Unit	Rp 11,532,008,454.90
2	Arrangement of Masonry	Rp 1,685,871.77	8848.67	m^3	Rp 14,917,730,843.73	1238.95	m^3	Rp 2,088,715,228.04	1300.00	m^3	Rp 2,191,633,306.48
3	Procurement and Placement of KPG extra protection	Rp 1,748,994.00	58.00	Unit	Rp 101,441,652.00	58.00	Unit	Rp 101,441,652.00	0.00	Unit	Rp -
4	Procurement and Placement of Tetrapod	Rp 6,142,865.07	0.00	Unit	Rp -	1920.00	Unit	Rp 11,794,300,942.12	0.00	Unit	Rp -
IV	OTHERS				Rp 3,500,000.00			Rp 3,500,000.00			Rp 3,500,000.00
1	Report, As-build Drawing, Documentation	Rp 3,500,000.00	1.00	Ls	Rp 3,500,000.00	1.00	Ls	Rp 3,500,000.00	1.00	Ls	Rp 3,500,000.00
Sum					Rp 15,122,672,495.73			Rp 14,087,957,822.16			Rp 13,827,141,761.38
Tax PPN					Rp 1,512,267,249.57			Rp 1,408,795,782.22			Rp 1,382,714,176.14
Total Sum					Rp 16,634,939,745.30			Rp 15,496,753,604.38			Rp 15,209,855,937.51
Rounded					Rp 16,634,939,745.00			Rp 15,496,753,604.00			Rp 15,209,855,937.00

4. Conclusion and Suggestion

4.1. Conclusion

The results, analysis, and discussion of the research can be summarized as follows:

- Base on analysis of wind data result, wind direction is dominantly from Northeast.
- From hind casting calculation, it is known that maximum wave height from 2001-2010 is 3.424 meter from north direction.
- From analysis, known that the cause of damage in protective structure in Batu Berhanti Island is lack of protective armor that serves to damp the blow of wave.
- To prevent widespread damage to protection structure, it is necessary to add protective armor structure such as crushed stone, tetrapod, and A-jack.
- Armor weight for crushed stone material is 3.6 Ton, for tetrapod armor 2.9 Ton and for A-jack armor material is 1 Ton with structure slope 1: 1.5.
- Factors for consideration in selecting alternative solution is:
    - Material Availability Onsite
    - Economy factor which is construction cost
    - Impact on environment
    - Methodology
- KPG materials can be used as a core for layer 2 and 3 because it meet the minimum requirements in terms of minimum armor weight and thickness for layer 2 and 3.
- Adding some extra armor as a solution with some alternatives in constituent material by comparison as follows:

No	Considerations factors	Stone Crushed	Tetrapod	A-Jack
1	Economic factor	More expensive	More expensive	cheaper
2	Environment impact	-	-	-
3	Availability of Materials	Ready from karimun island	manufacturing	manufacturing
4	Social impact	-	-	-

4.2. Suggestion

- Batu Berhanti Island is one of the outermost islands that limit the sovereignty of Indonesia, therefore it is recommended to construct protective armor immediately so the existence of Batu Berhanti Island can be maintained.
- Because the limited APBN, it is best for government to see the priority, so available budget can be used well and on target.
- Based on consideration of several factors including material availability, economic factor and environment impact, it is recommended to use A-jack material because the cost is cheaper, with lighter material will ease the implementation.
- Geotextille Sand Bag (KPG) should not be used as external structure (armor) as it can be easily damaged from external force.

References

CERC, 1984. Shore Protection Manual, US Army Coastal Engineering Research Center, Washington.

Kamphuis, 2002. J. William, Introduction to Coastal Engineering and Management, Allied Published Limited, Queen's University, Canada,.

Rais, J. et al, 2004. Menata Ruang Laut Terpadu, Percetakan Penebar Swadaya, Jakarta.

Reeve D., Chadwick A., & Fleming C., 2004. Coastal Engineering: Processes, Theory and Design Practice, Spon Press, Oxon, United Kingdom.

Sorensen, 2006 R.M., Basic Coastal Engineering, 3rd edition, Department of Civil and Environmental Engineering of Lehigh University, Bethlehem, Pennsylvania.

Sutikno, 1993. Karakteristik Bentuk dan Geologi di Indonesia, Diklat PU Wil. III. Dirjen Pengairan DPU, Yogyakarta.

Syamsidik, Iskandar, A., & Rasyif, T.M., 2014. Progress Of Coastal Line Rehabilitation After The Indian Ocean Tsunami Around Banda Aceh Coasts, Recovery from Indian Ocean Tsunami., Editor Shaw, Springer, Tokyo, pp175-189.

Triatmodjo, B., 1999. Teknik Pantai, Beta Offset, Yogyakarta.

Yuwono, N., 1986. Teknik Pantai, Volume I, Biro Penerbit Keluarga Mahasiswa Teknik Sipil Fakultas Teknik, Universitas Gajah Mada, Yogyakarta.

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

The 3rd SCESCM

Special Topics in Public Works Research and Technology

Causes of termination of contract in construction works in North Sumatera Province in Indonesia

Medy Juliana[a*], Sarwono Hardjomuljadi[b], Anton Soekiman[b], Hasan Basri[c]

[a]*Postgraduate Student in Construction Project Management, Parahyangan Catholic University, Bandung, West Java - Indonesia*
[b]*Lecturer in Postgraduate Programme in Civil Engineering,Parahyangan Catholic University, Bandung, West Java - Indonesia*
[c]*Staff in Center for Human Resource Development Region I Ministry of Public Works and Housing, Bandung, West Java - Indonesia*

Abstract

The termination of contract is the legal/allowed in the execution of construction contracts, but the termination of the contract is not an expected thing. From the observation of several cases of termination of the construction contract, it seemed that they have encountered some problems due to the termination of a construction contract that led to the dispute in court. This would be detrimental for the parties involved in the implementation of construction projects.

Based on these indicators, this research is conducted in order to identify factors causing the termination of construction contracts. Besides this, recommendations for action are proposed how to prevent the termination of the construction contract. This study is conducted using quantitative analysis, by doing the rating using the method of Relative Importance Index (RII), as well as doing Mann Whitney test to determine differences in perception between the parties.

The results of the ratings using RII show that there are five most dominant factors that cause termination of a construction contract. From the comparison of the ratings being made based on the answers of respondents is suspected there is a difference in perception between the parties. To test this indication Mann Whitney U Test is used in order to know how big the difference in perception between the parties are. The test results using Mann Whitney U Test showed that out of 38 factors that cause the termination of construction contracts, there are 16 factors that differ significantly between the perceptions of user and contractors. This is because the parties in North Sumatera Province in Indonesia have different interests.

In this study the sample of respondents was collected only from the service user and contractors. Therefore, in future research it is recommended to study the perception of the other stakeholders in order to know the perception of all parties involved in the construction project.

Keywords: Contracts; Termination; Contractors

1. Introduction

According to the Law on Construction Services No. 18/1999 article 1, paragraph (5), the construction work contract is the entire document that governs the legal relationship between service user and service providers in the implementation of construction work. In the process of implementation of construction services agreement, the possibility of occurrence of various barriers/constraints such as delays, negligence of one party (the default), either accidentally or because of force majeure is very likely to occured. A number of obstacles/constraints may impact on the additional project completion time, and on the additional project costs, even finally can also lead to the termination of the construction contract. Termination of the construction contract is not to be expected in a project implementation, due to termination of the contract reflects the discrepancy with the actual conditions in the contract terms. Besides that, the termination of a construction contract also potentially leads to disputes because of differences on their perceptions and those who feel aggrieved due to the termination of the construction contract. Therefore, the issue of termination of the construction contract is one important thing that deserves to be discussed, to provide a positive input to the implementation of construction projects in the future. This study was conducted to: (1) Identify the factors that led to the termination of construction contracts in general; (2) Finding the most dominant factors that causes the termination of construction contracts in the North Sumatra provincial government that serve as the object of study in this research; (3) Provide recommendations to prevent the termination of the construction contract.

This research is expected to provide benefits in the form of positive feedback for the implementation of government construction projects, particularly a better understanding of the problems of the termination of construction contracts in Indonesia especially in North Sumatra.

2. Literature Review

Garner (2004) state that: "*Contract is an agreement between two or more parties creating obligations that are enforceable or otherwise recognizable at law*" or "*a promise or set of promises by a party to a transaction, enforceable or otherwise recognizable at law*". Construction contracts differ from other types of contracts in general, as expressed by John Adriaanse (2007): "*A variety of factors makes a constructions contract different from most other types of contracts. These include the length of the project, its complexity, its size and the fact that the price agreed and the amount of work done may change as it proceeds*". With the enactment of a contract as a legal for both parties, the parties should comply with all agreed in the contract, and breach of contract may lead to legal action for the parties who breach.

2.1. Termination of Contract Construction

Termination of the contract is legitimate and allowed in the execution of construction contracts, but the termination of the contract is not an expected thing. In the case of termination of the contract, the losses will be experienced by the parties, i.e. service user and service providers. For service user, termination will have implications for the assessment of performance due to the lack of work and low realization of the budget. For service providers, the company's performance has implications for contract termination, material losses and other sanctions as included in the black list. Termination of contract may also result in disagreement or dispute between the providers with user that require solution through arbitration or requires settlement by the court and to avoid this, recommended that the contracting parties should strive as much as possible so that the contract is not terminated before completion.

In construction contracts, the parties may terminate the contract if one party is unable to perform its obligations. Law on Construction Services explained that the construction contracts shall contain provisions on termination of a contract arising from breach of obligation of one party. Furthermore, in the explanation of article 22 of Law Construction Services explained that the breach is a situation where one party to the contract of construction work:

- Not doing what is agreed; and/or
- Implement what is agreed , but not in accordance with the agreement; and/or
- Doing what is agreed , but too late; and/or
- Doing something that should not be done base on agreement.

Other source that can be used as a reference in the termination of the construction contract is FIDIC (*Federation Internationale des Ingenieurs-Conseils*). In FIDIC MDB Harmonized Edition (2006) and FIDIC EPC/Turn Key Project (1999) explained about the cause of termination of the contract, the obligation if it is to break the contract, as well as the rights due to termination of the contract, either by the user or the service provider.

2.1. Prior research Regarding Termination of Contract Construction

There are several sources of literature regarding the termination of the construction contract used in this study. Based on each literature from prior research the factors that cause the termination of construction contracts in general will be identified and then elaborated for further process. This will be done to determine the suitable factors that cause the termination of construction contracts for use in this study. Some of these sources include: El Kariri, A.A, et all. (2011), Elsawalhi, N.I dan Eid, K. A (2012), Enhassi, at all. (2006), Fuadi, M. (1998), Hardjomuljadi, S (2014), Putra, C. S. P (2015), Rauf, A.S.M (2012), and Wilson, S (2008).

3. Research Methods

3.1. Methods of Analysis

The method used in this research is descriptive analysis, using data from respondent. The data collected are then processed statistically using Relative Importance Index (RII). The objective is to rate the factors that are the most dominant causes for the termination of construction contracts. Next will be test to determine advanced statistical methods that suitable for use in this study. Therefore, in this test the normality of data and reliability of data is investigated. In this study, the validity test is done by using the formula Pearson Product Moment, while for reliability testing used Cronbach alpha formula.

The calculation result data is then analyzed based on rank of the factors from very not dominant till very dominant, according to the RII value range as shown in the Table 1 below .

Table 1. Rating for RII.

Range of Values for RII	Rate
0,834 – 1,000	Very Dominant
0,668 – 0,833	Dominant
0,501 – 0,667	Rather Dominant
0,334 – 0,500	Less Dominant
0,168 – 0,333	Not Dominant
0,000 – 0,167	Very Not Dominant

3.2. Identification and Codification Causes of Termination of Contract Construction

First, determination what factors causes the termination of contracts in government construction projects are summed up. Secondly, the process of identifying the causes of termination of the contract are obtained from secondary data. There are a number of factors were identified as factors that led to the termination of construction contracts in general. The results of initial identification got 123 factors obtained from references. Against these factors do the selection process, because there are several factors which not suitable for use in this research. From the results of the selection process gained 104 factors. The next process is the process of combining several factors that have meaning / purpose of the same. Result of the merger process factors obtained 40 factors. Furthermore, these factors are grouped and carried codification, as presented in Table 2 below.

4. Analysis and Discussion

4.1. Data and Respondents

Data success collected totaled 103 respondents with a composition of 38 respondents (37%) come from user service and 65 respondents (63%) come from service providers. Complete characteristics of respondents can be seen in figure 1 below, include work experience of respondent and their job position. The validity test performed using Pearson Product Moment produce 2 variables (A 17 and C 3) are invalid, so there are 38 valid variables. Meanwhile from reliability test using analysis Cronbach alpha indicates that all variables in the questionnaire can be declared reliable, so making it feasible to further analysis.

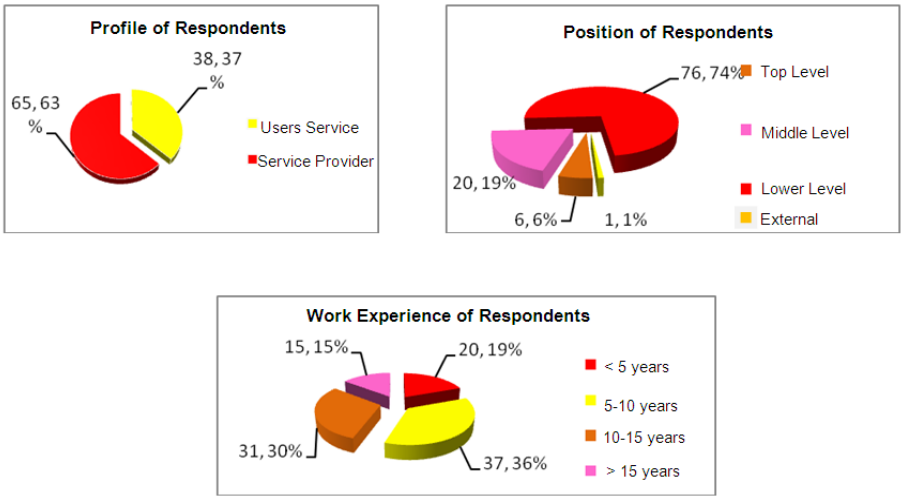

Fig. 1. Profile of Respondents, Work Experience, and Job Position.

Table 2. Factors Causes Termination of Contract Construction.

No	Factors Causes Termination of Contract Construction	Codification
I.	Internal Factor	
I. 1.	Service provider	
1	Service provider failed to maintain the enforceability of the guarantee implementation	A.1
2	Services Provider stop works/ ignore Works / delay works without the consent of Trustees or for no apparent reason	A.2
3	Service provider does not start works on appropriate starting date	A.3
4	Service provider failed to improve works / defect quality	A.4
5	Service provider subcontract the entire job	A.5
6	Service Provider bankrupt or insolvent	A.6
7	Service provider giving or offering bribe, gift, gratuity or commission	A.7
8	Penalty for delay of work execution due to service provider error has exceeded 5 % (five percent) of the contract value and the commitment maker officials (PPK) judge that the provider will not be able to complete the remaining work,	A.8
9	Service provider proven doing corruption, collusion and nepotism, and/or forgery in the procurement process that decided by the competent authority	A.9
10	Service provider is not able to complete the entire job until the specified time limit	A.10
11	Service providers encourage unhealthy competition	A.11
12	Service providers create and/or submitting incorrect documents and/or other information that is required for the preparation and execution of the contract.	A.12
13	Service provider lack experience in the field of the job	A.13
14	Errors in managing cash flow	A.14
15	Service provider shortage of capital	A.15
16	Service provider fails to make payment to the sub provider	A.16
17	The contract award is given to the lowest offer price	A.17
I. 2.	User Service	
1	User service fails to provide evidence of their financial arrangements to the contractor (if there is a request from the contractor)	B.1
2	Engineer failed to publish the Minutes of Payment	B.2
3	User service fails to comply with the terms of payment (late payment or not paying the proper amount)	B.3
4	User service fails to perform the contract agreement within 28 days after service provider receive appointment letter	B.4
5	User service perform the prolonged work stoppage	B.5
6	User service is insolvent or bankrupt	B.6
7	Service provider does not receive notification engineer to start work	B.7
8	User service giving the contract to a third party	B.8
9	User service does not convey design information with respect to execution of work	B.9
10	User service failed in land acquisition	B.10
11	User service interfere too much or hindering job of services provider	B.11
I.3.	Sharing	
1	All Parties fail to comply with the final decision of the dispute settlement	C.1
2	Errors in calculation of estimated costs	C.2
3	Low profits due to competition	C.3
II.	External Factors	
II.1.	Natural circumstances or environment	
1	The need of goods / services cannot be postponed till beyond the expiration of the contract limits	D.1
2	Bank stopping loans or credit which are used by user services to conduct a payment to service provider	D.2
3	Force majeure	D.3
4	The local government's decision that declared work must be stopped	D.4
5	Internal political issues, such as: rebellion, civil war	D.5
6	Limitations in imports	D.6
7	The increasing of material price	D.7
8	The location of projects in areas of conflict (dangerous)	D.8
9	Lack of resources	D.9

4.2. Factors Causes *Termination* of Contract

Factors causes termination of contract was analyzed using RII method against all variables from all data collected and produce the top 5 of factors as shown in Table 3.

Table 3. The Top 5 Factors Causes Termination of Contract

Code	Causes Termination of Contract	Value of RII	Ranking
A10	Service provider is not able to complete the entire job until the specified time limit	0,704	1
B10	User service failed in land acquisition	0,701	2
A8	Penalty for delay of work execution due to service provider error has exceeded 5% (five percent) of the contract value.	0,672	3
A2	Services Provider stop works/ ignore Works / delay works without the consent of Trustees or for no apparent reason	0,670	4
D3	Force majeure	0,668	5

When explored further, it turns out there is a difference in perception between service user and service providers of the factors that cause the termination of the contract, especially in the rank order of the top five factors . In the rank of top 5 factors there are only 2 of the same factors, although with different rank order, that is: (1) User service failed in land acquisition and (2) Service provider is not able to complete the entire job until the specified time limit. RII calculation results to rank the top 5 dominant cause of the termination of the contract based on user service's perception can be seen in the Table 4 below.

Table 4. The Top 5 Factors Causes Termination of Contract Based on User Service's Perception.

Code	Causes Termination of Contract	Value of RII	Ranking
A10	Service provider is not able to complete the entire job until the specified time limit	0,754	1
A8	Penalty for delay of work execution due to service provider error has exceeded 5 % (five percent) of the contract value and the commitment maker officials (PPK)	0,741	2
D3	Force majeure	0,711	3
A4	Service provider failed to improve works / defect quality	0,706	4
B10	User service failed in land acquisition	0,684	5

Meanwhile, RII calculation results to rank the top 5 dominant cause of the termination of the contract based on service provider's perception can be seen in the Table 5 below.

Table 5. The Top 5 Factors Causes Termination of Contract Based on Service Provider's Perception.

Code	Causes Termination of Contract	Value of RII	Ranking
B10	User service failed in land acquisition	0,710	1
B11	User service interfere too much or hindering job of services provider	0,695	2
B5	User service perform the prolonged work stoppage	0,687	3
A2	Services Provider stop works/ ignore Works / delay works without the consent of Trustees or for no apparent reason	0,679	4
A10	Service provider is not able to complete the entire job until the specified time limit	0,674	5

4.3. Comparison Test for Respondents' Perception

Furthermore, based on the indication of different perception was done test difference in perception. Because normality analysis of the data shows that the data are not normally distributed, then the appropriate statistical test is a nonparametric statistical test for two independent samples using the Mann Whitney U test against each variable cause termination of the construction contract. Hypothesis used in this test are:

Ho = There is no significant differences between respondents' perceptions of user service and service providers

H_1 = There is significant differences between respondents' perceptions of user service and service providers.

The results of the Mann Whitney U test can be seen in table 6 below and the conclusions made base on asymptotic significance value as follow:

- If Asymptotic Significance ≥ 0.05 than Ho accepted, H_1 rejected
- If Asymptotic Significance < 0.05 than Ho accepted, H_1 rejected

The result of Mann-Whitney U test shown that from 38 variables tested, there are 16 variables or 42.11% significantly different, or in other words, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted for 16 variables. This means that there is a difference of perception between user service and service providers against cause termination of contract.

Table 6. The Result of Mann Whitney U test on the Perception between Service User and Service Providers.

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
A4	760,000	2905,000	-3,345	0,001
A8	834,500	2979,500	-2,827	0,005
A10	858,000	3003,000	-2,670	0,008
A11	823,500	2968,500	-2,889	0,004
B1	949,000	1690,000	-2,003	0,045
B2	734,500	1475,500	-3,509	0,000
B3	692,500	1433,500	-3,812	0,000
B4	937,000	1678,000	-2,085	0,037
B5	731,000	1472,000	-3,578	0,000
B6	661,500	1402,500	-4,001	0,000
B11	680,000	1421,000	-3,904	0,000
C2	924,000	1665,000	-2,175	0,030
D2	784,500	1525,500	-3,159	0,002
D5	809,500	1550,500	-2,970	0,003
D8	784,500	1525,500	-3,163	0,002
D9	849,500	1590,500	-2,697	0,007

4.4. Discussion

Based on the analysis, there are 5 factors having value of RII $\geqslant$ 0,668 and indicated that there are 5 factors categorized as dominant factors causes termination of contract. The five factors are: (1) Service provider is not able to complete the entire job until the specified time limit, (2) User service failed in land acquisition, (3) Penalty for delay of work execution due to service provider error has exceeded 5% (five percent) of the contract value and the commitment maker officials (PPK) judge that the provider will not be able to complete the remaining work, (4) Services provider stop works/ ignore works / delay works without the consent of trustees or for no apparent reason, and (5) Force majeure.

Then based on dominant factors causes termination of the construction contract, it can be further analyzed the root causes and preventive measures that can be undertaken by all parties and stakeholders so that the construction can be done better and can avoid construction disputes.

4.4.1. Service Provider is Not Able to Complete the Entire Job until the Specified Time Limit

In regulation by the Minister of Public Works of the Republic of Indonesia Number: 14/PRT/M/2013 about Changes in Regulation of the Minister of Public Works Number: 07/PRT/M/2011 about Standard and Guidelines for Procurement of Works Construction and Consulting Services, mentioned in Book Standard PK 01 joint article 43.3 (d), that the service user can terminate the contract unilaterally, if:

- The goods/services cannot be postponed beyond the expiration of the contract limits
- Base on observation by the commitment maker officials (PPK), goods/services provider will not be able to complete the entire job although given the opportunity to 50 (fifty) calendar days after the expiration of the implementation of work to finish the job; and/or
- After being given the chance to complete a job up to fifty (50) calendar days after the expiration of the implementation work, goods/services provider were unable to complete the job

Unilateral termination of contract can be done if the previous action has been taken to handle critical contract. In the critical contract handling actions (article 43.2 and 43.3) service providers have been given the opportunity to finish the job. However, if the service provider is not able to complete the work by the deadline that has been determined, the user service can immediately terminate the contract.

Based on the explanation above, it should be noted that to anticipate the termination of the contract, one has to make use of critical contracts. But if service providers remain were unable to finish the job until the specified time limit, the possible cause of the problem is not just due to improper service providers, but could have been caused by user service error. Things might be a

mistake by services provider is a matter of poor management by the service provider, such as problem in financial contractor's, the unavailability of equipment, unavailability of resources, etc. To anticipate those things, contractor should improve the management system in the company, by improving the competence of every worker, in order to perform their jobs better. Things may be a user services error is changes in the design and error in execution time estimation. To anticipate these problems user service should prepare the planning in detail and accurate, as well as perform estimation the implementation time accurately.

4.4.2. User service Failed in Land Acquisition

Base on FIDIC MDB Harmonized Edition 2006 clause 2.1, service users must give to the contractor to enter and mastery the field in the time specified in the contract. If the contractor has the delayed and / or bear the cost as a result of failure user services provide and prepare the location or giving mastery the field within the stipulated time, the contractor is entitled to submit an extension of time for the delay, as well as the payment of costs plus profit, which must be incorporated into the contract price.

Ideally the land acquisition process should be done before bidding process of the works. But sometimes with consideration to safe time, the implementation of land acquisition is carried out at the same time as the implementation of the project. If the implementation of land acquisition is delayed, it will have an impact on project implementation delays and additional cost of implementing the project. In the worst case this can lead to a termination of the contract. In anticipation of this, you should avoid the implementation of the project before land acquisition process has been completed, because the uncertainty of the time of the completion of the land acquisition would be at risk of harm to all parties. As a recommendation in the process of land acquisition, one should prepare and note the following:

- User service should approach the landowners, especially by studying and understanding the local culture.
- Approach to the public can also be done with the involvement of community leaders in the area.
- In the case of money compensation to the land-owners, should be done in an honest and transparent, and explain the importance of the project for the common good, so that people can understand and be willing to relinquish the right of their land.

4.4.3. Penalty for Delay of Work Execution Due to Service Provider Error has Exceeded 5% (Five Percent) of the Contract Value and the Commitment Maker Officials (PPK) Judge that the Service Provider will not be able to Complete the Remaining Work

In regulation by the Minister of Public Works of the Republic of Indonesia Number: 14/PRT/M/2013 about Changes in Regulation of the Minister of Public Works Number: 07/PRT/M/2011 about Standard and Guidelines for Procurement of Works Construction and Consulting Services, mentioned in Book Standard PK 01 joint article 42.4 (g), that the user service can terminate the contract by notice in writing with reasons that penalty for delay execution of the work has exceeded to 5% (five percent) of the contract value and the Commitment Maker Officials (PPK) judge that the service provider will not be able to complete the remaining work.

Service providers are subject to a fine if the work is not completed on the completion date and is not a result of force majeure or a compensation event or for errors or omissions service provider (article 28.2). No fines subject to the provider if the settlement date agreed by the parties to be extended (article 28.3). In the event that payment of the fine, in article 59 states that the Commitment Maker Officials (PPK) wearing fines by cutting payment installments service provider. The penalty does not reduce the responsibility of the contractual provider.

Based on the above explanation it is clear that the cause of this problem is the fault of the service providers themselves. Things might become the error of service provider is a problem of poor management by the service provider, such as a problem in contractor's finances, lack of equipment, lack of resources, etc. To anticipate those things, the contractor must repair system of work management, such as equipment selection and planning of the schedule, perform financial arrangements well, providing manpower according to the needs, and avoiding rework due to quality defects.

4.4.4. Services Provider Stop Works/ Ignore Works / Delay Works without the Consent of Trustees or for no Apparent Reason

In regulation by the Minister of Public Works of the Republic of Indonesia Number: 14/PRT/M/2013 about Changes in Regulation of the Minister of Public Works Number: 07/PRT/M/2011 about Standard and Guidelines for Procurement of Works Construction and Consulting Services, mentioned in Book Standard PK 01 joint article 42.4 (c), that the service user can terminate the contract by written notice if the providers stop work for 28 (twenty eight) days and the termination is not listed in the quality program and without the approval of the job supervisor.

Base on FIDIC MDB Harmonized Edition 2006 clause 15.2 (b), mentioned that user service having the right to terminate the contract if the contractor neglects work or clearly showed the intention not to continue the implementation of its obligations under the contract. The same thing is also mentioned in FIDIC EPC/Turn Key Project 1999.

Actions of service providers who stop/ignore/suspend work without permission or no obvious reason is very detrimental to the service users. The action of these providers can be caused by many things, for example service providers having financial difficulties or error in managing cash flow and making it difficult to continue the implementation of the project. However, any action to stop/ignore/delay work like this will only hurt their own service provider, because the service provider will get the achievement that is not good due to his own mistakes. As much as possible service providers must keep to attempt to settle its obligations to complete the project activities.

To anticipate those problems, the following things needs to be observed:

- Providers should prepare the enough capital before carrying out a construction project. Sufficient capital greatly affects the smooth r u n n i n g of the project, so providers will not experience financial difficulties when carrying out their work
- Ability in managing cash flow by service providers is also very influential in the smooth implementation of the project
- User services must make selection correctly at the time of auction. Recommend that you choose a provider that has good credibility for the success of the project

5. Force Majeure

In regulation by the Minister of Public Works of the Republic of Indonesia Number: 14/PRT/M/2013 about Changes in Regulation of the Minister of Public Works Number: 07/PRT/M/2011 about Standard and Guidelines for Procurement of Works Construction and Consulting Services, mentioned in Book Standard PK 01 joint article 41.6, that in the case of the occurrence of force majeure, the contract shall be suspended until the force majeure ends with the provisions, the provider is entitled to receive payment in accordance with achievement or progress of implementation of the work that has been achieved. If in the time of force majeure, the Commitment Maker Officials (PPK) give orders in writing to the service provider to continue the work as far as possible, the service provider is entitled to receive payment as specified in the contract and be reimbursed reasonable costs in accordance with the previously issued to work in force majeure situations. Reimbursed costs shall be regulated in a contract addendum. In clausal 41.2 mentioned that the event that can be classified as force majeure include: natural disasters, non-natural disasters, social disasters, strikes, fires, and/or other industrial disorders as expressed through a joint decree among Ministry of Finance another relevant ministry.

From the above explanation, it can be concluded that the force majeure is an extraordinary event caused by external circumstances, which is beyond the power of the parties. Force majeure is a condition that cannot be avoided or prevented, because these problems are caused by environmental or beyond the control of the parties.

6. Conclusions and Recommendations

Based on the analysis performed, we can conclude:

- Based on identification, in general there are 38 factors that cause the termination of government construction contracts and was obtained five (5) most dominant factors that cause the termination of construction contracts in the Provincial Government of North Sumatra:
    - Service Provider is not able to complete the entire job until the specified time limit
    - Service User failed in land acquisition
    - Penalty for delay of implementation work because of errors Service Provider has exceeded 5% of the contract value and the commitment maker officials (PPK) judge that the provider will not be able to complete the remaining work
    - Service provider stop/ignore/suspend work without supervisor approval or for no apparent reason
    - Force Majeure
- There is a difference perception between the service user and service provider. Each party assumes that the cause of the termination of the contract was not caused by factors that are under his control.
- Based on the result analysis and discussion, some recommendations are proposed for action that can be taken to prevent the termination of the construction contract:
    - To anticipate the failure of the service providers in completing the work, then the provider should improve the management system in the company; improve the competence of every worker in order to perform their jobs better. While the user should do the planning in detail, as well as calculating the estimate of execution time more accurately
    - To anticipate the user's failure in land acquisition, then it should be a cultural approach to the community by involving community leaders for the socialization of the land acquisition benefits that received by communities and Land owners
    - In anticipation of service providers doing stop/ignore/delay the work, then the service provider should do better selection at the time of the auction, by choosing a provider that has good credibility

- In this study the sample of respondents was collected only from the service user and contractors. Therefore, in future research it is recommended to study the perception of the other stakeholders in order to know the perception of all parties involved in the construction project.

References

Bryan A. Garner, 2004, Black's Law Dictionary, Thomson West in Sarwono Hardjomuljadi.

El Karriri, A.A., et all, 2011, Investigating Key Drivers For Contract Termination in Construction Projects in the Gaza Strip, The Islamic University Journal, Vol. 19, No. 1, pp 179-195.

Elsawalhi, N.I. and Eid, K.A., 2012, Factors Affecting Termination of Construction Contracts, The 4th International Engineering Conference – Towards engineering of 21st century, pp. 16.

Enhassi, A., et all., 2006, Causes of Contractor's Business Failure in Developing Countries: The Case of Palestine, Journal of Construction in Developing Countries, Vol. 11, No. 2.

FIDIC EPC/ Turn Key Project, 1999.

FIDIC MDB Harmonised Edition, 2006.

Fuadi, M., 1998, Kontrak Pemborongan Mega Proyek, PT. Citra Aditya Bakti, Bandung.

Hardjomuljadi, S., 2014, Practical Use of FIDIC Conditions Contract – Risk, Force Majeure & Termination, National Seminar - Construction Contract, Bandung.

Hardjomuljadi, S., 2014, Factor Analysis on Causal of Construction Claims and Disputes in Indonesia (with reference to the construction of hydroelectric power project in Indonesia)", International Journal of Applied Engineering Research, ISSN 0973-4562, Volume 9, November 22, pp. 12421-12445.

John Adriaanse, 2007, "Construction Contract Law: The Essentials" in Sarwono Hardjomuljadi.

Putra, C.S.P., 2015, Pemutusan Perjanjian Secara Sepihak Oleh Pengguna Jasa Konstruksi Dalam Perjanjian Pemborongan Pekerjaan Dengan Penyedia Jasa Konstruksi, Artikel Ilmiah, Universitas Brawijaya, pp. 6-7.

Rauf, A.M.S., 2012, Analisis Faktor-Faktor Penyebab Pemutusan Hubungan Kontrak Di Lingkungan Kementerian Pekerjaan Umum, Tesis, Universitas Katolik Parahyangan, Bandung, pp. 48.

Wilson, S., 2008, Terminating Contracts, Journal of Building Appraisal, Vol. 4 No. 3, pp 225-230.

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

The 3rd SCESCM

Special Topics in Public Works Research and Technology

Bridge maintenance priority based on load rating factor criteria: a study case

Tasman Hidayat[a], S.A. Kristiawan[a], Budi Yulianto[a]

[a]*Department of Civil Engineering, Faculty of Engineering, Sebelas Maret University, Ir Sutarni 36A, Surakarta 57126, Indonesia*

Abstract

Bridge damage will lead to disfunctioning of the road network, unsmooth traffic flow, blocked regional development, interrupted traffic transportation of goods and services resulting in delay of welfare and economic growth. When assessing the bridge condition, monitoring system has been depended on the results of visual observation while the influence of vehicle load on the total bridge load has been ignored. The heaviest vehicle passing the bridge will affect the safety index value of the bridge. If the bridge safety factor is not eligible, immediate effort has to made to increase the bridge capacity. Thus the bridge safety assessment could be a major criteria for concerning which bridge should be prioritized for strengthening. In this study, bridge safety assessment will be conducted by using the Load Rating Factor calculation. The obtained Load Rating Factor will be used to establish which bridge should be a priority for repairing. Results from this study is that there are five (5) unsafe bridges to be passed by the heaviest vehicles that will strengthening.

Keywords: bridge; Load Rating factor; maintenance

1. Introduction

Bengkulu province is directly adjacent to the Indonesia ocean on a coastline of approximately 525 kilometers. Eastern part is hilly with fertile plateaus, while the western part is a lowland that relatively narrow, elongated from north to south interspersed by bumpy area.

As geographical circumstances as mentioned above, resulting to be a lot of river and valley encountered that divide the Bengkulu province. The consequence of this situation is the number of the road network in the province of Bengkulu that is connected by a bridge.

Bridge Infrastructure in a road network is the main support in creating the public welfare and the major support for the smooth traffic transportation of the goods and services, so that the existence of the bridge must always be maintained in a good state, steady and adequate and will have an optimal service traffic. If the bridge damage is not repaired immediately, this will result the road network is not functioning properly, traffic flows is not running smoothly, regional development becomes blocked, traffic transportation of goods and services is interrupted, so that the public welfare and economic growth will be delayed.

For national roads in the Bengkulu province, SNVT *Perencanaan dan Pengawasan Jalan Nasional* (P2JN) in Bengkulu province was using the Bridge Management System (BMS) for bridge condition data processing on national road in Bengkulu province. Each bridge handling was done, always wear a priority scale based on the condition of the bridge.

During this time, the bridge condition assessment based solely on visual observation alone. Based on the current condition of the bridge, the visual observation could not be the only variable of bridge condition assessment. Lots of bridge on the national road segment of Bengkulu province were damaged namely the collapsing slab bridge and girder bridge is cracked. Such damage was usually caused by a vehicle passing through the bridge that did not has an eligible load value that can be borne by the bridge. We all know that the vehicle capacity at this time is developing so rapidly. Increased traffic load (traffic volume) resulted in the increasing burden of serviceability of the bridge, which in turn can cause damage to the bridge structure. To determine bridge load limit value on vehicle load, we can use a method by evaluating load value (Load Rating). During this time, the load value (Load Rating) and loading limit for the heaviest vehicles through the bridge were almost never be considered as one of the variables in determining the bridge management priority. As a result, there will be a very fatal damage to the bridge structure due to the vehicle load that passing the bridge, which in turn has disrupted the access road on National Highway sections in Bengkulu Province.

Based on the above facts, this study aims to determine whether the heaviest vehicles crossing the bridge located in Bengkulu Province National roads meet the restrictions of the bridge load itself.

2. Research Method

The location study is planned on 20 steel frame bridges, which are located in several national roads in the Bengkulu province. Bridges data were obtained from relevant agencies, in this case, SNVT *Perencanaan dan Pengawasan Jalan Nasional* of Bengkulu province as a responsible survey of the bridge condition on National Highway sections in Bengkulu. Besides this, the actual load data that crossing the bridge is a direct observation to the field. Especially observation about types of heavy vehicles passing on the bridge are considered being the object of research. Further calculation was done by using Load Rating Factor in each bridge, and done by referring to the *Peraturan Perencanaan Teknik Jembatan* in 1992 issued by the Ministry of Public Works. Determining the load rating factor consists of several steps:

- Bridge Load Assessment
- Bridge Condition Factor Determining
- Total Load Assessment
- Equivalent Load Factor
- Safety factor

3. Result and Discussion

3.1 Heaviest Vehicle Load Calculation

From the direct observation result conducted on heavy vehicles passing on the road section of Bengkulu Province National road showed that the type of the heaviest vehicles passing through is coal and oil palm fruit vehicle. Weight combination of heavy vehicles passing in the segment of National Road if Bengkulu Province based on *Surat Edaran Direktur Jenderal Perhubungan Darat Kementerian Perhubungan* in 2008, could be seen in Table 1.

Table 1. Coal truck overload scenario.

No.	Vehicle Type	Axis configuration	MST Max	
			Class road II	Class road III
1.	Trucks transporting oil palm fruit	1.2	12 Ton	10 Ton
2.	Truck transporting coal	1.2	12 Ton	10 Ton
3.	Fuso Truck transporting coal	1.2	16 Ton	14 Ton

To determine the weight of the vehicle, then the first step is to calculate the volume of the vehicle tanks. tailgate volume can be calculated by the formula:

$$V = P\ x\ L\ x\ T \quad (1)$$

The result of the truck volume calculation for heavy vehicles passing on National Road segment is shown in Table 2.

Table 2. Truck Volume Calculation.

No.	Vehicle Type	Length (m)	Width (m)	High (m)	Volume (m^3)
1.	Trucks transporting oil palm fruit	4.3	2	1.25	10.75
2.	Truck transporting coal	4	2	1.3	10.4
3.	Fuso Truck transporting coal	4.8	2.3	1.5	16.56

To convert units of cubic meters to tons, it is necessary to know the density of the mass being transported by the vehicle. In this case, the mass transported is coal. The density of coal is known by 1346 kg/m^3, while the density of the palm fruit is 626.5 kg/m^3 (Damhir Anugrah, 2012).

The relationship between the volume of the truck with a load calculated by the formula below.

$$Density = (Weight\ of\ the\ cargo)/(Vehicle\ volume\ load) \quad (2)$$

Thus obtained the heavy vehicle of the cargo weight calculation passing in Bengkulu Province National Road segment as shown in Table 3 below.

Table 3. Weight of the cargo calculation.

No.	Vehicle type	Truck volume (m^3)	Cargo density (ton/m^3)	Cargo weight (ton)
1.	Trucks transporting oil palm fruit	10.75	0.6265	6.734875
2.	Truck transporting coal	10.4	1.346	13.3584
3.	Fuso Truck transporting coal	16.56	1.346	22.28976

Coal and oil palm fruit transported by truck always be higher than the truck. In this study, assumed that coal and oil palm fruit exceeding a maximum of 20 cm, so made a scenario by every 10 cm higher from the height of the truck.

Here is a scenario from the cargo truck overload:

- Scenario charge over 1 (one), the weight of coal is at the point of 0 (zero) cm, which means the charge is in accordance with the height of the truck.
- Scenario charge over 2 (two), the charge of coal is at a point 10 cm above the height of the truck.
- Scenario charge over 3 (three), the charge of coal is at a point 20 cm above the height of the truck.

From the above scenario, it can be calculated the overload transported by truck. The results of calculation of any kind of overloaded heavy vehicles can be seen in Table 4.

Table 4. Vehicle Weight Mass Calculation.

No.	Vehicle type	Length (m)	Width (m)	Height (m)	Volume (m^3)	Density (ton/m^3)	Weight Load (kN)
Scenario 1 (0 cm)							
1.	Trucks transporting oil palm fruit	4.3	2	1.25	10.75	0.6265	66.00178
2.	Truck transporting coal	4	2	1.3	15.2	1.346	137.1843
3.	Fuso Truck transporting coal	4.8	2.3	1.5	16.56	1.346	218.4396
Scenario 2 (10 cm)							
1.	Trucks transporting oil palm fruit	4.3	2	1.35	11.61	0.6265	71.28192
2.	Truck transporting coal	4	2	1.4	11.2	1.346	147.737
3.	Fuso Truck transporting coal	4.8	2.3	1.6	17.664	1.346	233.0023
Scenario 3 (20 cm)							
1.	Trucks transporting oil palm fruit	4	2	1.45	76.5621	0.6265	76.5621
2.	Truck transporting coal	4	2	1.5	12	1.346	158.2896
3.	Fuso Truck transporting coal	7	2.4	1.7	18.768	1.346	247.5649

After obtained the weight of cargo trucks that became the object of research, the next step is to determine the Maximum Payload Heaviest Axis (MST Max). MST Max is the sum of the empty weight of the vehicle and weight of cargo from vehicles. Max MST calculation results can be seen in Table 5.

Table 5. MST Max Calculation.

No.	Vehicle Type	Empty weight (kN)	Cargo weight (kN)	MST Max (kN)
Scenario 1				
1.	Trucks transporting oil palm fruit	23.128	66.00178	89.1298
2.	Truck transporting coal	23.128	137.1843	160.3123
3.	Fuso Truck transporting coal	44.982	218.4396	263.4216
Scenario 2				
1.	Trucks transporting oil palm fruit	23.128	71.28192	94.4099
2.	Truck transporting coal	23.128	147.737	170.865
3.	Fuso Truck transporting coal	44.982	233.0023	277.9843
Scenario 3				
1.	Trucks transporting oil palm fruit	23.128	76.5621	99.6901
2.	Truck transporting coal	23.128	158.2896	181.4176
3.	Fuso Truck transporting coal	44.982	247.5649	292.5469

3.2 Load Rating factor Calculation

In this study, we will try to do the calculation of load rating of 20 steel frame bridges on national roads in Bengkulu province. The steel frame become a research priority because of the location of the Bengkulu Province is geographically located in the western region of the island of Sumatra that is directly adjacent to the Indian Ocean.

The position of national roads in the Bengkulu province that extends along the coast will make a bridge with steel frame construction a very vulnerable to damage, especially damage due to corrosion. Under these conditions, this research tries to focus on the steel frame bridge research.

A total of 20 steel frame bridge will be the object of research, which is located scattered in various national roads in the Bengkulu province. The bridge selected as the research object consists of a bridge which has a value of general conditions 2, 3 and 4, which means that require the routine management, periodic or duplication. The majority of the bridge condition is quite alarming as a result of the framework conditions that had experienced severe corrosion.

Steel frame bridge that becomes the object of the research can be seen in Table 6 below.

Table 6. List of Steel Frame Bridge as the object of the research.

No.	Road	Bridge number	Bridge Name	Length	Span number	Year of construction
1.	Border of Prov Sumbar – Muko muko	13.001.014.0	Menjunto	102.90	2	1991
2.	Muko-muko - Bantal	13.002.012.0	Pelokan	46.10	1	1991
3.	Muko-muko - Bantal	13.002.008.0	Dikit Penarik	91.30	2	1991
4.	Bantal - Ipuh	13.003.001.0	Pisang	36.50	1	1992
5.	Ipuh - sebelat	13.004.003.0	Senabah	40.00	1	1984
6.	Ipuh - sebelat	13.004.005.0	Kelikut	41.50	1	1991
7.	Ipuh - sebelat	13.004.029.0	Ipuh	145.00	3	1991
8.	Sebelat - Ketahun	13.005.008.0	Karang Pulau Beasr	45.00	1	1991
9.	Ketahun - Ds.Air Limas - Bintunan	13.006.005.0	Serangai	60.00	1	1992
10.	Bintunan - Lais	13.007.002.0	Padang	46.40	1	1991
11.	Betungan - Tais	13.018.001.0	Tanjung Aur	51.20	1	1983
12.	Tais - Maras	13.019.025.0	Maras A	40.00	1	2008
13.	Sp.Rukis - Tj.Kemuning	13.021.008.0	Martam	46.00	1	1991
14.	Tj.Kemuning - Linau	13.022.002.0	Kinal	143.80	3	1993
15.	Tj.Kemuning - Linau	13.022.003.B	Ilik B	50.00	1	1993
16.	Tj.Kemuning - Linau	13.022.007.B	Tetap B	60.00	1	1998
17.	Linau – Bts.Lampung	13.023.005.0	Muara Nasal	97.80	2	1988
18.	Linau – Bts.Lampung	13.023.011.0	Kolik II	60.00	1	1988
19.	Linau – Bts.Lampung	13.023.020.0	Manulah	95.00	2	1992
20.	Sp.Taba Mulan – Bts.Kota Curup	13.026.001.0	Merah	36.00	1	1979

3.2.1 Bridge Nominal Load calculation

Nominal load measurement is a measure of bridge load capacity to bear the standard load. In general, accounted for two nominal load ratings of each bridge, one for building up, and the second is the span support system. The third nominal load rating may be required is for the substructure, if there is a weakness on the part of the bridge (*Peraturan Perencanaan Teknik Jembatan, Direktorat Jenderal Bina Marga*, 1992).

In this research, bridge as an object research constructed in above 1970 or according to the *spesifikasi pembebanan Bina Marga* in 1970. Nominal load rating for the upper building based on *spesifikasi pembebanan Bina Marga* in 1970 is 100%, will have a nominal load rating Qs, according to the diagram about determination of nominal load for bridges with spans $\leqslant$ 40 m and span > 40 m contained in the *Peraturan Perencanaan Teknik Jembatan 1992*.

List of nominal load values for bridge object research can be seen in Table 7.

Table 7. Nominal load value of upper building.

No.	Road	Bridge number	Bridge Name	Lenght	Year of construction	Nominal load Qs (%)
1.	Border of. Prov Sumbar – Muko muko	13.001.014.0	Menjunto	102.90	1991	113
2.	Muko-muko - Bantal	13.002.008.0	Dikit Penarik	91.30	1991	111
3.	Muko-muko - Bantal	13.002.012.0	Pelokan	46.10	1991	104
4.	Bantal - Ipuh	13.003.001.0	Pisang	36.50	1992	101
5.	Ipuh - sebelat	13.004.003.0	Senabah	40.00	1984	102
6.	Ipuh - sebelat	13.004.005.0	Kelikut	41.50	1991	103
7.	Ipuh - sebelat	13.004.029.0	Ipuh	145.00	1991	116
8.	Sebelat - Ketahun	13.005.008.0	Karang Pulau Beasr	45.00	1991	104
9.	Ketahun - Ds.Air Limas - Bintunan	13.006.005.0	Serangai	60.00	1992	103
10.	Bintunan - Lais	13.007.002.0	Padang	46.40	1991	104
11.	Betungan - Tais	13.018.001.0	Tanjung Aur	51.20	1983	105
12.	Tais - Maras	13.019.025.0	Maras A	40.00	2008	102
13.	Sp.Rukis - Tj.Kemuning	13.021.008.0	Martam	46.00	1991	104
14.	Tj.Kemuning - Linau	13.022.002.0	Kinal	143.80	1993	116
15.	Tj.Kemuning - Linau	13.022.003.B	Ilik B	50.00	1993	104
16.	Tj.Kemuning - Linau	13.022.007.B	Tetap B	60.00	1998	103
17.	Linau – Bts.Lampung	13.023.005.0	Muara Nasal	97.80	1988	112
18.	Linau – Bts.Lampung	13.023.011.0	Kolik II	60.00	1988	103
19.	Linau – Bts.Lampung	13.023.020.0	Manulah	95.00	1992	102
20.	Sp.Taba Mulan – Bts.Kota Curup	13.026.001.0	Merah	36.00	1979	101

3.2.2 Bridge Condition Factor

At this stage, there will be an assessment of bridge condition survey conducted periodically every once a year. The old bridge should be inspected periodically to determine the level of any damage or destruction of the components.

Building condition factor on a bridge, F_{KS}, can be obtained from Table 8.

Table 8. Condition and association between condition factor.

Condition Mark from Ref. C	FKS
0	1.00
1	1.00
2	0.90
3	0.70
4	0.30
5	0

Source: *Peraturan Perencanaan Teknik Jembatan (Dirjen Bina Marga)*

Based on the condition of a bridge that becomes the object of study, from the results of periodic surveys, we will obtain the building condition factor based on Table 8 above. The bridge condition factor in the object research can be seen in Table 9.

Table 9. Upper building condition factor in bridge object research.

No.	Road	Bridge number	Bridge name	Upper building condition value	Condition factor Fks
1.	Border of Prov Sumbar – Muko muko	13.001.014.0	Menjunto	2	0.90
2.	Muko-muko - Bantal	13.002.008.0	Dikit Penarik	2	0.90
3.	Muko-muko - Bantal	13.002.012.0	Pelokan	4	0.30
4.	Bantal - Ipuh	13.003.001.0	Pisang	2	0.90
5.	Ipuh - sebelat	13.004.003.0	Senabah	3	0.70
6.	Ipuh - sebelat	13.004.005.0	Kelikut	3	0.70
7.	Ipuh - sebelat	13.004.029.0	Ipuh	3	0.70
8.	Sebelat - Ketahun	13.005.008.0	Karang Pulau Besar	4	0.30
9.	Ketahun - Ds.Air Limas - Bintunan	13.006.005.0	Serangai	3	0.70
10.	Bintunan - Lais	13.007.002.0	Padang	4	0.30
11.	Betungan - Tais	13.018.001.0	Tanjung Aur	2	0.90
12.	Tais - Maras	13.019.025.0	Maras A	2	0.90
13.	Sp.Rukis - Tj.Kemuning	13.021.008.0	Martam	3	0.70
14.	Tj.Kemuning - Linau	13.022.002.0	Kinal	3	0.70
15.	Tj.Kemuning - Linau	13.022.003.B	Ilik B	4	0.30
16.	Tj.Kemuning - Linau	13.022.007.B	Tetap B	2	0.90
17.	Linau – Bts.Lampung	13.023.005.0	Muara Nasal	2	0.90
18.	Linau – Bts.Lampung	13.023.011.0	Kolik II	4	0.30
19.	Linau – Bts.Lampung	13.023.020.0	Manulah	4	0.30
20.	Sp.Taba Mulan – Bts.Kota Curup	13.026.001.0	Merah	2	0.90

3.2.3 Total Load Assessment

Total Load rating for bridge is calculated from nominal load by using the following formula:

$$Q_S^* = F_{KS} Q_S \tag{3}$$

Note:
Q_S* = upper building total load assessment (%)
F_{KS} = upper building condition factor
Q_S = upper building nominal load assessment (%)

Total load rating of object research could be seen in table 10 below:

Table 10. Total Load rating of upper bridge.

No.	Road	Bridge number	Bridge name	Condition factor Fks	Nominal load Qs (%)	Total load rating Q_S*
1.	Bts. Prov Sumbar – Muko muko	13.001.014.0	Menjunto	0.90	113	1.017
2.	Muko-muko - Bantal	13.002.008.0	Dikit Penarik	0.90	111	0.999
3.	Muko-muko - Bantal	13.002.012.0	Pelokan	0.30	104	0.312
4.	Bantal - Ipuh	13.003.001.0	Pisang	0.90	101	0.909
5.	Ipuh - sebelat	13.004.003.0	Senabah	0.70	102	0.714
6.	Ipuh - sebelat	13.004.005.0	Kelikut	0.70	103	0.721
7.	Ipuh - sebelat	13.004.029.0	Ipuh	0.70	116	0.812
8.	Sebelat - Ketahun	13.005.008.0	Karang Pulau Besar	0.30	104	0.312
9.	Ketahun - Ds.Air Limas - Bintunan	13.006.005.0	Serangai	0.70	103	0.721
10.	Bintunan - Lais	13.007.002.0	Padang	0.30	104	0.312
11.	Betungan - Tais	13.018.001.0	Tanjung Aur	0.90	105	0.945
12.	Tais - Maras	13.019.025.0	Maras A	0.90	102	0.918
13.	Sp.Rukis - Tj.Kemuning	13.021.008.0	Martam	0.70	104	0.728
14.	Tj.Kemuning - Linau	13.022.002.0	Kinal	0.70	116	0.812
15.	Tj.Kemuning - Linau	13.022.003.B	Ilik B	0.30	104	0.312
16.	Tj.Kemuning - Linau	13.022.007.B	Tetap B	0.90	103	0.927
17.	Linau – Bts.Lampung	13.023.005.0	Muara Nasal	0.90	112	1.008
18.	Linau – Bts.Lampung	13.023.011.0	Kolik II	0.30	103	0.309
19.	Linau – Bts.Lampung	13.023.020.0	Manulah	0.30	102	0.306
20.	Sp.Taba Mulan – Bts.Kota Curup	13.026.001.0	Merah	0.90	101	0.909

3.2.4 Equivalent Load Factor

Equivalent load factor is a measure of the influence of an axle series compared to the standard load effects. equivalent load factor of the standard load is 100%. Equivalent load factor depends on the bridge span and width of the bridge.

On the roads as a research areas passed by the heaviest vehicles namely tronton trucks transporting coal, a vehicle with a single axle. In *Spesifikasi Pembebanan Jembatan Bina Marga 1970* mentioned that the length of the base, equivalent to a single axle is zero. Thus the equivalent load factor for a single axle are:

$$F_{LN} = \frac{WG}{WN} \% \quad (4)$$

Note:
F_{LN} = Equivalent Load factor
W_G = Static Load from single axle (kN)
W_N = equivalent standard load (kN)

This research will try to use the static weight of a single axle in accordance with the actual static weight or according to the heaviest vehicle condition at this time. As known at this time, the heaviest vehicles on the road across the bridge which is the object of research is 9.5228 tons (93.39 kN), 20.4592 tons (200.64 kN), and 47.49 tons (465.72 kN).

The equivalent standard load can be determined based on the span length and width of the bridge floor. equivalent standard load value can be obtained from Table 11.

Table 11. Equivalent Load factor based on static weight in single axle.

Span	Roadway Width / Bridge Width					
	4.5 m	6.0 m	7.0 m	8.5 m	10.0 m	11.25 m
	WN kN					
35	597.5	381.7	414.9	351.9	351.9	370.7
40	628.7	401.7	436.6	358.5	360.9	390.0
45	659.9	421.6	458.2	363.7	378.8	409.4
50	691.1	441.5	479.9	367.8	396.7	428.7
55	720.5	460.33	500.4	373.6	413.6	447.0
60	750.0	479.2	520.8	388.9	430.6	465.3
65	779.5	498.0	541.3	404.2	447.5	483.6
70	808.9	516.8	561.8	419.4	464.4	501.8
75	838.4	535.7	582.2	434.7	481.3	520.1
80	867.9	554.5	602.7	450.0	498.2	538.4
85	897.3	573.3	623.2	465.3	515.1	556.7
90	926.8	592.1	643.6	480.6	532.1	575.0
95	958.0	612.1	665.3	496.7	550.0	594.3
100	989.2	632.0	686.9	512.9	567.9	613.7

Source: *Peraturan Perencanaan Teknik Jembatan (Dirjen Bina Marga)*

Equivalent load factor of the bridge which is the object of research based on the actual single axle static weight from payload carried by the scenario that has been done before. used vehicle load is the vehicle total (MST Max). Equivalent load factor of the single axle static weight based on the actual load can be seen in Table 12 and Table 14.

Table 12. Equivalent load factor based on actual single axle static weight (scenario 1 = 0 cm).

No.	Bridge number	Bridge name	Length of bridge	W_G (kN)	W_N (kN)	F_{LN}
1.	Menjunto	102.90	6.00	89.12978	632	14.10281
2.	Dikit Penarik	46.10	6.00	89.12978	592.1	15.05316
3.	Pelokan	91.30	6.00	89.12978	421.6	21.14084
4.	Pisang	36.50	6.00	89.12978	381.7	23.35074
5.	Senabah	40.00	6.00	160.3123	401.7	39.90847
6.	Kelikut	41.50	6.00	160.3123	401.7	39.90847
7.	Ipuh	145.00	6.00	160.3123	632	25.36587
8.	Karang Pulau Besar	45.00	6.00	160.3123	421.6	38.02474
9.	Serangai	60.00	6.00	160.3123	479.2	33.45416
10.	Padang	46.40	6.00	160.3123	421.6	38.02474
11.	Tanjung Aur	51.20	6.00	160.3123	441.5	36.31083
12.	Maras A	40.00	7.00	160.3123	436.6	36.71835
13.	Martam	46.00	6.00	263.4216	421.6	62.48142
14.	Kinal	143.80	6.00	263.4216	632	41.68064
15.	Ilik B	50.00	6.00	263.4216	441.5	59.66515
16.	Tetap B	60.00	6.00	263.4216	479.2	54.97113
17.	Muara Nasal	97.80	6.00	263.4216	612.1	43.03572
18.	Kolik II	60.00	6.00	263.4216	479.2	54.97113
19.	Manulah	95.00	6.00	263.4216	612.1	43.03572
20.	Merah	36.00	6.60	160.3123	414.9	38.63879

Table 13. Equivalent load factor based on actual single axle static weight (Scenario 2 = 10 cm).

No.	Bridge Name	Length of bridge	Width of bridge	W_G (kN)	W_N (kN)	F_{LN}
1.	Menjunto	102.90	6.00	94.40992	632	14.93828
2.	Dikit Penarik	46.10	6.00	94.40992	592.1	15.94493
3.	Pelokan	91.30	6.00	94.40992	421.6	22.39324
4.	Pisang	36.50	6.00	94.40992	381.7	24.73406
5.	Senabah	40.00	6.00	170.865	401.7	42.53546
6.	Kelikut	41.50	6.00	170.865	401.7	42.53546
7.	Ipuh	145.00	6.00	170.865	632	27.03559
8.	Karang Pulau Besar	45.00	6.00	170.865	421.6	40.52774
9.	Serangai	60.00	6.00	170.865	479.2	35.65629
10.	Padang	46.40	6.00	170.865	421.6	40.52774
11.	Tanjung Aur	51.20	6.00	170.865	441.5	38.70101
12.	Maras A	40.00	7.00	170.865	436.6	39.13536
13.	Martam	46.00	6.00	277.9843	421.6	65.93555
14.	Kinal	143.80	6.00	277.9843	632	43.98486
15.	Ilik B	50.00	6.00	277.9843	441.5	62.9636
16.	Tetap B	60.00	6.00	277.9843	479.2	58.01008
17.	Muara Nasal	97.80	6.00	277.9843	612.1	45.41485
18.	Kolik II	60.00	6.00	277.9843	479.2	58.01008
19.	Manulah	95.00	6.00	277.9843	612.1	45.41485
20.	Merah	36.00	6.60	170.865	414.9	41.1822

Table 14. Equivalent load factor based on actual single axle static load (scenario 3 = 20 cm).

No.	Bridge name	Length of bridge	Width of bridge	W_G (kN)	W_N (kN)	F_{LN}
1.	Menjunto	102.90	6.00	99.69006	632	15.77374
2.	Dikit Penarik	46.10	6.00	99.69006	592.1	16.83669
3.	Pelokan	91.30	6.00	99.69006	421.6	23.64565
4.	Pisang	36.50	6.00	99.69006	381.7	26.11739
5.	Senabah	40.00	6.00	181.4176	401.7	45.16246
6.	Kelikut	41.50	6.00	181.4176	401.7	45.16246
7.	Ipuh	145.00	6.00	181.4176	632	28.70532
8.	Karang Pulau Besar	45.00	6.00	181.4176	421.6	43.03074
9.	Serangai	60.00	6.00	181.4176	479.2	37.85843
10.	Padang	46.40	6.00	181.4176	421.6	43.03074
11.	Tanjung Aur	51.20	6.00	181.4176	441.5	41.09119
12.	Maras A	40.00	7.00	181.4176	436.6	41.55236
13.	Martam	46.00	6.00	292.5469	421.6	69.38969
14.	Kinal	143.80	6.00	292.5469	632	46.28907
15.	Ilik B	50.00	6.00	292.5469	441.5	66.26205
16.	Tetap B	60.00	6.00	292.5469	479.2	61.04903
17.	Muara Nasal	97.80	6.00	292.5469	612.1	47.79398
18.	Kolik II	60.00	6.00	292.5469	479.2	61.04903
19.	Manulah	95.00	6.00	292.5469	612.1	47.79398
20.	Merah	36.00	6.60	181.4176	414.9	43.72562

3.2.5 Safety factor

The safety factor for usual traffic loads account for the variability of load-bearing (including excessive burden), and the fact is more than one regular traffic load can be on the bridge at the same time. If a bridge has a safety factor of less than 1.0 for regular traffic load, it is necessary to make restrictions load on the bridge until the bridge can be strengthened or duplicated.

Outstanding traffic loads that provide a safety factor of less than 1.0, should be prohibited from passing through the bridge, but the bridge has to be strengthened to increase the capacity of its weight.

The safety factor can be determined by the following formula:

$$F_N^S = \frac{Q_S^*}{F_{LN}} \quad (5)$$

Note:
F_N^S = safety factor for usual traffic load
Q_S^* = upper building load rating (%)
F_{LN} = equivalent load factor (%)

The safety factor for bridge which is the object of research is by using a single axle actual static weight by excessive load scenario, and can be seen in table 15 to the table 17.

Table 15. Safety factor of upper building based on actual single axle static weight (scenario 1 = 0 cm).

No.	Bridge name	Length of bridge	Width of bridge	F_{LN} (%)	Total load rating Q_S*	Safety factor F_N^S
1.	Menjunto	102.90	6.00	14.10281	1.017	7.211328
2.	Dikit Penarik	91.30	6.00	15.05316	0.999	6.636479
3.	Pelokan	46.10	6.00	21.14084	0.312	1.475817
4.	Pisang	36.50	6.00	23.35074	0.909	3.89281
5.	Senabah	40.00	6.00	39.90847	0.714	1.789094
6.	Kelikut	41.50	6.00	39.90847	0.721	1.806634
7.	Ipuh	145.00	6.00	25.36587	0.812	3.201151
8.	Karang Pulau Besar	45.00	6.00	38.02474	0.312	0.820518
9.	Serangai	60.00	6.00	33.45416	0.721	2.155188
10.	Padang	46.40	6.00	38.02474	0.312	0.820518
11.	Tanjung Aur	51.20	6.00	36.31083	0.945	2.602529
12.	Maras A	40.00	7.00	36.71835	0.918	2.500112
13.	Martam	46.00	6.00	62.48142	0.728	1.165146
14.	Kinal	143.80	6.00	41.68064	0.812	1.948147
15.	Ilik B	50.00	6.00	59.66515	0.312	0.522918
16.	Tetap B	60.00	6.00	54.97113	0.927	1.68634
17.	Muara Nasal	97.80	6.00	43.03572	1.008	2.34224
18.	Kolik II	60.00	6.00	54.97113	0.309	0.562113
19.	Manulah	95.00	6.00	43.03572	0.306	0.711037
20.	Merah	36.00	6.60	38.63879	0.909	2.352558

Table 16. Safety factor of upper building based on actual single axle static weight (Scenario 2 = 10 cm).

No.	Bridge Name	Length of bridge	Width of bridge	F_{LN} (%)	Total load rating Q_S*	Safety factor F_N^S
1.	Menjunto	102.90	6.00	14.93828	1.017	6.808014
2.	Dikit Penarik	91.30	6.00	15.94493	0.999	6.265315
3.	Pelokan	46.10	6.00	22.39324	0.312	1.393277
4.	Pisang	36.50	6.00	24.73406	0.909	3.675094
5.	Senabah	40.00	6.00	42.53546	0.714	1.678599
6.	Kelikut	41.50	6.00	42.53546	0.721	1.695056
7.	Ipuh	145.00	6.00	27.03559	0.812	3.003448
8.	Karang Pulau Besar	45.00	6.00	40.52774	0.312	0.769843
9.	Serangai	60.00	6.00	35.65629	0.721	2.022083
10.	Padang	46.40	6.00	40.52774	0.312	0.769843
11.	Tanjung Aur	51.20	6.00	38.70101	0.945	2.441797
12.	Maras A	40.00	7.00	39.13536	0.918	2.345705
13.	Martam	46.00	6.00	65.93555	0.728	1.104108
14.	Kinal	143.80	6.00	43.98486	0.812	1.84609
15.	Ilik B	50.00	6.00	62.9636	0.312	0.495524
16.	Tetap B	60.00	6.00	58.01008	0.927	1.597998
17.	Muara Nasal	97.80	6.00	45.41485	1.008	2.219538
18.	Kolik II	60.00	6.00	58.01008	0.309	0.532666
19.	Manulah	95.00	6.00	45.41485	0.306	0.673788
20.	Merah	36.00	6.60	41.1822	0.909	2.207264

Table 17. Safety factor of upper building based on actual single axle static weight (Scenario 3 = 20 cm).

No.	Bridge name	Length of bridge	Width of bridge	F_{LN} (%)	Total load rating Q_S*	Safety factor F_N^S
1.	Menjunto	102.90	6.00	15.77374	1.017	6.447423
2.	Dikit Penarik	91.30	6.00	16.83669	0.999	5.933469
3.	Pelokan	46.10	6.00	23.64565	0.312	1.319482
4.	Pisang	36.50	6.00	26.11739	0.909	3.48044
5.	Senabah	40.00	6.00	45.16246	0.714	1.580959
6.	Kelikut	41.50	6.00	45.16246	0.721	1.596459
7.	Ipuh	145.00	6.00	28.70532	0.812	2.828744
8.	Karang Pulau Besar	45.00	6.00	43.03074	0.312	0.725063
9.	Serangai	60.00	6.00	37.85843	0.721	1.904464
10.	Padang	46.40	6.00	43.03074	0.312	0.725063
11.	Tanjung Aur	51.20	6.00	41.09119	0.945	2.299763
12.	Maras A	40.00	7.00	41.55236	0.918	2.209261
13.	Martam	46.00	6.00	69.38969	0.728	1.049147
14.	Kinal	143.80	6.00	46.28907	0.812	1.754194
15.	Ilik B	50.00	6.00	66.26205	0.312	0.470858
16.	Tetap B	60.00	6.00	61.04903	0.927	1.518452
17.	Muara Nasal	97.80	6.00	47.79398	1.008	2.109052
18.	Kolik II	60.00	6.00	61.04903	0.309	0.506151
19.	Manulah	95.00	6.00	47.79398	0.306	0.640248
20.	Merah	36.00	6.60	43.72562	0.909	2.078873

In the calculation of the safety factor of the building are based on the weight of the static axle single real-time scenarios, 20 bridges were the object of research, five (5) bridge has a value of less than 1.0, whereas 15 (fifteen) bridge has a value of more than 1.0. In scenario 1 (0 cm), all the bridges has a value of more than 1.0. At the time of scenario 2 (10 cm) turns out there are five (5) bridges that have a value of less than 1.0.

4. Conclusion

- The entire bridge as the research object has a Load Rating Factor of more than 1.0 at the time of loading scenario is when the scenario 1 is done or when the cargo of the truck does not exceed the height of the truck.
- At the time of cargo at the position of scenario 2 (10 cm), there are five (5) bridges that have a value of less than 1.0. It can be said that if the payload of the truck has exceeded the height of the truck itself it will cause the load rating factor value will be less than 1.0 or unsafe for vehicles to pass through the bridge. Bridge which has a safety factor with less than 1.0 can be seen in Table 18.

Table 18. Bridge with Safety factor value less than 1.0

No.	Bridge name	Safety factor F_N^S	Management
1.	Karang Pulau Besar	0.725063	Strengthen the upper building
2.	Padang	0.725063	Strengthen the upper building
3.	Ilik B	0.470858	Strengthen the upper building
4.	Kolik II	0.506151	Strengthen the upper building
5.	Manulah	0.640248	Strengthen the upper building

References

Direktorat Jenderal Bina Marga, 1992. PanduanPemeriksaan Jembatan, Departemen Pekerjaan Umum, Jakarta.
Direktorat Jenderal Bina Marga, 1992. Peraturan Perencanaan Teknik Jembatan, Jilid 1, Departemen Pekerjaan Umum, Jakarta.
Hariman, F,dkk, 2007. Evaluasi dan Program Pemeliharaan Jembatan Dengan Metode Bridge Management System (BMS), Jurnal, Yogyakarta.

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

The 3rd SCESCM

Special Topics in Public Works Research and Technology

The leadership assessment study on the level of road technical personnel competence at "*Dinas Prasarana Jalan Tata Ruang dan Permukiman*" Province of West Sumatera using requirement-satisfaction analysis

Welly Juwita [a,*], Yosritzal [a], Dedi Rinaldi [b]

[a]*Magister Tranportation Univ. Andalas, Padang 25163*
[b]*Dinas Prasarana Jalan Tata Ruang dan Permukiman Prop Sumatera Barat, Kota Padang 25138*

Abstract

In carrying out the task of building infrastructure in the Province of West Sumatera, the *Dinas Prasarana Jalan Tata Ruang dan Permukiman* is required to provide technical personnel who are reliable and competent in their fields. However, in the document *Daftar Urut Kepangkatan (DUK) Pegawai Dinas Prasjal Tarkim* in 2013, it is revealed that about 59.4% of the personnel at staff level have insufficient education. It gives a presumption that there are still some technical personnel who have low competence. This study has objectives to identify factors/aspects required by technical competence, to find out about the level of competence, and to formulate a recommendation to increase their competence for the road technical personnel (Inspector, General Assistant, and Project Manager/PPTK) at the *Dinas Prasjal Tarkim* Province of West Sumatera. From this research it is know that Inspectors are required to know as much as 10 aspects, General Assistant are required to know as much as 11 aspects and Project Manager/PPTK as much as 11 aspects. From the method of *Requirement-Satisfaction Analysis* (RSA), the level of competence of Inspectors are in a Good position with average satisfaction level of 3.04 but they still have a gap for Requirement *value* of-0.51. The level of competence for Technical Chief is Enough position with average satisfaction value of 2.90 but still have a gap for *requirement value* of -0.88. The level of competence Project Manager/PPTK is a Good position with average satisfaction value of 3.13 but still have a gap for *requirement value* of -0.75. In gap analysis of value it can be identified that aspects of competence required to be improved by the Inspector are Technical Specification, Implementation Method of Road Construction and Quality Control, Dimension, Time and Cost. In General Assistant aspects of competence required to be improved is Estimated Volume of Work and Ability/Additional Skill. In Project Manager/PPTK aspects of competence required to be improved are Quality Control, Dimension, Time and Cost.

Keywords: Competence; Technical Personnel; Inspector; General Assistant; Project Manager/PPTK; Requirement-Satisfaction Analysis; Quadrant of Method; Gap of Method

1. Introduction

Currently, existence of professional technical personnel is needed by every organization, including technical offices such as "*Dinas Prasarana Jalan Tata Ruang dan Permukiman*" Province of West Sumatera. With the presence of professionals, success to achieve objectives of an organization can be quickly realized expectedly. Therefore, in building an integrated system in the management of professionals Civil Servants from planning, the recruitment and selection to placement at the office must consider some compliance aspects satisfying minimum competency.

In Regulation No. 100/2000 about Promotion of Civil Servants emphasized that the promotion of Civil Servants must based on the principle of professionalism in according to their competence. It means that each position is only stuffed when there is conformity between competence's Civil Servants concerned with the demands of the job competency will be held. The competency-based principle is also strengthened by the issued of Governmental decree No. 81/2010 about Grand Design of Bureaucratic Reform 2010-2025. This Governmental Decree explains that the Structural Official in the future must switch to the best of the profession which is characterized by competence and achievement.

* Corresponding author.
E-mail address: ummiwelly@gmail.com

2. Literature Review

2.1. The Activity Competency Standard

Activity competence is satisfaction of each individual that cover some aspects of knowledge, skill and attitudes adjust with standard . This is in conformity with Constitution No.13 about employment and Ministry of Public Works Regulation No. 07/2010 that explain that activity competency is satisfaction of each individual that cover some specific aspects, skill and attitudes that applied for achieving the required standard performance in the workplace.

2.2 Indonesian national Competency Standard of Job (SKKNI) in Construction Sector

2.2.1 SKKNI Road Field Manager

Based on the SKKNI, some aspects to be acquired by Road Field Manager are able to:

- Understand detail engineering drawing and specification contain in the contract.
- Coordinate internally and externally.
- Plan a job program and its methods.
- Direct and guide the implementation of the job.
- Inspect the implementation of the job.
- Evaluate the changes to design, volume, cost and time (if necessary).
- Exercise control for quality, resources and time according to job plan.
- Report the result of implementation of the job.

2.2.2 SKKNI Quality Control Of Road

Based on the SKKNI, some aspects to be acquired by Quality Control of Road are able to:

- Coordinate and direct Search to testing of material processes or system related to the job.
- Monitor and evaluate from job implementation to the finished one.
- Analyze reports on the workload, workers, productivity, quality of materials and performance.
- Perform a research, testing, and evaluation quality of the suitability of materials and products related to the job.
- Cooperate and lead the research and testing of materials such as soil, rock, asphalt, concrete, steel, wood, type of plastics an others by consider factors like tension and strain, the estimated load, water pressure, air pressure and temperature fluctuations.
- Advise for executive and other officer about the material and method of implementation that suitable for solve the job problem.

2.3 Requirement-Satisfaction Analysis

Requirement-Satisfaction Analysis that was introduced by Martilla and James (1977) is modification of the Important-Performance Analysis (IPA) Method and Important Satisfaction Analysis (ISA) Method. This method is intended as a tool or instrument that can be used to determine priority in handling the various issues arising based on the desire of customers. The data that are used in this analysis is the value technical competence data based on perception of leader. There are two types of analysis in IPA-ISA namely also known as quadrant method and gap analysis. There are can be explain in part 2.3.1 and 2.3.2.

2.3.1 Quadrant Method

In principle, the quadrant method is performed by plotting the measure of central tendency (such as average or median) from The Level of Required and The Level of Satisfaction in four of quadrant that separated by a line that represent the average The Level of Required and The Level of Satisfaction. In Horizontal line is The Level of Satisfaction and Vertical line is The Level of Required like Fig. 1.

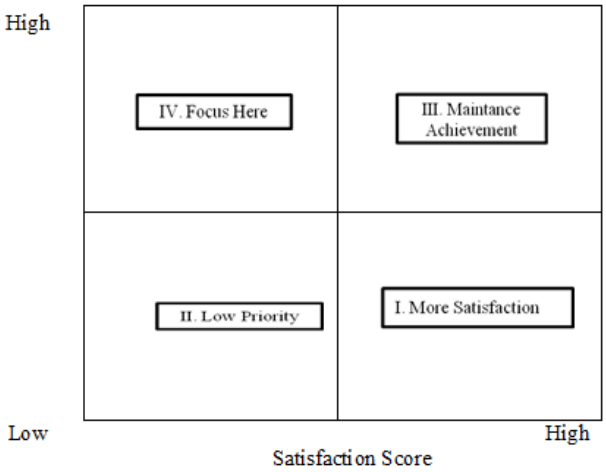

Fig. 1. Quadrant Method (Source: Yosritzal, 2015).

2.3.2 Gap Analysis

The Gap analysis is the difference between The average rate of Required item and the Average of Satisfaction. The score in value gap that are plot in bar chart so that make it easy to look the items that requires more priority handling such as shown in Fig. 2.

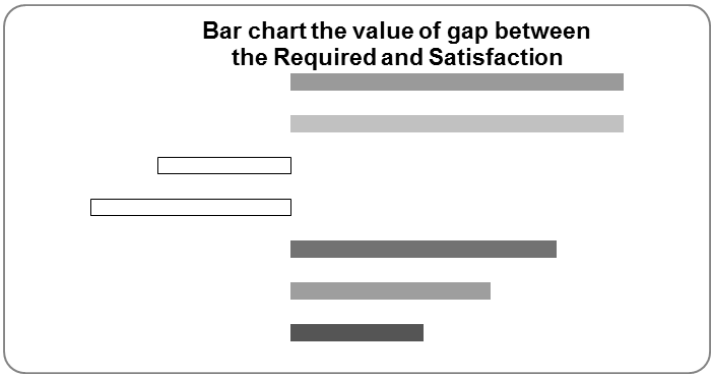

Fig. 2. Barchart Gap Analysis (Source: Yosritzal, 2015).

3. Research Methodology

The study began by identifying and compiling the problems associated with the implementation by technical competency of the road in the *Dinas Prasjal Tarkim* Province of West Sumatera. The problem formulation is prepared by gathering information through short interviews with officials in the *Department Prasjal structural Tarkim*. From this phase, it can be formulated a draft questionnaire for the assessment of technical competence. The questionnaire is also based on the *Standar Kompetensi Kerja Nasional Indonesia* (SKKNI) Construction Sector and also based on the experience of relevant officials.

Having composed the draft questionnaire, then set the value of the standard requirements by official of road division at *Dinas Prasjal Tarkim*. In collecting the data, the system used a qualitative assessment. Each item Satisfaction is categorised into four scales such as shown in Table 1.

Table 1. Scale Qualification.

Scale	Qualification
1	Low (< 50%)
2	Enough (50%-65%)
3	Good (66%-85%)
4	Very Good (>85%)

Each technical personnel was rated by 2 (two) Assessor (respondent). The two assessors are the current direct superior and the previous employer within the last three years. The technical personnel who has the same employer for the last 3 (three) years is adequately evaluated by the current direct employer. Each Satisfaction values are

averaged and compared with the Requirement values. The value will be obtained from the gap between the satisfaction value/score of the requirement values. The biggest gap will be seen to be the main satisfaction is enhanced by the technical personnel.

4. The Result and Analysis

4.1 Inspectors Competence

4.1.1 Requirement Satisfaction Quadrant Analysis

In this study, there are 12 inspectors assessed. From the questionnaire which was filled by Technical Chief, found the satisfaction value of each Inspectors in Table 2

Table 2. Inspector Competence Score.

Point/ Object	A	B	C	D	E	F	G	H	I	J	Average
1	3.13	3.00	3.00	2.86	2.25	2.75	3.00	2.50	2.75	3.00	2.82
2	2.75	3.00	2.67	3.00	3.00	2.50	3.00	3.00	2.75	2.75	2.84
3	3.25	3.00	3.33	3.57	2.83	3.00	3.50	3.00	3.00	3.25	3.17
4	2.88	2.50	2.67	2.71	2.83	3.25	2.75	2.00	3.00	2.75	2.73
5	3.00	3.00	3.00	3.29	3.33	3.00	3.50	3.00	3.25	3.00	3.14
6	3.25	3.50	3.00	3.43	3.50	3.50	3.50	3.00	3.50	3.50	3.37
7	2.75	3.00	2.67	2.93	3.00	3.00	2.75	3.00	2.75	3.25	2.91
8	3.00	3.25	3.33	3.14	3.25	3.00	3.00	3.00	3.38	2.88	3.12
9	2.75	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.25	2.75	2.98
10	2.75	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.50	3.50	3.08
11	3.00	3.00	3.00	3.14	3.00	3.00	3.25	3.00	3.00	3.50	3.09
12	3.00	3.50	3.00	3.14	3.00	3.25	3.50	3.00	3.25	3.50	3.21
Satisfaction Average	2.96	3.06	2.97	3.10	3.00	3.02	3.15	2.88	3.11	3.14	3.04
Requirement average	3.25	3.25	3.67	4.00	3.83	3.75	3.00	3.25	3.75	3.75	3.55
Gap	-0.29	-0.19	-0.70	-0.90	-0.83	-0.73	0.15	-0.38	-0.64	-0.61	-0.51

Plot the Satisfaction and Requirement Average value in Table 2 on a quadrant such as shown in Fig.3

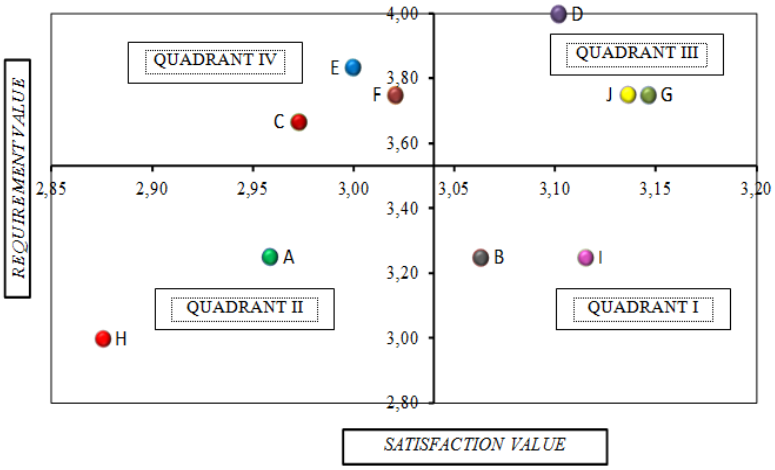

Fig. 3. Requirement-Satisfaction Quadrant.

Note:

A. Health and safety in a job
B. Plan and schedules in a job
C. Technical specification
D. Estimate of volume in a job
E. Methods of Construction
F. Quality control, dimensional, time and cost
G. Measurement and reporting of result in a job
H. Project administration
I. Management and control system construction
J. Other additional satisfaction

4.1.2 Gap Analysis

From Table 2, it can be plotted the Gap value to barchart such as shown in Fig. 4.

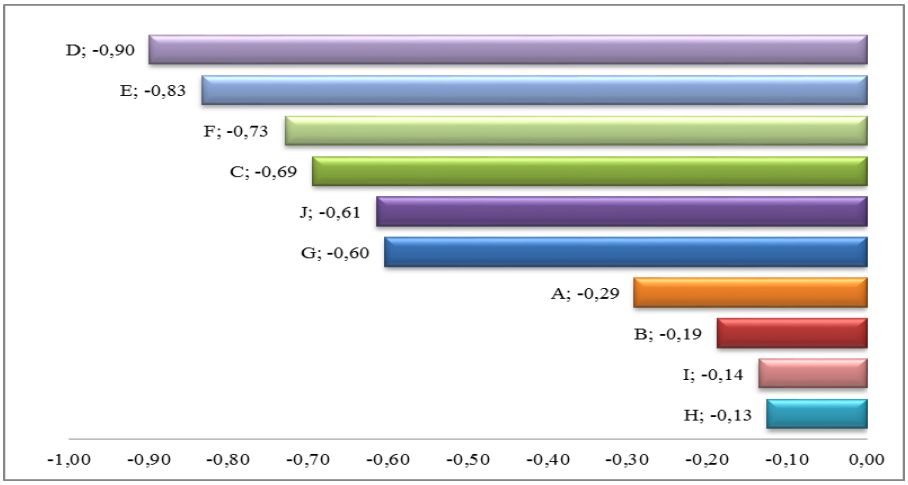

Fig.4. Requirement-Satisfaction Gap Value Barchart of Inspector

From the Fig. 4, it can be seen that points C, D, E and F have the biggest gap value. But in point D already in good quadrant (Quadrant III, achievement) so it means aspects of competence at points C, E and F is priority to improving Inspector Competence. In detail of value satisfaction from points C, E and F contain in Table 3.

Table 3. Competence Value Point C, E and F.

No.	Description	Satisfaction value	Requirement Value	Gap
C	Technical Specification			
1	The Technical Specification of road	3.00	4.0	-1.0
2	The Special Specification of road	3.00	3.0	-1.0
3	The Technical Drawing in technical Specification	2.89	4.0	-1.11
E	Method of Construction			
1	The Working method on Soil Jobs	3.11	4.0	-0.89
2	The rigid pavement work method	2.89	4.0	-1.11
3	The working method of flexible pavement	3.06	4.0	-0.94
4	The working method of arrest and detention building work ground	2.94	4.0	-1.06
5	The pollution of environment and security	2.83	3.5	-0.6
6	The Traffic management in the worksite	2.94	3.5	-0.56
F	The Quality Control, Dimension, time and Cost			
1	The Control Dimension, Quality of materials and Work Result	3.06	4	-0.94
2	The Control Time Implementation	2.94	3.5	-0.56

From the gap values in Table 3, it can be identified that the structure of improvement priority to increase the competence for Inspector are:

- The Special Specification of road
- The Technical Drawing in technical Specification
- The working method of arrest and detention building work ground
- The Technical Specificationof road
- The Special Specification of road
- The working method of flexible
- The Control Dimension, Quality of materials and Work Result
- The Technical Training working method earthworks
- The Training The pollution of environment and security
- The Training Traffic management in the workplace
- The Training Control time Implementation

4.2 General Assistant Competence

4.2.1 Requirement-Satisfaction Quadrant Analysis

There are 10 Technical chief assessed in this study. From the questionnaire which was filled by PPTK, it was found that the satisfaction value of each technical chief are shown in Table 4.

Table 4. General Assistant Competence Score.

Point/ Object	A	B	C	D	E	F	G	H	I	J	K	Average
1	3.00	3.20	4.00	3.00	3.33	3.83	3.00	3.60	4.00	3.00	3.0	3.36
2	2.50	3.00	2.17	2.64	2.50	3.08	2.67	2.60	2.67	2.70	2.5	2.64
3	3.00	3.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00	2.00	2.2	2.75
4	2.75	3.20	2.71	2.67	3.00	3.00	3.00	3.00	3.00	2.60	3.2	2.92
5	2.75	2.80	3.00	2.79	2.50	2.83	2.50	2.50	2.83	2.30	2.6	2.67
6	3.00	3.00	3.00	2.86	3.00	3.00	3.33	3.00	3.00	2.90	3.3	3.04
7	3.00	3.20	3.00	3.00	2.83	2.50	3.00	3.00	3.00	2.50	2.8	2.89
8	2.88	3.00	2.33	3.00	2.92	3.08	2.67	2.60	2.67	2.85	2.6	2.78
9	3.00	3.00	3.00	2.86	3.00	3.00	3.33	3.00	3.00	2.90	3.3	3.04
10	2.75	3.20	2.71	2.67	3.00	3.00	3.00	3.00	3.00	2.60	3.2	2.92
Satisfaction Average	2.86	3.06	2.98	2.85	2.88	3.04	2.79	2.96	3.07	2.57	2.80	2.90
Requirement Average	3.63	3.60	4.00	3.86	3.67	3.83	3.67	4.00	3.83	3.55	3.90	3.78
Gap	-0.77	-0.54	-1.02	-1.01	-0.79	-0.80	-0.88	-1.04	-0.76	-0.98	-1.10	-0.88

Plot of the satisfaction and requirement values are shown in Table 4 and on a quadrant Fig. 5.

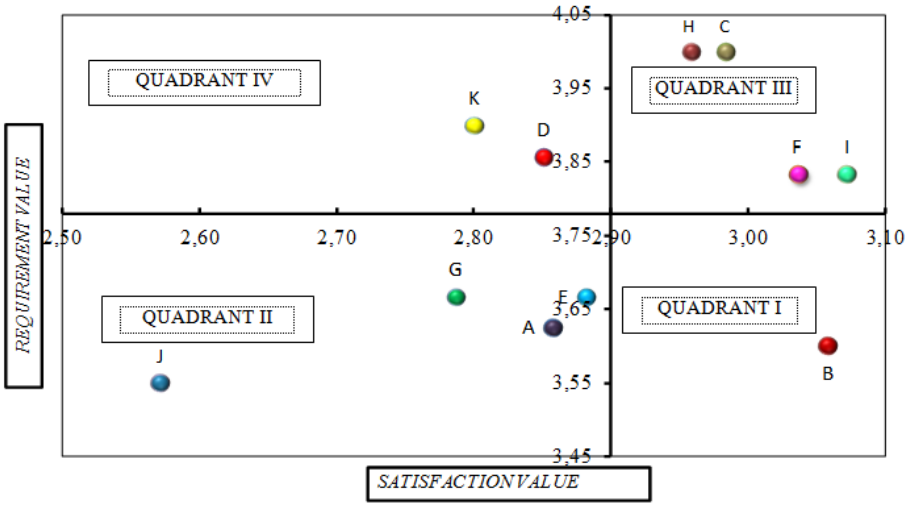

Fig. 5 Requirement-satisfaction quadran of Technical chief competence.

Note:

A. Health and Safety in Work
B. Plan and Schedule
C. Technical Specification
D. Estimate of Volume
E. Method of construction
F. Field Engineering, Optimization and Design
G. Quality Control, Dimensional, Time and Cost
H. Measurement and reporting of result
I. Project Administration
J. Management System and Construction Control
K. Other Additional Skills

4.2.2 Gap Analysis

From Table 4, the plot the Gap values to barchart is shown in Fig. 6.

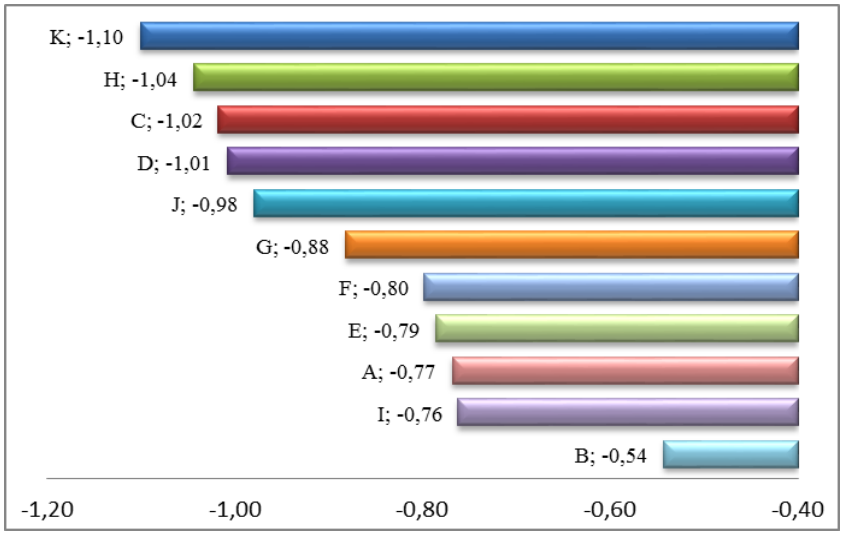

Fig. 6. Requirement-Satisfaction Gap Value Barchart of Technical Chief.

From Fig. 6, it can be seen that aspects of C, D, H, K and J have a better gap score. But aspects of H and C in good quadrant position (Quadrant III, achievement) and aspect of J in Quadrant II (Low Priority). So that the competence aspects of D and K are priority to improving satisfaction or Inspector competence. In detail a score satisfaction from point D and K have in Table 5.

Table 5. Competence Value Point D and K.

No	Task	Satisfaction Value	Requirement Value	Gap
D	Estimate of volume			
1	The control measurement and payment of corresponding technical specification	2.93	4.00	-1.07
2	Introduction and use of measuring instruments	2.67	3.00	-0.33
3	Understanding of method measurement and tolerance	2.73	4.00	-1.27
4	Understanding volume measurement technique work	2.87	4.00	-1.13
5	Able to compare volume estimate of quantity contained in the list (BOQ)	2.53	4.00	-1.47
6	Reported a case of inequality volume	3.07	4.00	-0.93
7	Understanding the measurement book and report	3.13	4.00	-0.87
K	Satisfaction / Additional Skill			
1	To able establish communication and good cooperation with the parties involve in project site	3.00	4.00	-1.00
2	Understanding basic of computer skill such as MS. Office and AutoCad	2.67	4.00	-1.33
3	Quickly response and or coordination and provide reports to the Inspector	2.93	4.00	-1.07
4	Have a sense of responsibility and commitment the job	3.07	4.00	-0.93
5	Understanding the rules and regulation related to the implementation of work	2.67	3.50	-0.83

Based on the value of the difference in Table 5 the priority order feature enhancement to be done for inspectors' competence like:

- Able to compare volume estimate of quantity contained in the list
- Understanding basic of computer skill such as MS. Office and autocad
- Understanding of method measurement and tolerance
- Understanding volume measurement technique work
- Understanding control of measurement and payment of corresponding technical specification
- Quickly response and or coordination and provide reports to the Inspector
- To able establish communication and good cooperation with the parties involve in project site
- Reported a case of inequality volume

- Have a sense of responsibility and commitment the job
- Understanding the measurement book and report
- Understanding the rules and regulation related to the implementation of work
- Introduction and use of measuring instruments

4.3 Project Manager (PPTK) Competence

4.3.1 Requirement-Satisfaction Quadrant Analysis

There are 13 PPTK assessed in this study from the questionnaire which was filled by Head of Division and Section Chief, found the satisfaction value of each technical chief are in Table 6.

Table 6. PPTK Competence Score.

Point/ object	A	B	C	D	E	F	G	H	I	J	K	Average
1	2.50	2.90	3.00	2.93	3.17	3.08	3.00	3.00	3.00	3.13	2.67	2.94
2	2.50	3.00	3.00	3.00	3.25	3.08	3.00	3.00	3.00	3.00	2.50	2.94
3	3.00	3.70	3.67	3.36	3.83	4.00	3.50	3.90	3.67	3.54	3.67	3.62
4	3.00	3.70	3.83	3.36	3.83	3.83	3.67	3.67	3.67	3.71	3.58	3.62
5	3.00	3.50	3.67	3.21	3.75	3.67	3.50	3.90	3.50	3.42	3.58	3.52
6	3.00	3.00	2.50	2.93	2.92	3.00	2.83	3.00	3.00	2.83	2.67	2.88
7	3.00	3.00	3.00	2.93	2.92	3.00	3.00	2.90	3.00	2.92	2.67	2.94
8	3.00	3.00	3.00	2.93	2.83	3.00	2.83	3.00	3.00	2.88	3.33	2.98
9	3.13	3.20	3.67	3.50	3.67	3.75	3.17	3.40	3.67	3.54	3.33	3.46
10	3.00	3.00	2.50	2.93	3.17	3.08	3.00	3.00	3.00	2.96	3.33	3.00
11	2.63	3.00	3.00	2.86	2.75	2.50	2.50	3.00	3.00	2.71	2.58	2.77
12	3.00	3.00	3.00	2.93	3.17	3.08	3.00	3.00	3.00	2.96	2.83	3.00
13	3.00	3.10	3.00	2.93	3.17	3.08	3.00	3.00	3.00	3.25	3.08	3.06
Satisfaction Average	2.90	3.16	3.14	3.06	3.26	3.24	3.08	3.21	3.19	3.14	3.06	3.13
Requirement Average	3.75	3.80	4.00	3.86	3.67	4.00	4.00	4.00	4.00	3.92	3.67	3.88
Gap	-0.85	-0.64	-0.86	-0.80	-0.40	-0.76	-0.92	-0.79	-0.81	-0.78	-0.60	-0.75

Plot the value in Table 6 on a quadrant Fig.7

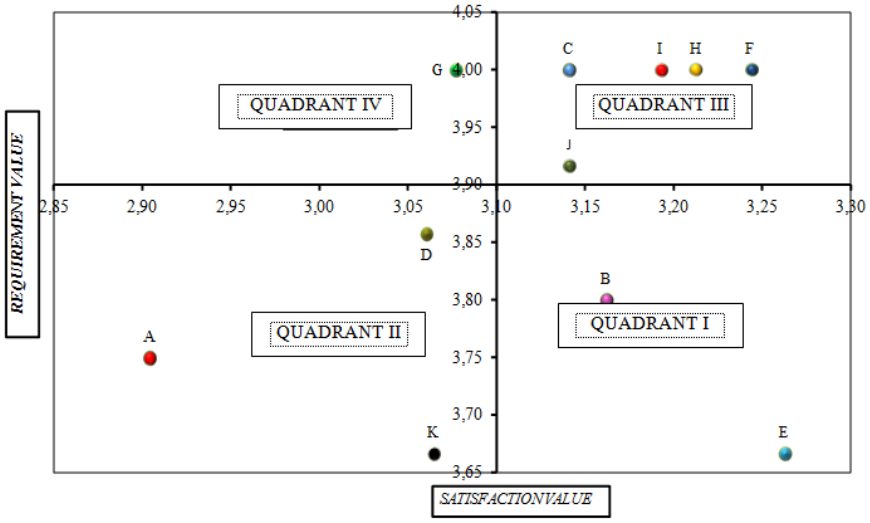

Fig. 7 Requirement-satisfaction quadran of PPTK chief competence.

Note:

A. Health and Safety in Work
B. Plan an Schedule
C. Technical Specification
D. Estimate of Volume
E. Method of construction
F. Field Engineering, Optimization and Design
G. Quality Control, Dimensional, Time and Cost
H. Measurement and reporting of result
I. Project Administration
J. Management System and Construction Control
K. Other Additional Skills

4.3.2 Gap Analysis

From Table 6 plot the Gap value to barchart Fig. 8.

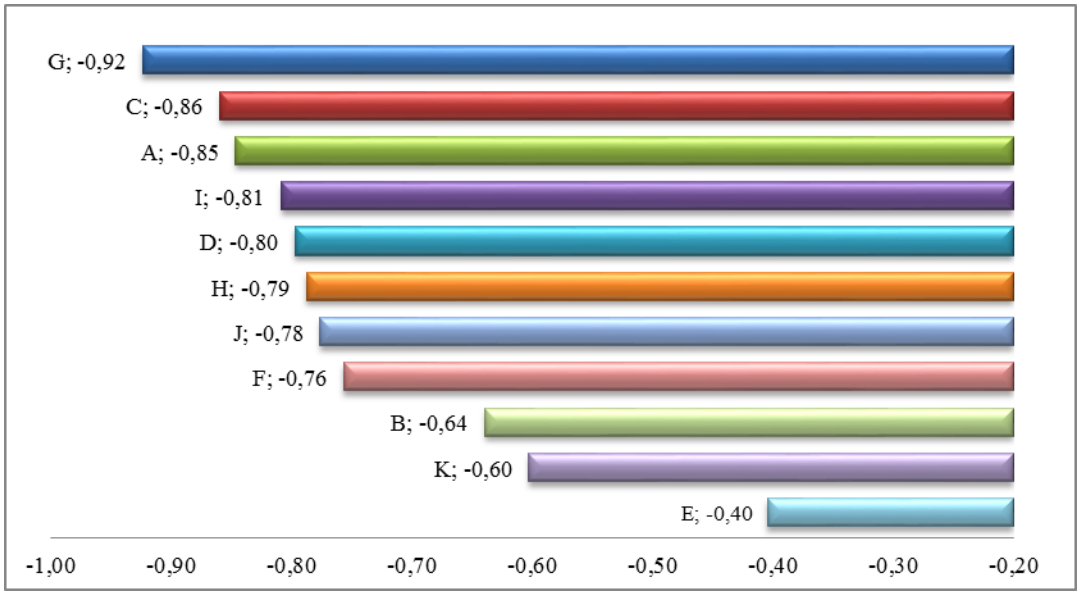

Fig. 8. Requirement-Satisfaction Gap Value Barchart of PPTK.

In Fig. 8 all aspects in competence still have big gap score for needed score. Point A, C and G have the best gap-score, while point A in quadrant II means the low priority and point C is in the best quadrant (Quadrant III, achievement) so that only competence aspect in point G is priority to improve satisfaction or competence supervisor. In detail satisfaction score have in Table 7.

Table 7. Competence value of Point G.

No	Description	Satisfaction	Requirement	Gap
G	Quality Control, dimension, optimization, time and cost			
1	The quality control, dimension, quality of material in job	3.29	4.00	-0.71
2	The implementing time of control	3.26	4.00	-0.74
3	The implementing of cost control.	3.00	4.00	-1.00

By the gap score Table 7 so the structure to improve must be for PPTK Competence like:

- The implementing of cost control
- The implementing time of control
- The quality control, dimension, quality of material in job

5. Conclusion

- Generally, the inspectors competence in GOOD position with average satisfaction 3, 04. In qualification in 5 people (42%) in Grade A+, 3 people (25%) in grade A, 3 people (25%) in grade A- and 1 (8%) in grade B+.
- The level of Technical Chief position is enough with satisfaction average 2,.90. In qualification is not achieve qualification A+, 1 people (10%) in grade A, 2 people (20%) in grade A- and 3 (30%) B+ and 4 people (40%) in grade B.
- The level of PPTK is GOOD position with average satisfaction 3.13. In qualification in 3 people (23%) in Grade A+, 1 people (8%) in grade A, 7 people (54%) in grade A- and 2 (15%) in grade B+.
- All of the competence have technical personnel (Inspector, Technical chief and PPTK) in *Bidang Pelaksana Dinas Prasarana Jalan Tata Ruang Permukiman* Province of West Sumatera that have a needed score which has been set. Because have a gap negative between Satisfaction Score to Required Score like Inspector is -0.51, Technical chief is -0.86, and PPTK is -0.75.

References

ASTTI, 2009, Pedoman Umum Sertifikasi Keahlian dan Bakuan Kompetensi, BSA ASTTI.

Departemen PU, 2007, SKKNI Sektor Jasa Konstruksi, Departemen Pekerjaan Umum, Jakarta.

Lewis, R. 2004, Importance-performance analysis.Australasian Journal of Engineering Education, 02.

Martilla, J. A. and James, J. C. 1977, Importance-Performance Analysis.The Journal of Marketing, 41(1), pp. 77-79.

Yosritzal, Adji, B.M., Nofrizal, F., Andika, R., 2015, Studi Implementasi Metode Importance-Satisfaction Analysis pada Penentuan Prioritas Penanganan Pelayanan Kereta Api Padang-Pariaman.1st Andalas Civil Engineering (ACE) National Conference 2014, 27th November 2014, Andalas University, Padang, Indonesia. Padang.

Yosritzal, Dissanayake,D., Bell, M., 2014, Importance-Satisfaction Analysis of Rail Services in The Uk with Respect to Travel Time Use. The 17th FSTPT Intenational Symposium August 23th 2014, Jember University.

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

The 3rd SCESCM

Special Topics in Public Works Research and Technology

Vehicle over-loading impacts against overlay thickness and remaining life of flexible pavement (case study: National road in West Sumatera)

Suriyatno[a], Purnawan[b], Elsa Eka Putri[b]

[a,b]*Engineering Faculty Andalas University, Kampus Unand Limau Manih Kecamatan Pauh, Kota Padang 25163, Indonesia*

Abstract

Due to limited availability of vehicle load data, estimator often use standard load in order to calculate the pavement thickness and overlay thickness. This will certainly make the calculation of pavement thickness and overlay thickness become not accurate. Inaccurate calculation results less capability of the pavement to sustain the traffic loads, causing the pavement becomes damaged before it reaches its service life as planned. The aim of this study is to calculate overlay thickness of flexible pavement based on actual loads, standard loads and remaining life of flexible pavement. The standard load used is based on official letter (*Surat Edaran*) Directorate General of Land Transportation, Ministry of Public Works No. 2, 2008. The actual load was obtained from vehicle load survey using Portable Weight instrument. Overlay thickness was calculated using Pavement Design Manual No. 02/M/BM/2013. The study case was conducted on four road segments, i.e., Tanah Badantung–Kiliran Jao Road, Batas Kota Padang–Kota Painan Road, Batas Provinsi Riau–Payakumbuh Road and Sicincin–Lubuk Alung Road. The traffic load estimation showed that the actual traffic load was greater than standard load. This results the overlay thickness based on actual load was greater than the overlay thickness based on the standard load. The biggest difference is obtained on Tanah Badantung–Kiliran Jao load, wherein the thickness of overlay that results by actual load is 56.4% greater than the thickness of overlay that results by standard load. The greater traffic load also results reduction on pavement service life. Due to overloading, service life of Tanah Badantung - Kiliran Jao road is reduced by 56.8 % of 5 years of service life (becomes 2 years and 10 months).

Keywords: Overload Vehicle; Overlay; Remaining Life.

1. Introduction

Roads are infrastructure that support economy must be developed and maintained. The condition of infrastructure has to be maintained in a stable state to ensure the movement of goods and people without obstacle. Among other challenges in maintaining the condition of the pavement in the stable state is the rate of traffic growth, both in numbers and loads of vehicles, which can quickly exceeding the allowable limit.

Due to limited availability of vehicle load data, estimator often use standard load alone in pavement thickness and overlay calculation. This certainly makes the calculation of pavement and overlay thickness become less accurate. Inaccurate calculation results in less capability of the pavement to support the traffic load, resulting the pavement become damaged before it reaches its service life.

In this study, there are two sources of vehicle load data used. The first data is a data based on survey by consultant of *Balai Besar Pelaksanaan Jalan Nasional II* in West Sumatera Province using Portable Weight instrument. These data is considered as actual load. The second data is based on standard load. This data is based on manual of maximum limits Calculation JBI (allowed total of heavy vehicle) and JBKI (allowed total combined load) (for carrier, particular vehicles, trailers) issued by Directorate General of Land Transportation, Department of Transportation in 2008. The difference weight between actual load and standard load considered as overloaded.

According to AASHTO (1993), the purpose of added overlay course is to fix function and pavement structure and or to delay pavement surface damaging processes. The decrease of pavement function give negative impact on road users. Among the decreasing of pavement function are changes in texture and changes in surface roughness, deformation, potholes, and others. The decline of pavement structure adversely affects the ability of pavement to carry loads.

Economical based estimation of overlay course thickness was made using Pavement Design Manual No. 02/M/BM/2013 whose load is determined based on *Cumulative Equivalent Single Axle* Load (CESA). For CESA value < 10^5, it is not required to check the fatigue of asphalt, thus maximum deflection (d1) is sufficient. Traffic loads with CESA value between 10^5 and 10^7 it

uses the Curvature Function (d1-d2) approach, because there is fatigue of asphalt potential. For CESA value > 10^7 it uses AASHTO method approach.

1.1. Cumulative Equivalent Single Axle Load (CESA) Structure

Cumulative Equivalent Vehicle axle Load (CESA) is the prediction of the designed cumulative number of axle load on traffic line design during the designed service life. CESA value determined by Equation 1 below:

$$CESA = \sum_{Traktor-Trailer}^{MP} m\ x\ 365\ x\ E\ x\ C\ x\ N \quad (1)$$

Where:
CESA : Cumulative Equivalent Vehicle axle Load (CESA)
m : Number of each type of vehicle
365 : Number of days in a year
E : Equivalent of vehicle axle load
C : Coefficient of vehicle distribution
N : Factor of correlation of designed service life (traffic growth adapted)

1.2. Falling Weight Deflectometer (FWD) Analysis

FWD is an instrument of non-destructive test for measuring the road deflection dynamically, where the operation and evaluation are computerized. This instrument is used to evaluate physical properties of pavement. The principle is to provide a load impulse against the pavement structure, through the circular shaped-plate which give the same effect as a vehicle.

Overlay thickness calculation was held on each test point based on the length of segment. This segment determined based on the uniformity of deflection. In order to determine deflection uniformity factor, use the following equation 2:

$$FK = \frac{s}{dR} \times 100\% < Fk\ izin \quad (2)$$

Where:
FK : Factor of uniformity
FKizin : Allowable Factor of uniformity
: 0% - 10%; excellence uniformity
: 11% - 20%; good uniformity
: 21% - 30%; fair uniformity
dR : Average deflection on a road segment
S : Deviation Standard

After the deflection segments obtained, to determine the value of deflection that represents a segment of the road, use the following equation:

$$Dwakil = dR + 2\,S \text{ ; for arteries/highway} \quad (3)$$

$$Dwakil = dR + 1{,}64\,S \text{ ; collector road} \quad (4)$$

$$Dwakil = dR + 1{,}28\,S \text{ ; local road} \quad (5)$$

Where:
Dwakil : deflection that represent a road segment
S : Deviation Standard

1.3. Road Pavement Improvement

According to Ministry of Public Works (2013) one of the criteria for a good design is a design with minimum life cycle cost. There are many factors that have to be considered in order to obtain this design, such as traffic load, Roughness index (IRI), existing pavement structure capacity (Obtained by FWD Survey or BB), and pavement distress.

Pavement Design Manual No. 02/M/BM/2013 provides the method for selecting the best type of improvement for flexible pavement by considering factors in determining the type of improvement. Table 1 below presents a selection of the type of road improvement for traffic load lower than1 million ESA of IRI value, structure capacity and damage as trigger. The value of trigger that has been used can be seen on table 2. Table 2 provides trigger value of deflection (FWD and BB).

Table 1. Selection of the type of road improvement at Design phase for Existing flexible Pavement and Traffic Load lower than 1 million ESA.

Road Improvement		Trigger for each uniform segment
1	For preventive preservation road improvement only	IRI is below IRI 1 trigger, serious distress area lower than 5% of total area
2	Heavy Patching	Deflection exceeds deflection trigger 2 or the surface is severely distress and a surface area of the entire road segment that requires heavy patching is not more than 30% of the total area (if its more than 30% than see point 5 or 6)
3	Scrubbing and material replacement in certain area	Required if the elevation shall be equal to the elevation of the structure or curbs, etc., if the condition of existing pavement has a quite deep rutting and quite severely cracked.
4	Overlay	IRI 1 Trigger exceeded
5	reconstruction	Deflection of trigger 2 is exceeded, bitumen layer thickness lower than 10 cm, or heavy patching more than 30% of the total area, or been considered more worth or inexpensive than recycling.
6	Recycle	Deflection is above trigger 2 deflection, bitumen layer greater than 10 cm or heavy patching more than 30% of the total area.

Table 2. Roughness trigger for overlay and reconstruction.

10 years traffic (million ESA/line)	Type of Surface layer	Trigger deflection for overlay (trigger deflection 1)		Trigger deflection for investigation for Reconstruction or recycle (deflection trigger 2)	
		Benkelman Beam Characteristic deflection (mm)[3]	FWD curve d_1–d_2 (mm)	Benkelman Beam Characteristic deflection (mm)[4]	FWD curve d_1–d_2 (mm)
<0,1	HRS	>2,3	N/A	>3,0	
0,1 – 0,2	HRS	>2,1	0,63		N/A
0,2 – 0,5	HRS	>2,0	0,48	>2,7	
0,5 - 1	HRS	>1,5	0,39	> 2,5	0,66
1-2	HRS	>1,3	0,31		0,54
2-3	AC	>1,25	0,28		0,46
2-5	AC	>1,2	0,23		0,39
5-7	AC	>1,15	0,21		0,35
7-10	AC	>1,1	0,19		0,31
10-30	AC	>0,95	0,13	1,35	0,180
30 - 50	AC / Rigid Pavement	>0,88	0,11	1,2	0,175
50 - 100	AC / Rigid Pavement	>0,8	0,091	1,0	0,170
100 - 200	AC / Rigid Pavement	>0,75	0,082	0,9	0,160

1.4. Pavement thickness

In Manual of Pavement Design 2013, the method for designing overlay thickness is different for each different CESA value. Based on traffic load, there are three procedures of overlay layer thickness, for example:

- Traffic is less than or equal to 10^5 CESA
  Because the fatigue performance of asphalt is not a common damage on roads with a light traffic, then it is not required to check the fatigue performance of asphalt of overlay for the design with traffic load less than 10^5 CESA. An Approach with maximum deflection (d1) is sufficient.

- The Traffic is > 10^5 CESA and <= 10^7 CESA
  There is potential fatigue of asphalt layer for this traffic. Permanent deformation criteria and asphalt fatigue criteria have to be considered for this traffic then there is potential for fatigue layer of asphalt. Criteria permanent deformation and fatigue criteria asphalt should be considered for this type of traffic. Overlay thickness can be determined by using deflection curve.

- Traffic > 10^7 CESA
  For the rehabilitation works with traffic load designs greater than 10^7 CESA, using the 1993 AASHTO method to estimate the value of the modulus and a thick layer of the existing pavement.

1.5. Remaining Life

Remaining Life of pavement is asphalt fatigue damage concept caused by repeated load that occurred repeatedly that can be carried out by a pavement until it collapse (failure).

Sentosa and Roza (2012) conducted a study on road Simpang Lago - Sorek KM 77 + 000 to KM 78 + 000. The study aimed to calculate the cumulative value of CESA and compare the remained service life of pavement with the data that has been used in the plan. Calculation of remained service life of pavement is using AASHTO 1993 method.

The research shows that there is overloaded vehicle which is reach 77.33% compared to planning data. This overloaded caused decreasing in service life of pavement to only 54.75% (obtained by using remained service life of pavement equation in AASHTO 1993), or converted to year, there is a decreased about 8 years life service of 20 years planned service life.

AASHTO (1993) provides equation for determining the remaining life of pavement, that is:

$$RL = 100\left[1 - \left(\frac{N_p}{N_{1,5}}\right)\right] \quad (6)$$

Where:
RL : Remaining Life (%)
N_P : Total traffic to date (CESA)
$N_{1,5}$: Total traffic to pavement "failure" (CESA)

2. Methodology

The method used of this research can be seen in Fig. 1. The steps of the research described as follows:

- The data that has been used in this research is secondary data obtained from *Bidang Perencanaan Balai Besar Pelaksanaan Jalan Nasional II*. The required data are: Falling Weight deflecto-meter (FWD), the Irregularity Roughness Index (IRI), vehicle weight, Traffic Data and Test Pit.
- In order to predict cumulative value of the vehicle axle load (CESA), it requires correlation between the value of traffic growth rate and planned service life. Traffic growth rate in this study was obtained from the calculation of average traffic growth on 2011 to 2014 of each studied road.
- In this study, two type of E values were calculated, E value on the field and the value of E standard. E value in the field calculated from vehicle weight survey using Portable Weight instrument obtained from *Bidang Perencanaan Balai Besar Pelaksanaan Jalan Nasional II*. The value of E standard obtained based on *Surat Edaran Direktur Jenderal Perhubungan Darat Departemen Perhubungan* No. 2 of 2008 on Maximum Limitation Calculation from JBI (Total weight allowed) and JBKI (allowed combination of Total Weight) for carrier, particular Vehicles, Trailer.
- Road improvement is determined based on Pavement Design Manual No. 2/BM/M/2013.

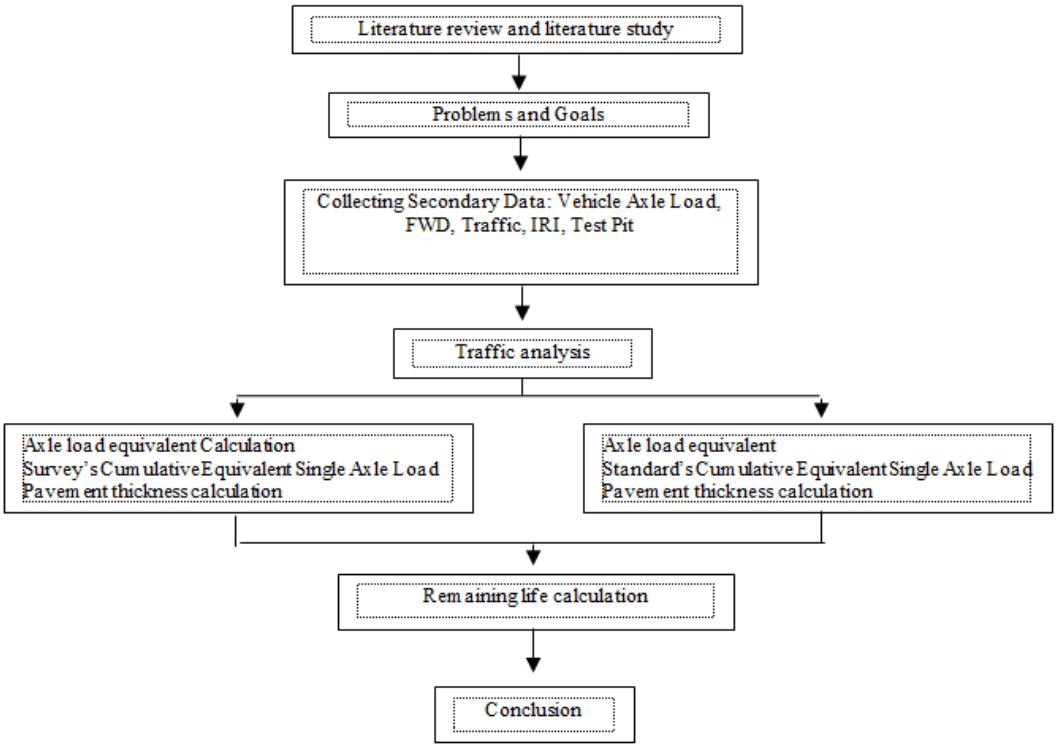

Fig. 1. Research Flowchart.

3. Results and Discussion

3.1. The Rate of Traffic Growth

Traffic growth rate is obtained from the calculation of average daily traffic of study road from 2011 until 2014. The traffic growth rate of Tanah Badantung – Kiliran Jao road can be seen in Table 3 below.

Table 3. Vehicle growth rate in Tanah Badantung – Kiliran Jao Road.

Vehicle Group	Average Daily traffic				Average Traffic Growth
	2011	2012	2013	2014	
2	1.112	1139	1230	1197	2,58
3	918	944	1018	986	2,51
4	677	696	753	732	2,74
5a	336	351	398	404	6,45
5b	119	121	134	145	6,88
6a	445	464	514	512	4,89
6b	485	517	569	562	5,14
7a	570	605	661	650	4,58
7b	265	298	278	294	3,83
7c	26	34	27	31	8,33

3.2. Equivalent of Vehicle Axle Load (E)

E is a factor that shows the damage of the pavement that caused by a certain class vehicle in units of Equivalent of Standard Axle (ESA). E value on the field and E standard of Tanah Badantung – Kiliran Jao road can be seen in Table 4 below. Table 4 shows that E value of vehicles group 6b and 7a in the field are higher than the standard E. This means that the vehicle group 6b and 7a are overloaded.

Table 4. The Value of E (Survey) and E (Standard) of Tanah Badantung – Kiliran Jao Road.

No	Vehicle Group	E (Survey)	E (Standard)	Overloaded rate (%)
1	2	0,001	0,001	0,000
2	3	0,001	0,001	0,000
3	4	2,513	2,513	0,000
4	5a	0,060	0,060	0,000
5	5b	0,748	0,748	0,000
6	6a	1,386	3,048	-54,538
7	6b	11,824	3,780	212,847
8	7a	20,860	4,452	368,499
9	7b	6,202	6,708	-7,542
10	7c	8,225	10,451	-21,292

3.3. Cumulative Vehicle Axle Load (CESA)

The cumulative value of vehicle axle load (CESA) is prediction of traffic load that will pass through a road section. In this study, CESA values was used in determining the roughness trigger value and deflection. These roughness trigger value and deflection will be used in determining type of road improvement. Table 5 described prediction value for 10 years of CESA in the field and CESA Standard. From the CESA calculation, it is found that CESA value in the field is 131.94% greater than CESA standard.

Table 5. Predicted CESA (survey) and CESA (standard) of Tanah Badantung – Kiliran Jao Road.

Year	CESA (Survey)	CESA (standard)
2015	4.661.042	2.023.768
2016	9.536.449	4.137.179
2017	14.636.334	6.344.449
2018	19.971.301	8.650.008
2019	25.606.239	11.176.782
2020	31.391.492	13.574.822
2021	37.500.596	16.204.095
2022	43.892.599	18.951.714
2023	50.580.941	21.823.345
2024	57.579.722	24.824.944

3.4. Deflection analysis

Deflection analysis is performed to determine the capacity of the old pavement structure. The first step in the analysis is to divide roads deflection based on deflection uniformity (segmentation). In this study, the uniformity value that has been used is lower than 30%. Based on the uniformity, there are 46 segments in Tanah Badantung – Kiliran Jao Road. After the segment is obtained, the next step is to determine the type of treatment that is proper for each segment. Fig. 2 below shows how the improvement was selected. A road segment with a value of deflection at load centre (d1) less deflection at a distance of 200 mm (d2) smaller than the trigger deflection of overlay, then the segment does not need the overlay. A road segment that the value of d1-d2 is greater than the deflection trigger of overlay but smaller than the reconstruction trigger, than the proper improvement is overlay.

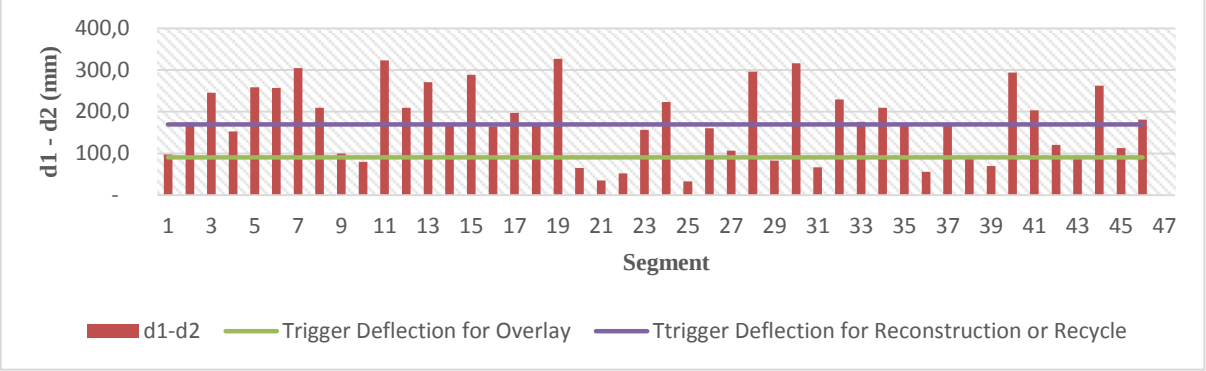

Fig. 2. Selection of the type of improvement in Tanah Badantung – Kiliran Jao Road.

3.5. Overlay Thickness Analysis

Prediction of CESA 10 years in Tanah Badantung – Kiliran Jao Road is 57,579,722 CESA. Due to the predicted value CESA 10 years greater 30 million, thus the pavement thickness calculation method that used is the AASHTO 1993 method. In this study, the designed service life of the overlay was 5 years.

The calculations show that for Tanah Badantung – Kiliran Jao Road, the layer thickness due to survey load is 48.7% greater than the layer thickness due to the standard load. Summary of calculated overlay layer thickness of each segment can be seen in Table 6.

Table 6. The Thickness of overlay thickness due to survey load and standard load of Tanah Badantung – Kiliran Jao Road

No. of Segment	Overlay thickness (survey load) (cm)	Overlay thickness (Standard load) (cm)	Percentage of different of overlay thickness (%)
4	18,7	12,8	45,6
16	22,5	16,8	33,7
18	12,9	7,0	83,2
23	21,6	15,9	35,8
26	19,0	13,1	45,2
37	19,2	13,4	43,6
42	12,1	6,5	86,8
Average different of overlay thickness			48,7

3.6. Remaining Life

From 5 years service of life design, due to overloaded vehicles on Tanah Badantung - Kiliran Jao Road, there is a reduction of 56.8% pavement life (2 years 10 months) to only 2 years and 2 months. This means that the overlay should be implemented again after 2 years and 2 months due to overloading vehicle (not after 5 years as planned).

Table 7. Summary of Remaining Life.

No	Road Segment	Service Life		Reduction of Service Life		Remaining Life					
		Overlay	Reconstruction	Overlay	Reconstruction	Overlay	Reconstruction	Overlay	Reconstruction	Overlay	Reconstruction
1	Tanah Badantung - Kiliran jao	3	5	58,5	58,7	1 yr 9 m	2 yr 11 m	41,5	41,3	1 yr 3 m	2 yr 1 m
2	Batas Kota Padang - Kota Painan	3	5	5,8	5,7	2 m	4 m	94,2	94,3	2 yr 10 m	4 yr 8 m
3	Batas Provinsi Riau - Payakumbuh	3	5	16,9	17,2	6 m	10 m	83,1	82,8	2 yr 6 m	4 yr 2 m
4	Sicincin - Lubuk Alung	3	5	44,3	41,4	1 yr 4 m	2 yr 1 m	55,7	58,6	1 yr 8 m	2 yr 11 m

4. Conclusions

Based on the research results, obtained the following conclusions:

- Based on the calculations, there is a difference equivalent value axle vehicle (E) based on survey data and based on standard load. This shows that there is overloading vehicle that passing through the road link investigated.
- Overloading vehicle resulting overlay thickness using survey vehicle load greater than that of using standard vehicle load. In Tanah Badantung – Kiliran Jao road, due to overloading vehicle, overlay thickness using survey vehicle load is greater 48.7% compared with a standard load;
- Due to overloading vehicle, there is reduction of pavement of life service. In Tanah Badantung – Kiliran Jao, there is reduction 56.8% (2 years 10 months) from life service design 5 years becoming 2 years and 2 months.

Acknowledgements

The author would like to thank all those who have assisted in completing this research, among others: colleagues in the Civil Engineering, Engineering Faculty, Andalas University and *Balai Besar Pelaksanaan Jalan Nasional II* that have been willing to provide the necessary secondary data.

References

American Association of State Highway and Transportation Officials (AASHTO), 1993. Guide for Design of Pavement Structures, AASHTO, Washington DC.

Departemen Pekerjaan Umum Direktorat Jenderal Bina Marga, Pedoman Perencanaan Tebal Perkerasan Lentur Nomor Pt T-01-2002-B, Departemen Pekerjaan Umum, Jakarta, 2002.

Departemen Pekerjaan Umum Direktorat Jendral Bina Marga, Pedoman Perencanaan Tebal Lapis tambah Perkerasan Lentur dengan Metode Lendutan Nomor Pd T-05-2005-B. Departemen Pekerjaan Umum, Jakarta, 2005.

Kementerian Pekerjaan Umum Direktorat Jenderal Bina Marga, Manual Desain Perkerasan Jalan Nomor 02/M/BM/2013, Kementerian Pekerjaan Umum, Jakarta, 2013.

Sentosa, L dan Roza, AA., 2012. *Analisis Dampak Beban Overloading Kendaraan pada Struktur Rigid Pavement Terhadap Umur Rencana Perkerasan (Studi Kasus Ruas Jalan Simp. Lago – Sorek* KM 77s/d 78), Jurnal Teknik Sipil. Vol. 19 No.2, pp 161-168.

*Surat Edaran Direktur Jenderal Perhubungan Darat Departemen Perhubungan Nomor 2 Tahun 2008 Tentang Batasan Maksimum Perhitungan JBI (Jumlah Berat yang diizinkan) dan JBKI (Jumlah Berat Kombinasi yang diizinkan) untuk Mobil Barang, Kendaraan Khusus, Kendaraan Penarik berikut Kereta Tempel*an/K

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

The 3rd SCESCM

Special Topics in Public Works Research and Technology

Study of process of the project procurement for road and bridge using e-Procurement based on Presidential Regulation No. 04 Year 2015

Moses Siburian[a,*], Anton Soekiman[a]

[a]*Postgraduate Programme in Construction Project Management,Parahyangan Catholic University, No.30 Merdeka Rd.,Bandung 40117,West Java – Indonesia*

Abstract

Procurement of government goods/services, especially in the construction field commonly still has multiple interpretations, conspiracy and errors in the evaluation that led to the project failure because of the incompetency of service providers. To anticipate this, the initial step that needs to be done is to identify any irregularities that occurred during the implementation auction of roads and bridges using e-Procurement.
The study was conducted in the auction of roads and bridges using e-Procurement in South Sulawesi and West Sulawesi. Data was collected from 30 respondents of road and bridges tender committee. Qualitative data from respondents processed using quantitative analysis method with statistical test using Likert scale.
From 8 (eight) factors that has been studied in this research, the irregularities that most often occur in the implementation of the auction were "problems of interoperability" with percentage 68.67%. While in practice, the evaluation process is still being done completely manually so it cannot be monitored using the procurement portal. E-Procurement system only displays the final result of evaluation with some information. Another factor which often happens is "auction is not following the rules that is accountable to the supervisor" with percentage 60.41%. Manual evaluation to detect false administrative documents is difficult to apply by committee. It relates to manual examination of the offer document is often not done by the committee because of too many work packages to be auctioned.

Keywords: E-Procurement; Procurement of Government Goods/Services; Procurement Irregularities; Procurement Portal

1. Introduction

Infrastructure development by the Ministry of Public Works and Public Housing (PUPR) can improve the movement of the national economy and leveling the economic pulse throughout Indonesia. In addition to careful planning and execution of appropriate specifications, good infrastructure needs to be supported by the selection of appropriate service providers. Especially in the construction field, procurement of government goods/services, generally still has multiple interpretations, conspiracy and errors while using the existing regulations.

Because of the incompetency of service providers' evaluation has led to the project failure. Due to this reasons the government has sought to find a solution to enhance the implementation of the procurement system. One of the latest and most fundamental solutions by the government in the procurement implementation is the application of e-Procurement system.

The Deputy of Human Resources Development and Training Institute for Procurement of Goods/Services (LKPP) mentioned that e-Procurement, in principle, is changing the mindset. The mindset will change from things that are manual and prone to abuse into an electronic system which reduces face to face system. Realizing the advantages offered by e-Procurement, the Ministry of PUPR has been implementing it in the construction procurement of roads and bridges in nearly all parts of Indonesia. The main problem in the auction implementation problems mainly occur in the evaluation phase. Besides that, the counter that stops in process of the auction time can also cause a repeated tender. The repeated tender could be caused by the receipt of the objection appeal, the error evaluation by the committee and the insufficient number of bidders due to Self-Estimated Price (HPS) is too small. Referring to the above problems, the e-Procurement system is often considered inefficient and impressed just as digital storage space replacing the physical document transactions on conventional procurement.

The most crucial in the process of procurement of construction roads and bridges in the Ministry of PUPR is the activity to get competent service providers who can properly deal with government infrastructure projects in Indonesia. Therefore, the

* Corresponding author. Tel.: +81-11-841-1698; fax: +81-11-841-3502.
E-mail address: siburiandemon@gmail.com

authors recognize the need for research to know the deviations from the basic principles of government goods/services procurement using e-Procurement and find the solution related to the principle of good management being efficient, effective, open and competitive, transparent, fair/non-discriminatory and accountable.

The objectives of this research is: (1) To identify irregularities factors of procurement principles in the construction services procurement using e-Procurement in the Ministry of Public Works & Housing, and (2) To provide proposals related to procurement principles and solution for irregularities of e-Procurement including strategic planning.

This research will be referring to: (1) Presidential Decree of the Republic of Indonesia Number 04 year 2015 about the Fourth Amendment to the Presidential Decree Number 54 year 2010 concerning the Procurement of Government Goods/Services and its derivatives, and (2) Procurement is restricted to the procurement of construction roads and bridges Using web of Institution for Electronic Procurement from Ministry of Public Works & Housing in South Sulawesi and West Sulawesi.

2. Theoretical Background

Regulation in the form of Presidential Decree Number 54 in 2010 on Procurement of Government Goods/Services had undergone four changes since its launch. These changes also occured at the associated regulation from the Ministry of PUPR. The purpose of these amendments is solely to achieve excellence in the implementation of procurement principles. The seven principles applied in government procurement in general should be effective, open, competitive, transparent, fair / non-discriminatory and accountable.

Considering the needs of the community/public, procurement of government goods/services should be based on principles of good governance and clean government. The government should implement the principles of accountability and efficient in resources management. This should be manifested through regulation and good actions and impartially (independent). To achieve this goal the government should not just rely on the spending of budgets to be transferred to the activity by any company.

2.1. The System of Procurement of Goods/Services using e-Procurement

The weakness of conventional procurement can be minimized but the deviation from the regulation is still increasing along with the procurement system development. In a supportive environment in terms of human resources issues and the auction process, conventional construction procurement process is not much different compared to procurement while using e-Tendering (Lou et al.,2009) Therefore, the ability of an organization to implement e-Procurement is not merely from technological knowledge but depends on human resources compliance to auction based regulation.

The principles that generally apply in government procurement are listed below:

- Efficient, must be cultivated using limited funds and resources to achieve the target goal in the shortest possible time and still could be accountable;
- Effective, must be in accordance with the requirements specified and may provide as much benefit as possible in accordance with the target goal;
- Open And Competitive, should be opened to providers of goods/services that meet the requirements and conducted through healthy competition among similar level of providers of goods/services that qualified based on the clear and transparent provisions and procedures;
- Transparent, all the provisions and information on the procurement of goods/services, including administrative requirements, evaluation procedures, the results of the evaluation, determination of suppliers of goods/services candidates, are opened to goods/services provider participants who are interested as well as for society;
- Fair/Non-Discriminatory, gives equal treatment for all potential goods / services providers, and does not lead to advantages to certain parties, in any way or for any reason;
- Accountable, should reach the target of physical, financial and benefits for the convenience of the public administration and public services in accordance with the principles and regulations of procurement of goods/services.

The principles contained in the objectives of e-Procurement by the Policy Institute for Procurement of Goods/Services (LKPP) can be seen in Fig. 1 below.

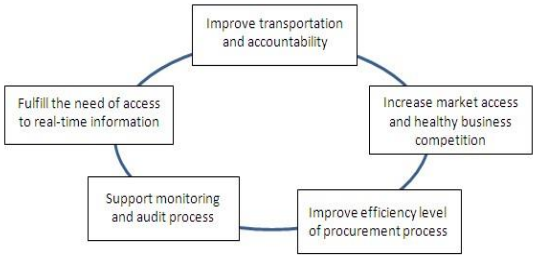

Fig. 1. Objectives of e-Procurement Implementation in Procurement of Government Goods/Services

The five goals of the e-Procurement is a unity. Good information access that gives positive effects on the transparency principle. Likewise, the good results of monitoring and auditing are achieved from the increasing of accountability. In connection with the above purpose, LKPP added two principles of government goods/services procurement to support the implementation of e-procurement: principle of interoperability and guarantees for data security. Summarized:

- Interoperability, the ability of various systems or different applications to work together and interact with each other allowing the possibility to exchange information through a mutually agreed protocol.
- Warranty Data Security, e-Procurement system is a data storage media service, users and service providers can operate, delete or add at any time. In the implementation of an electronic procurement, it needs assurance of data security so that the goal can be achieved.

2.2. The Parties Involved in the Procurement of Roads Construction and Bridges

In Presidential Decree Number 4 Year 2015 about the Fourth Amendment of Presidential Decree Number 54 Year 2010 concerning Procurement of Government Goods/Services, it is stated that the organization of government goods/services procurement consists of:

- Budget User/Budget Authority (PA/KPA),
- PA is the official holder who has the authority to use the budget of the Ministry/Institution/Regional Work
- Units, or the officials who equated as User Institution for APBN/APBD,
- The commitment maker officials (PPK),
- PPK is the official, who is responsible for the implementation of Procurement Goods/Services Project,
- Working Group on Procurement Services Unit (ULP),
- ULP is a permanent organizational unit of the Ministry/Institution/Regional Government/Institutions that responsible to implement the Procurement of Goods/Services. It can be stand alone or attached to a unit that already exist, and
- Recipient of the Works Committee (PPHP),
- Recipient of the Works Committee is the committee/officials chosen by the PA/KPA who are in charge of examining and accepting the work.

Besides the organizations mentioned above, other parties that also have a role in the procurement of road and bridge construction using e-Procurement are providers of Goods/Services as the bargainer of the job and the Center for Data Processing and Information Technology (*Pusdatin*). *Pusdatin* is an electronic procurement service agencies owned by the Ministry PUPR. LPSE of Ministry of PUPR recently joined the LPSE of LKPP in 2015.

The main functions of the *Pusdatin* Ministry of PUPR are as an administrator of electronic systems, a registration unit, user verification, and user services units. As an administrator, *Pusdatin* is also responsible for maintaining traffic data transactions between procurement committee with service providers such as shown in Fig. 2 below.

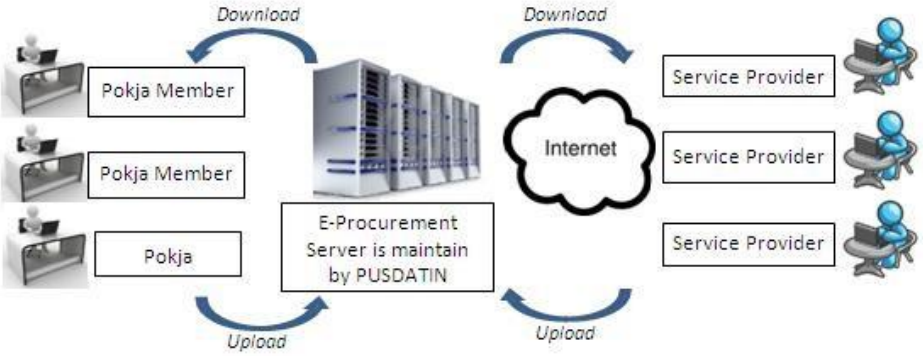

Fig. 2. Circulation of Data in e-Procurement.

Circulation of data between providers and procurement committee is possible running in parallel. This infrastructure is expected to be able to guarantee the originality of data (cross check) and gives an easy and transparent audit.

3. Assessment Method

Assessment method is used to develop ideas related to the research topic. One of objectives in this research is to identify deviations in the implementation of the electronic auction. Facts in the field indicate that the deviation of procurement principles is still present in the implementation of electronic auctions. To achieve that objective, this study used qualitative

method, where the existing variables are translated into quantitative form. Qualitative variables used in this research were observed through respondents by instruments such as questionnaires. The research instrument is then tested for its validity and reliability to discover the extent of instrument's precision and accuracy in performing its functions.

Table 1. Number of deviation indicators used to build the questionnaire.

No.	Variable	Number of Deviation Indicators
A	**Auction does not use resources efficiently**	11
A.1.	Standard prices set by the Regional Head is not represent field conditions well, making it less feasible to use for the calculation of HPS	
A.2.	The increase of budget as a result of deliberate mark up of HPS and inflation the cost of the auction	
etc.		
B	**Auction does not fit the needs and does not benefit**	4
B.1.	With the current qualification assessment criteria, it is still often found some cases where the providers who pass the qualification are not a potential service providers	
etc.		
C	**Auction is not open and not compete**	11
C.1.	General Procurement Plan (RUP) does not appear in the procurement portal or RUP appear in conjunction with the announcement of the auction	
C.2.	The technical specifications leads towards one particular product with the argument that it is a local product and there has been no study on the product substitution	
etc.		
D	**Information related to the auction does not reach the society**	10
D.1.	The process of evaluation by the committee did not do in the procurement area of ULP office in order to avoid the influence of other elements outside of the committee and prevent information leakage	
D.2.	Information obtained through aanwijzing is not entirely poured into the addendum so there is a difference in the quality of information among auction participant who attended and did not attend aanwijzing	
etc.		
E	**Gives different treatment to some auction participants**	8
E.1.	Doing auction and get-together openly without going through the ideal evaluation	
E.2.	The evaluation criteria that is in favor towards particular auction participant, for example: obliges that heavy tool has to be the local ownership status and located near the project site	
etc.		
F	**The auction does not follow the rules that can be accounted to supervisor**	14
F.1.	ULP is not using its authority in terms of supervision during the evaluation process	
F.2.	The committee abort the deals because of the unsubstantial problems	
etc.		
G	**Problems in interoperability**	3
G.1.	Implementation of the auction in the procurement portal has not been completed, but in reality the progress of the auction has reached the stage of contract or even more	
etc.		
H	**The lack of data security**	3
H.1.	Auction participants have difficulties in submitting the offering documents due to the attempts of other auction participants to block the entry process documents	
etc.		

The variables in Table 1 above were measured using each indicator which is converted into question. Before being used as a research instrument, indicators items in the form of 64 questions should be tested for its validity and reliability in advance to 10 respondents who are experts in the auction of government goods/services.

This study is using Likert Scale as measurement instrument. This type of measurement is used to measure attitudes, opinions and perceptions of a person or group about events or social phenomena. The answer on this instrument is the ordinal data based on ranking from the highest level to the lowest level. After that, in the stage of the result analysis and discussion, the deviation indicators that are considered to occur most often by several speakers are then presented. Next, the discussion is done to make recommendations on how to response to each of those indicators.

4. Analysis and Discussion

4.1. Overview Study Areas

Handling of national roads in South Sulawesi and West Sulawesi is under control of the National Road Implementing Agency VI Makassar. Initially, West Sulawesi was merged with South Sulawesi province and split off into a new province in 2004. As a new province, handling of national roads in West Sulawesi province still needs the support of South Sulawesi province. As a result, the workers involved in the auction relatively consist of the same people. West Sulawesi province deserves to be the object of study because the roads and bridges auction using full e-Procurement in this region was newly implemented since 2013. Meanwhile, South Sulawesi province has been using Full e-Procurement system since 2009. So the respondent contained in this province has experienced a situation such as:

- Experience in the roads and bridges auction conventionally
- Experience the transition from conventional auction, semi e-Procurement auction, to full e-Procurement auction, including the application in the newly formed provinces (West Sulawesi)

4.2. Characteristics of Respondents

Respondents involved in this study are the tender committee, ULP support staff and ULP advisor/secretariat which have been certified for procurement of government goods/services. Experience in the procurement of government goods/services are observed not only in terms of involvement in a regular auction, but also experience in using e-Procurement system. Respondents were obtained from the Decree of the Head of the Implementation of the National Road VI Makassar responsible for the auction of roads and bridges in South Sulawesi and West Sulawesi.

The position and experience of staff involved in the roads and bridges auction in South Sulawesi and West Sulawesi can be seen in Fig. 3 below.

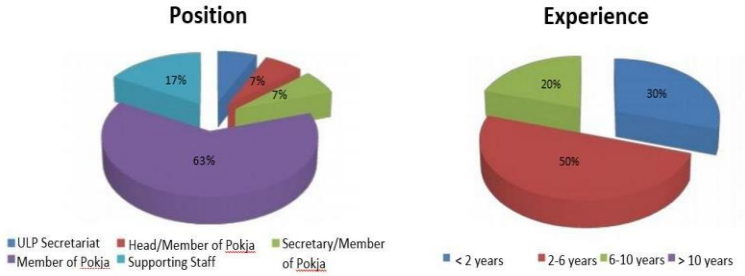

Fig. 3. Characteristics of Respondents.

The graph above shows that most respondents came from Members of the Working Group with the amount of 63.33%. Working Group members is spearheading the implementation of the auctions that are generally directly related to the evaluation process as well as web of LPSE the Ministry PUPR.

4.3. Analysis the Deviations in the Implementation of Services Auction for Roads Construction and Bridges

The questionnaire is designed as “closed-ended questions” where each question has been provided the choice of answer using basic format of Likert rating scale. The questionnaire consists of eight variables where each variable consists of several questions regarding the deviation indicator. From the result of each indicator and variable scoring calculation based on the Likert scale, the percentage weight of deviations in the implementation of e-Procurement auctions is obtained and can be seen in Fig. 4 below.

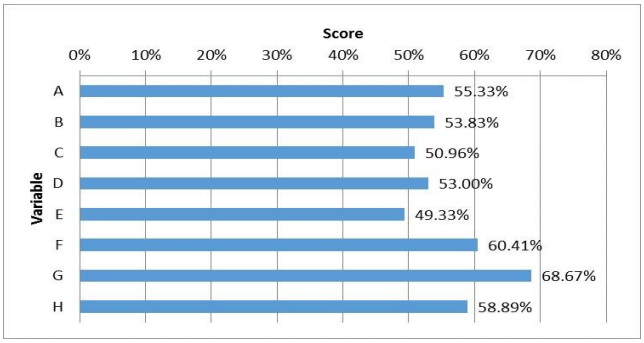

Fig. 4. Rank of Each Variable in Deviation of Auction in the Implementation of Roads Construction and Bridges.

Based on the chart above, the first position level of the irregularities in the implementation of the roads and bridges auction is variable G "Problems in the Interoperability" with percentage 68.67%, which means that it is occurred at the "often" level. Meanwhile, the second level of the irregularities in the implementation of auction in roads and bridges is variable F "The auction does not follow the rules that can be accounted to supervisor" at percentage 60.41%, which means that it is also occur at the "often" level. The further explanations of each variable irregularity are as follows:

4.3.1. The Auction does not Use Resources Efficiently

Scores of indicator item A.9 or "*Pokja* ULP is not provided with guidance in order to improve the integrity and professionalism regularly every budget year" is at level "often" occur. In fact, the events related to procurement of government goods/services are limited to socialization of the Presidential Decree, the Regulation of the Minister and the latest Standard Bidding Document. This event is held every budget year, however procurement committee special debriefing on improving the integrity and safety tips in procurement was never implemented. With a standard deviation of 1,124 and a probability of 95%, then the distribution of the data is high enough to item A.9 indicator. In other words, the opinion of the respondents to this item fluctuates. In addressing the subject development activities and increase integrity in the auction, the respondents can assume that SBD and regulations has been socialized as coaching. Meanwhile, some respondents consider coaching should assess include the mental and emotional side of the perpetrators of the auction. Indicator item A.11 or "high value of the contract for the preparation of technical specifications HPS or do not recognize the needs and involving service providers" pick the smallest standard deviation of all the indicators. This means that the confidence level is strong enough showing that indicator does happen even in a rating of "Sometimes".

Indicator item A.1 or "Book of Standard Unit Price of Goods/Services assigned by the Regional Head not represent the actual prices in the field well". This item is expected to be the first order aberrations due to the fact that even in the preparation of HPS, KDP elements seem reluctant to use local Book of Standard Unit Price because of its accuracy in corresponding the price to the field real price that may have more expensive price. Efficiently, PPK action is assumed to be correct because it chooses the lowest price, but in accountability, these actions are less accountable.

4.3.2. Auction does not Fit the Needs and does not Benefit

Scores for indicator item B.1 is categorized in rate "often" occurs. Item B.1 has a significant different score with the other item, therefore it is sufficient to focus only in indicators B.1. Indicators B.1 "With the current qualification assessment criteria, it is still often found some cases where the providers who pass the qualification are not a potential service providers" is a condition that is frequently complained by the tender committee. The process of qualification evaluation assessment consisting of yes or no is less represents the desire of PPK to implement the safe and smooth project. Type of qualification assessment such as the tool ownership status and reputation of the company should be present in the evaluation of qualifications, even though this is not accommodated in the regulations.

Indicator item B.3 or excessive technical evaluation that unrelated with the needs, for example: the status of its personal mandatory minimum equipment to avoid damage to the equipment during project implementation has the smallest standard deviation. This means that the confidence level is strong enough to show that indicator does happen even though in rating of "Sometimes".

4.3.3. Auction is not Open and not Compete

Scores of indicator item C.9 is categorized in the rate "often" occurs. Scores of indicator item C.9 has a significant different score with the other item, therefore it is sufficient to focus only in indicators C.9 alone. Indicator item C.9 or "Auction participants who submit several offers of work package is the same participants and the number of deals are very few compared to the number of applicants" are fairly common in West Sulawesi province. In general, the entire procurement of roads and bridges that were handled by the Ministry PUPR has a very few number of offers compared to the number of applicants. Most of the service providers that register was not motivated to give offering but want to download offering documents.

The condition where service providers who offer several work packages comes relatively from the same providers can occur because the work package is located quite far from Java Island or the economic center of the island. The service providers intentionally or unintentionally monopolize works because resources such as heavy equipment, AMP and fuel are owned by local service providers.

4.3.4. Information Related to the Auction does not Reach the Society

Score for indicator item D.5 is categorized in the rate "often" occurs. Indicator item D.5 or "Pressure to announce a tender soon push the committee to distribute the unready tender documents" is fairly common to happen when there is policy on auction prior fiscal year. Socialization about the new standard bidding document is always conducted every fiscal year, however it normally has not been formally authorized.

On one side, tender committee is pressed to quickly announce work package so that the procurement document which is uploaded by committee seem fall apart and confusing service providers. A side effect of this situation is many procurement document addendum and uncertainty legal basis of evaluation method by the committee.

Auction committees along with ULP parties mostly do not have a special room to carry out their activities. Concerns over the possibility of evaluation results leak before time cause the ULP decided to carry the implementation of evaluation outside the offices of the relevant agencies. Indicator item D.1 or "The process of evaluation by committee is not done at the ULP office/branch office area" quite often happens in ULP especially in West Sulawesi province.

Indicator item D.3 or "Service providers and employers who have an interest can know the evaluation process which is reported by the commitment maker officials (PPK) periodically" often occurs because many committee assume that the results of the auction evaluation could be accountable by supervisor if the entire results of evaluation report has been reported to supervisor. Presidential Decree no. 70 in 2012 and its derivatives clearly state that the results of tender is signed by the auction committee, therefore there is actually no interference of supervisor on the decision.

4.3.5. Gives Different Treatment to Some Auction Participants

Indicator item E.8 and E.3 are categorized at the level of "Sometimes". Indicator item E.8 or "Announcement of winner is delayed to give the opportunity to change the evaluation results for the benefit of certain parties" tend to occur in large-value work packages. It is actually also influenced by the habit of the tender committee who report the results of the evaluation to the supervisor (indicator item D.3) so it can obscure the decision to determine the winner of the auction. The number of persons who know the results of the evaluation led to a growing number of inputs to the auction committee in deciding the winner.

With the largest standard deviation among all items and a probability of 95%, the highest of the data distribution is for indicator item E.8. In other words, the opinion of respondent for this item is the most fluctuated. This condition can occur because the item is quite sensitive to be asked to the respondents so it really depends on the honesty of respondents. In addition, the leader's policy is different for each Unit where such policies affect the independence of the tender committee in determining the winner.

Indicator item E.3 or "the Committee is requested to win specific company which is already familiar so it violates some of the criteria in the evaluation" categorized at the level of "Sometimes" occurs. This is also influenced by the PPK desire to work with a service provider that has a good reputation in previous projects (indicators item B.1). This kind of demand forced the committee to make the evaluation criteria that has not been discussed previously with the service providers.

Indicator item E.1 or "Doing get-together tender openly without going through the ideal evaluation" should be on top. This deviation is in fact often happened, strengthen by the evidenced that the name of the bidder in several work packages is the same, which can be seen in the Portal for Procurement of Goods/Services of the Ministry PUPR.

4.3.6. The Auction does not Follow the Rules that can be counted to Supervisor

Indicator item F.7 or "The manually evaluation committee makes it difficult to detect false administrative documents" is categorized at level "often" occurs. E-Procurement system which is adopted by the Ministry of PUPR has not included the evaluation process in detail. E-Procurement system has not integrated with the database of blacklisted companies, database of tools and database of experts. Manual inspection of the supporting documents that support the validity of company, availability of equipment and the expertise of resources is often not done by the committee because of too many amounts of work packages to be auctioned.

4.3.7. Problems in Interoperability

Indicator item G.2 or "The evaluation process is still done completely manually so it cannot be monitored through the procurement portal" is categorized at the level of "Always" occur. This deviation indicator is related to the limitations of e-Procurement system. Evaluation of auctions that should be transparent, in reality, cannot be monitored by the service provider using online connection. E-Procurement system only displays the final result of evaluation with some information. The quality of the contents is also still dependent on the precision of the committee in providing the information.

4.3.8. The Lack of Data Security

Indicator item H.3 or "Offering documents of auction participants must not be opened at the opening of ceremony, however the committee must not accept the offering documents in physical form" is categorized at level "often" occurs. A deviation of this item is actually located on the e-Procurement system that is adopted by the Ministry of PUPR. E-procurement system has provided applications to inspect offering document called Hash Check. This application has actually been socialized but there only few people who use it.

Some providers claim to still have difficulties in uploading the offering documents. Because they focus on the uploading process, they ignore Check Hash application to examine the feasibility of document that has been uploaded. In current full e-

Procurement auctions, there is currently no tolerance for data loss or complaint of document upload speed. It is considered unfair because of inadequate infrastructure although service providers have already understood the risks.

E-Procurement system Ministry of PUPR which has been implemented is still included in traditional procurement support system so the implementation of the auction, in principle, still held traditionally. Traditional in this case means that the evaluation is done manually, with unavailability of auction supporting database and time of the auction that takes a long time.

The strategies that can be applied in e-Procurement systems the Ministry of PUPR are, for example:

- Design service provider database that are eligible to enter the auction. If this development is applied, the auction method can be implemented in the pre-qualification tender. Prequalification method is better in choosing a service provider rather than post-qualification method
- Design minimal equipment database and AMP which is certified operable so that there are no more conflicts about the availability of equipment and AMP.
- Design source materials database, such as asphalt, aggregate and cement that have passed the test of the relevant agencies. With the existence of this database, service providers can only use the approved source material.
- Evaluation of subjective work methodology is eliminated and replaced with an evaluation of service provider's innovation in carrying out the work. Assessment of work methodology is not transparent and can abort. The process of field work has standards of *Bina Marga* technical specifications. Good work methodology actually cannot guarantee the good performance at field work.

5. Conclusions

Based on the result of analysis and discussion, it can be concluded:

- In general, there are six deviation variables' level that occur in the implementation of roads and bridges auction in South Sulawesi and West Sulawesi. These are: (1) the auction does not use the resources efficiently, (2) the auction does not fit the needs and does not result in benefits, (3) the auction is not transparent and incomplete, (4) information related to the auction does not reach the society, (5) a treatment difference to some auction participants, and (6) the lack of data security. Meanwhile, the deviation variables are: (1) the auction does not follow the rules that can be accounted to supervisor, and (2) problems in interoperability occurring in the implementation of the auction.
- Factor irregularities in the "interoperability problems" occur during first manual evaluation of the committee, such as difficulties in detecting false administrative documents. To overcome this issue, the e -Procurement systems adopted by the Ministry PUPR was introduced but not included in the evaluation process in detail. Also, manual inspection of the supporting documents that support the validity of company, availability of equipment and the expertise of resources is often not done by the committee because of the high number of work packages to be auctioned.
- Factors in the variable deviation "auctions according to the rules that are accountable to the supervisor" who were in first level of the evaluation is conducted entirely manually so it cannot be monitored through the procurement portal. Evaluation of auctions that should be transparent, in reality, cannot be monitored by the service provider using online connection. E-Procurement system only displays the final result of evaluation with some information. The quality of the field is also still dependent on the precision of the committee in providing information.
- A dominant deviation present since the conventional auction is a deviation. In other words, the current implementation of e-procurement auctions actually does not significantly influence the minimizing of aberrations. Therefore, there needs to be a significant increase in terms of governance auction, information technology and human resources that play a role in the auction.
- Further research related to the development of e-Procurement system in the Ministry PUPR needs to be performed, so the system could be mentioned as web-based auction system. Some indicators of irregularities have one-way or two-way relationships. The research may be continued by analyzing the relationship between deviations so that the handling of the auction implementation deviation can be targeted optimally.

References

Anonymous. "Kajian Pengadaan Barang/Jasa Pemerintah Dari Perspektif Hukum Pidana dan Kriminologi", (www.pantau-pengadaan.org, downloaded at January 5th 2015).

Anonymous. "Laporan Tahunan Komisi Peberantasan Korupsi (KPK) tahun 2011", (http://www.kpk.go.id, accessed at October 18th 2015).

Anonymous. "Lembaga Kebijakan Pengadaan Barang/Jasa Pemerintah (LKPP) (2011)", Majalah Pengadaan Indonesia Kredibel Edisi 01 bulan Oktober 2011 – Desember 2011, (http://www.khalidmustafa.info, accessed at November 22th 2014).

Anonymous. "Portal Full E-Procurement Kementerian PUPR", (www.pu.go.id, accessed at October 10th 2015).

Eadie, R., Perera, S., Heaney, G. and Carlisle, J. 2007, "Drivers and Barriers to Public Sector E-Procurement within Northern Ireland's Construction Industry", *ITcon Vol. 12 (2007), pp. 103*.

Lou, E.W., & Ashalwi, M., 2009, "Critical Success Factors For E-Tendering Implementation in Construction Collaborative Environments: People and Process issues", *Journal of Information Technology in Construction, XIV, 98-109.*

Martin, Joe, 2008, "Web-Based Electronic Bidding United Kingdom, Practical Experience", *AACE International Transactions, 2008, Proquest Science Journals, page IT31*.

Maslani, 2011, "Audit Pengadaan Barang/Jasa: Mengenal Risiko Penyimpangan untuk Pencegahan", *Jurnal pengadaan Lembaga Kebijakan Pengadaan Barang/Jasa Pemerintah, Volume I, Number 1, Hal. 58-75*.

Nasril, 2010, "Kajian Pelaksanaan Pengadaan Jasa Pemborongan Pemerintah Berdasarkan Keppres 80/2003 (Studi Kasus Pada Pemda Kab. Padeglang)", Tesis Jurusan Manajemen Proyek Konstruksi, Universitas Parahyangan Bandung.

Nurchana, A.R., Haryono, B.S. and Adiono, R., 2014, "Efektivitas E-Procurement Dalam Pengadaan. Barang/Jasa: Studi terhadap Penerapan E-Procurement dalam Pengadaan Barang/Jasa di Kabupaten Bojonegoro", *Jurnal Administrasi Publik (JAP), Vol. 2, No. 2, Hal. 355 -359.*

Panayiotou, N.A., Gayaialis, S.P., Tatsiopoulos, I.P, 2004, "An E-Procurement System for Governmental Purchasing", *International Journal of Production Economics, Vol. 90, Hal. 79–102*.

Peraturan Menteri Pekerjaan Umum Nomor 31/PRT/M/2015 tentang Perubahan Ketiga Atas Peraturan Menteri Pekerjaan Umum Nomor 07/PRT/M/2011 tentang Standar dan Pedoman Pengadaan Pekerjaan Konstruksi dan Jasa Konsultansi.

Peraturan Presiden Republik Indonesia Nomor 4 Tahun 2015 tentang Perubahan Keempat Atas Peraturan Presiden Nomor 54 Tahun 2010 tentang Pengadaan Barang/Jasa Pemerintah.

Restianto, Yanuar, "Implementasi E-Procurement Pada Satuan Kerja Pemerintah/Pemerintah Daerah", (www.lpse.unsoed.ac.id, accessed at October 15th 2014).

Rinasari, 2010, "Upaya Pencegahan Persekongkolan Dalam Proses Pengadaan Barang/Jasa Pemerintah", Tesis Jurusan Manajemen Proyek Konstruksi, Universitas Parahyangan Bandung.

Rofikoh, Nurul dan Noor, As Martadani, 2013, "Mewujudkan Good Governance Melalui *E-Procurement"*, FISIP Universitas Widya Mataram Yogyakarta Dalem Mangkubumen KT III/237 Yogyakarta.

Wijaya, W.H.; Indryani, R., and Putri, Y.E., 2012, "Studi Penerapan E–Procurement Pada Proses Pengadaan Di Pemerintah Kota Surabaya", (digilib.its.ac.id, accessed at October 15th 2014).

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

Special Topics in Public Works Research and Technology

Spatial optimization model for raw water supply allocation (case study in Jabodetabek)

Edy Anto Soentoro[a,*]

[a]*Master Program in Water Resources Management, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia*

Abstract

Rapid economic growth in Jakarta and its surrounding areas (Jabodetabek) has led to the growth of industrial and business centers. This on their turn has led to a growing need for water for the centers resulting in water shortage. Solution to fulfill water demand is often only an approach that based on the cheapest cost and fastest time to make it ready, such as groundwater abstraction. Meanwhile, excessive groundwater abstraction in Jakarta has resulted in various environmental damages, such as land-subsidence, local inundation, increase of groundwater pollution and seawater intrusion. Due to these problems, groundwater abstraction should be minimized, and long-term solution of short of water supply in Jabodetabek should be based on surface water resources. This study is aimed to optimize raw water supply allocation for Jabodetabek based on location of water resources, utilizing existing infrastructure, and building new infrastructures as needed. Using estimated water demands at growth centers, available supply discharges from water resource locations and network flows, the author developed objective, strategies and constrains to spatially optimize water allocation through linear programing. Results of this study are optimal selection to build additional water infrastructures which related to degree of water demand fulfillment (supply/demand) at each of the growth centers.

Keyword: spatial optimization; linear programing; water allocation

1. Introduction

Rapid economic growth in Jakarta and its surrounding areas (Jabodetabek) through industrialization, economic centers, business and trading has led to the emergence of "clusters of growth" as satellite towns or centers of growth at around Jakarta. Along with the growth of the satellite towns, the water demand for Jabodetabek (Jakarta-Bogor-Depok-Tangerang-Bekasi) increased thus causing shortage of clean water. Solution to fulfill the water demand is based only on the cheapest cost and fastest time to make it ready, such as groundwater extraction. Exploitation of groundwater is simple and inexpensive, and the costs of treatment and distribution are cheaper comparing with those of surface water. Increments of demand can be satisfied with small progressive increases in investment in groundwater exploitation. Meanwhile surface water requires huge capital investments for getting the water (i.e., water rights, reservoir/intake structures), for the conveyance systems and for water treatment plant. The tendency in most cases in developing countries is that industrial and urban centers (cities) will continue to use groundwater as the low-cost water supply option for as long as possible, and as long as there is no obvious evidence of a harmful effect by Edworthy (1993). If this trend continues, groundwater abstraction may become excessive and beyond the availability of the aquifer to support.

Excessive groundwater extraction in Jakarta has already resulted in various environmental damages, such as land-subsidence, local flooding/inundation, as well as increased pollution of groundwater and seawater intrusion

In general, water resources for clean water to supply the greater Jakarta area is limited for both surface water and groundwater. Many existing surface water resources close to Jakarta are severely polluted resulting in a water treatment process that becomes very expensive. Groundwater aquifer volume in the area is also limited, so that too much withdrawal of groundwater in the area will lead to disaster such as land subsidence, local flooding and increase in sea water intrusion and others. Planning of providing enough water supply in Greater Jakarta for the long term should be emphasized on surface water resources and groundwater extraction should be minimized. For that purpose, we need to maximize the use of existing water

* Corresponding author.
E-mail address: edyas209@gmail.com

resource infrastructures to build additional dam/reservoir along with their conveyance channels. Given water demand for each satellite towns, locations and capacity of reservoirs, costs for water resources development and infrastructure constructions, and available investment fund, then the best allocation of raw water supply for clean water could be optimized. The study will optimize the existing resources (water resources, existing infrastructure, limited funds) in order to maximize the degree of fulfillment water demand for each demand cluster. It is also very useful for decisions making to rank priority of water sources development for clean water in the greater Jakarta area.

A simplified system simulation model (Supply sim) is used to determine the best water supply allocation to each demand cluster, the degree of water demand fulfillment (i.e., percentages of supply water per water demand) that can be fulfilled, and the best sources of raw water supply. The model helps to simulate and determine the allocation of flows for each cluster based on the purpose of a particular supply alternative. From many raw water sources, the model can provide 100% of the supply needed to meet the demand for some clusters and the other clusters can receive most of the supply needed to meet their demands. Where the entire demand cannot be met, the model can help identify strategies to equitably allocate the shortages to the demand clusters.

2. Methodology

Spatial optimization model for raw water supply allocation used for this study is called supply-sim model. Developed by the author in a spreadsheet, the model uses simulation and optimization methods to calculate water supply allocation for each demand cluster in the water supply network. Result of the model are the degree of water demand fulfillment (percentage of water supply per water demand can be fulfilled) of each demand cluster, and where the raw water supply comes from (e.g., reservoir A, reservoir B, or groundwater wells). Information from the results can lead to determine which water infrastructure (e.g., dam/reservoir, conveyance system) have to be built to obtain a certain degree of water demand fulfillment. And this information helps decision-making process to rank priority of building water infrastructures to fulfill the spatially rapid increase of water demand.

The supply-sim model applies network flow simulation in the spreadsheet, then it optimizes the percentage of supply/demand for each demand clusters by using “solver” tool of the spreadsheet. Based on network flow below, simulation and optimization procedure are applied as below:

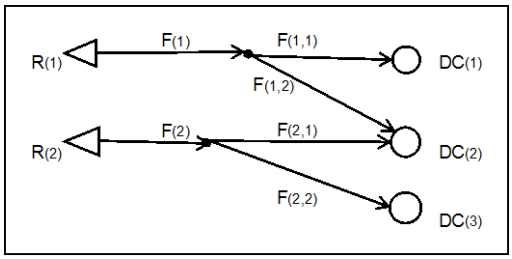

Fig. 1. The Supply-Sim model applies network flow simulation

- Flow pass through the node:

$F(i,j) = FR(j) * F(i)$
$FR(j) \leq 1$

- Network flow simulation:

a. $S_{(1)} = F_{(1,1)}$
   $S_{(2)} = F_{(1,2)} + F_{(2,1)}$
   $S_{(3)} = F_{(2,2)}$
b. $F_{(1)} = F_{(1,1)} + F_{(1,2)}$
   $F_{(2)} = F_{(2,1)} + F_{(2,2)}$
c. $\sum_1^n S(i) = \sum_1^n F(i)$

in which:
R : reservoir
DC : demand cluster
F : flow discharge of water supply
S : actual supply discharge to DC
D : water demand of DC
FR(j) : fraction flow of main flow F(i) that go to F(i,2), equal to F(i,2) / F(i)

The optimization objective is to minimize the different percentage of supply/demand among demand clusters:

Minimize : TLDELTA = $\sum_1^n$ DELTA (i)
Subject to :
1. DELTA(i) = Absolute {PR(i) – PR(i+1)}
2. PR(i) ≤ 100
3. FR(i) ≤ 1
4. Network flow simulation :
   a. $S_{(1)} = F_{(1,1)}$
      $S_{(2)} = F_{(1,2)} + F_{(2,1)}$
      $S_{(3)} = F_{(2,2)}$
   b. $F_{(1)} = F_{(1,1)} + F_{(1,2)}$
      $F_{(2)} = F_{(2,1)} + F_{(2,2)}$
   c. $\sum_1^n$ S (i) = $\sum_1^n$ F (i)

in which:
TDELTA : total difference percentage of supply/demand of all DCs
DELTA : difference percentage of supply/ demand of adjacent DCs
PR(i) : percentage of supply/demand
= 100 * S(i) / D(i)

The Solver tool in the spreadsheet finds solution of the optimization through calculus based search approach (i.e., Gradient search). It uses combination of direction search and step size to get an efficient search process. Gradient search works well to find solution (i.e., maxima or minima, local maxima or local minima) for unconstrained optimization problem. Meanwhile for constrained optimizaton problem, the problem is converted into unconstrained problem through the use of Lagrangian multiplier (i.e., λ) as a penalty term to force a feasible solution. Example of the use Lagrangian multiplier is presented as below:

Minimize : L = f (x)
Subject to : g_i (x) = b_i

From equation above, let we transform the optimization equation above with Lagrangian multiplier equation as:

Minimize : L(x, λ) = f (x) + $\sum_{i=1}^m \lambda_i$ [g_i (x) – b_i]

Optimal solution (i.e., minima point) can be found where all the derivatives of function above are equal to zero.

$\frac{d\ L\,(x,\lambda)}{dx}$ = 0 and

$\frac{d\ L\,(x,\lambda)}{d\lambda}$ = 0, in which all constraints must be satisfied.

3. Application of the model

3.1. General plan and strategy of raw water supply developments in Jabodetabek

The study area (Fig. 2.) is the Jakarta Special District Capital (DKI Jakarta) and its surrounding areas. It includes river basins that are linked to the new development areas in the region.

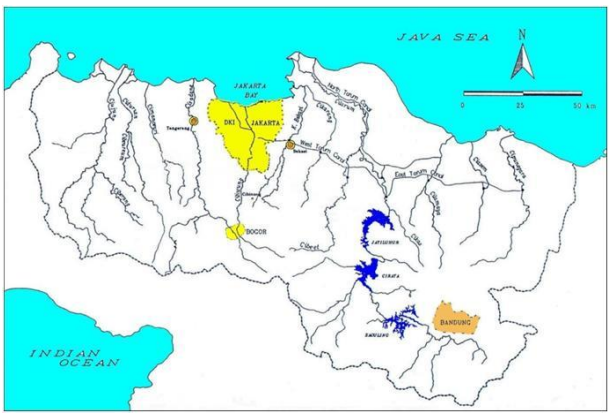

Fig. 2. Location of Jabodetabek, Indonesia.

The objective of raw water supply are to fulfill projected water demands in 2025 (for each water demand cluster), to support regional economic growth and to reduce negative impacts such as raw water shortage, excessive groundwater abstraction and land-subsidence. Water-demand estimation is based on regional population, development plan of each cluster, and economic growth projections for Jabodetabek in 2025, which is presented in Table 1.

Table 1. Water demand clusters and its estimated water demand for 2025

Regional Area		Jabodetabek						Outside Jabodetabek	
Water Demand Cluster		Jkt	Tng	Bks	Dpk	Bgr	Bgr-W	Ser	Krw
Area	Km^2	651	1397	1390	596	1304	1498	n.a.	n.a.
Estimated Water Demand in 2025	m^3/s	42.1	22.2	16.2	5.4	10.8	3.3	17.3	18.1

(Source : adjusted from DGWR, 1992)

The existing raw water sources for Jabodetabek are from groundwater, local medium-size rivers (e.g., Cisedane and Ciliwung), and the Jatiluhur reservoir on the Citarum river. Flow discharges of local small rivers are low in the dry season, severely polluted, and cannot be used for raw water supply. Although they are severely polluted downstream, the Cisedane and Ciliwung rivers are used as raw water supply due to their relatively constant discharges. Groundwater sources are usually closed or inside the industry or private-sector areas. The Jatiluhur reservoir provides urban water for part of Jabodetabek via the West Tarum Canal (WTC) and irrigation water for large area of padi fields through WTC, East Tarum canal and North Tarum canal. To fulfill future demand, additional reservoirs and conveyance systems were considered for the Ciujung, Cidurian and upper Cisadane rivers. The plan also includes an additional canal (canal-2) or pipe to deliver water for clean water directly from Jatiluhur reservoir to Jakarta. Operational management to improve reservoir operation of three reservoirs (Jatiluhur, Cirata and Saguling) in the Citarum river system and raising the Cirata dam are considered to increase water availability from the Jatiluhur reservoir. Raising the dam crest of Cirata dam had been considered to provide additional storage when it was designed. The general plan of all possible alternatives raw water supply developments in Jabodetabek is presented in Fig. 3. The plan presented locations of available raw water sources, potential locations to build reservoirs, and the network flows to provide raw water supply in Jabodetabek.

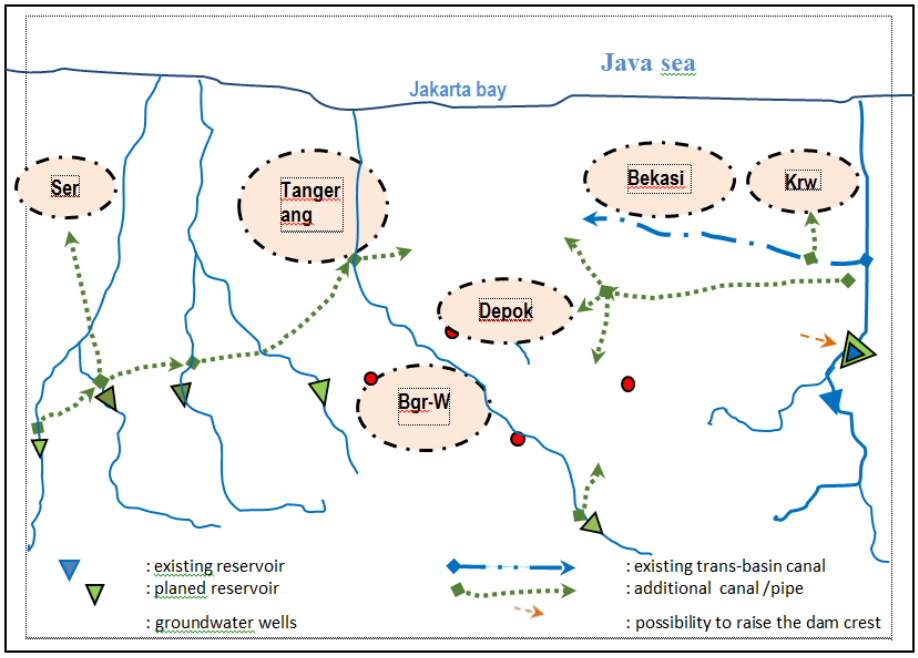

Fig. 3. The general plan of all possible alternatives raw water supply developments in Jabodetabek. (Source: adjusted from DGWRD, 1992)

Excessive groundwater abstraction has caused severe environmental problems in the northern and central part of Jakarta, where many industrial areas are located. Topographic surveys have shown that during the period of 1978-1990 the land has subsided between 10-100 cm (DGWRD, 1992). The most recent data (Wiwoho, 2010) stated that additional land-subsidence within 2002-2010 is between 11-116 cm. The greatest value is in the northern part of Jakarta, spreading to the central and southern parts of Jakarta. However, no map is available for this study. Saline water has been found in shallow wells of the northern and central parts of Jakarta, but saline water in deep groundwater has been found only in the northern part of Jakarta. No data is available for saline water in other areas.

3.2. Strategy of raw water supply developments in Jabodetabek

General strategies for raw water supply development for Jabodetabek that applied in the simulation and optimization of network flows include:

- Maximize use of the existing infrastructure of raw water supply sources.
- Build additional raw water infrastructure so that supply for each demand-cluster is at least 80%.
- Provide enough surface raw water supply to reduce groundwater abstraction.
- Reduce or eliminate groundwater abstraction in the northern part of Jabodetabek to stop or at least to reduce the rate of on going land-subsidence on that area.
- Use groundwater for the southern part of Jabodetabek only if supply from surface water is not enough.
- Avoid build new reservoirs that dislocate many people.
- Improve reservoir management in the Citarum river system to maximize water use, and build additional canals or pipes to carry more water.

A specific strategy can be added to general strategies above to form scenario or alternative with specific purpose in solving problem in Jabodetabek raw water supply. The specific strategies include:

- Minimum investment cost:
  Build a minimum set of new reservoirs to provide surface water and balance the allocation of water.
- No groundwater abstraction in areas of land-subsidence to stop or reduce the rate of ongoing land-subsidence:
  Fulfill water demands in area of land-subsidence (i.e., Jakarta, Tangerang and Bekasi) from surface water and build additional reservoirs that require little dislocation.
- Use mostly surface water source with additional groundwater from selected zones:
  Use groundwater up to maximum permissible to add supply, but only in the zones with no land-subsidence (e.g., Bogor area or southern part of Jabodetabek).

3.3. Operational management for Citarum river system

Based on JWRMS study (DGWR, 1992), there is option to raise supply release from Jatiluhur reservoir through operational management of reservoirs in Citarum river. The operational management refers to the improved operation of existing infrastructures and facilities, and a continue attention to an efficient operation. It will reduce huge investments (e.g., to build a new reservoir) and avoid problems (e.g., relocate many people due to build a new reservoir, political difficulties, social & environmental problems).

Options of the operational management for Citarum river system includes:

- Flow prediction:
  It is to improve reservoir operation based on real-time forecasting of unregulated flows. Diversion flow available from unregulated river in the system is added to reservoir. More accurate forecasting of the unregulated flows will allow more efficient use of water from reservoir, and save it for later use in dry period.
- Drought management:
  In anticipation of extreme drought, flows for parts of irrigation network canal may be disconnected to save water for M & I (municipal & industrial) water. It is possible since the Jatiluhur reservoir also supplies irrigation water for large area of paddy (rice) field. If any damage of paddy field occurs due to the flow disconnection, then the farmers are reimbursed for their losses. This method is much cheaper than to build a new reservoir.
- On-demand irrigation:
  Irrigation water demand varies over the time depending on the stage of plant's growth and season (e.g., dry and wet season). Rainfall input in wet season can provide supplement of water in paddy field so that it reduce water supply from irrigation canal. During period of high rainfall the flows to irrigation canals may be reduced and water can be saved in reservoir for M & I demand and for later use in dry period. Again, this method is much cheaper than to build a new reservoir.
- Raising Cirata dam:
  There are three existing reservoirs in the Citarum river system, Jatiluhur, Cirata, and Saguling, respectively from downstream to upstream. Cirata & Saguling reservoirs are mainly used for hydropower generation. The foundation of Cirata dam has been constructed so that a future of raising the dam up to 15 m will be possible. When the dam had been built in the 1980s, the increased benefit from hydropower generation was not sufficient enough to justify a high dam. The tight water supply situation foreseen in the 21th century together with the extra hydropower benefits may guarantee a raise of the dam in the future. The benefit of raising the dam should be followed by an efficient reservoir operation of the three cascade dams in the Citarum river system.

Impact of the operational management of Citarum river system will contribute a lot in providing raw water supply as well as reducing the need to build additional reservoirs to fulfill water demands for Jabodetabek.

3.4. Layout of raw water supply network flows

A layout of raw water network flow is established based on the location of raw water sources (including the existing infrastructure) and location of water demand clusters. Based on the network flow as shown in Fig. 4, the water supply allocation for each demand cluster is calculated using the Supply Sim model which considers the development strategies, source of supply, and estimated annual water demands for year 2025 as targets to achieve.

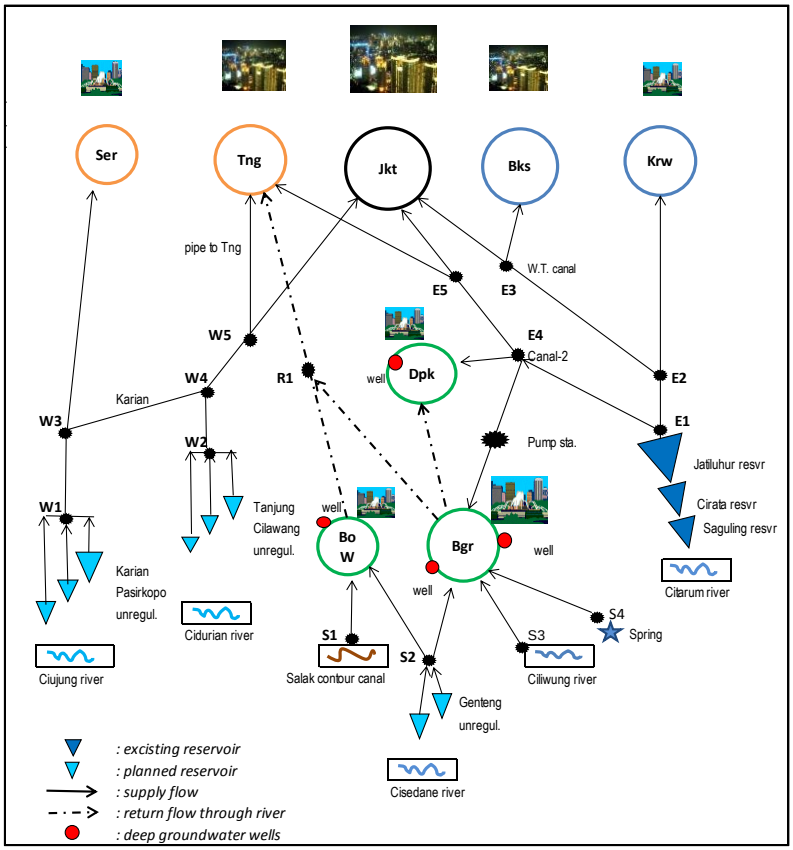

Fig. 4. Layout of network flows for Jabotabek raw water development.

Water demand and water supply in the model represent the average annual flow discharge for each cluster in m^3/s (1 m^3/s = 22.8 mg/d). The result of the water allocation is used to determine the need to build a particular reservoir with its associated conveyance system. Flow discharges in the network from the Supply Sim model is used to determine the capacity of the conveyance system.

New reservoirs are considered for urban-water first and then for irrigation water, if additional supply is available. Their design capacities are determined based on the hydrologic system, topography, number of people to be relocated, and construction cost. The Supply Sim model only determines whether there is a need to build a reservoir. Fig. 4 shows the layout of raw water network flows for Jabotabek raw water development.

3.5. Example of model's result

3.5.1. The objective is to increase water supply with minimum investment cost.

This means to build a minimum set of new reservoirs to provide surface water and balance the allocation of water (almost the same level of degree of water demand fulfillment).

Specificactions: Improve reservoir management in the Citarum river system to maximize water use, build additional canals and pipes to carry more water. In the west, build the Karian reservoir, its conveyance system, and use all available water from the rivers.

Simulation and optimization in a spreadsheet will contain data about:

- Urban centers (or demand cluster), estimated water demands for the year 2025
- Available raw water supply source (existing and proposed reservoirs, diversion from unregulated river, return flows, and springs/head water), including their maximum releases and actual releases.
- Network flows, existing and proposed conveyance system from raw water source to demand clusters.

Result of water supply allocation with objective is to increase water demand fulfillment with minimum investment cost, and at almost the same level for all demand clusters are presented in Table 2.

Table 2. Result of the Model with Strategy Minimum Investment Cost.

Supply_sim Model

Developed by: Edy Anto Soentoro

Raw Water Supply Allocation for Jabodetabek

Urban center	Serang Ser	Tanggerang Tng	Jakarta Jkt	Bekasi Bks	Karawang Krw	Depok Dpk	Bogor Bgr	Bogor West BoW	Total
Water demand	**17.3**	**22.2**	**42.1**	**16.2**	**18.1**	**5.4**	**10.8**	**3.3**	**135.40**
Surface water supply	*14.54*	*18.70*	*35.44*	*13.63*	*15.20*	*4.54*	*9.07*	*2.77*	*113.90*
Groundwater supply	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	***0.00***	***0.00***	***0.00***	*0.00*
Total water supply	***14.54***	***18.70***	***35.44***	***13.63***	***15.20***	***4.54***	***9.07***	***2.77***	***113.90***
Supply /demand (%)	**84.1**	**84.2**	**84.2**	**84.1**	**84.0**	**84.0**	**84.0**	**84.0**	**84.1**

Source of raw water supply :		**Surface raw water**					**Groundwater**	
(from actual release)		West-1	West-2	East-1	South	Retr. flow	GW	**Total**
	(in m3/s)	24.00	3.00	75.00	5.90	6.00	0.00	**113.90**
Fraction of flow	w3-sr/w1-3	w5-tng/w4-5	e1-2/e1	e2-3/e12	e3-jkt/e2-3	e4-5/e1-4	e4-bo-n/e4-5	e5-jkt/e4-5	s2-boe/s2
Fract. estimation	0.606	0.017	0.389	0.479	0.024	0.815	0.055	0.612	0.485

River	Reservoir	Max. Release	Act. Release	Canal	Flows	Canal	Flows	Grounwater pumping:	
Ciujung:	Karian	15	15	**West :**		**East :**		max /location	
	Pasirkopo	7	0	W1-W3	24.00	E1-E2	29.17	(m3/s):	**0**
	Unregulated	9	9	W3-Ser	14.54	E2-Krw	15.20	(mgd):	0.00
Cidurian:	Tanjung	7	0	W3-W4	9.46	E2-E3	13.97	**City/Area:**	
	Cilawang	4	0	W2-W4	3.00	E3-Bks	13.63	**Dpk :**	
	Unregulated	3	3	W4-W5	12.46	E3-Jkt	0.34	# of location:	1
Citarum:	Jatiluhur	50	50	W5-Tng	0.21	E1-E4	45.83	max (m3/s):	0
	* flow prediction	10	10	W5-Jkt	12.24	E4-E5	37.35	actual (m3/s):	**0**
	* drought mngmt.	10	10			E4-Dpk	2.54	**Bgr :**	
	* on demand irrigation	5	5	**South :**		E4-Bgr	5.94	# of location:	2
	* raised Cirata dam	15	0	S1-BoW	2	E5-Jkt	22.86	max (m3/s):	0
Cisedane:	Genteng	6.5	0	S2-BoW	0.77	E5-Tng	14.49	actual (m3/s):	**0**
	Unregulated	1.5	1.5	S2-Bgr	0.73			**BoW :**	
	Salak canal	2	2	S3-Bgr	2.00	**Return flow:**		# of location:	1
	downst.flow-W	3	3	S4-Bgr	0.40	Bgr-Dpk	2.00	max (m3/s):	0
	downst.flow-E	1	1			Bgr-R1	1.00	actual (m3/s):	**0**
Ciliwung :	upstream flow (S3-Bgr)	2	2			BoW-R1	3.00		
	spring	0.4	0.4			R1-Tng	4.00		
	downst.flow (Bgr-Dpk)	2	2						

Note:
: initial data, based on objective and optimization strategies
: optimization data
: Jatiluhur-Cirata-Saguling (E1) are the only existing reservoirs in the network right now, the others are need to be built.
: Present West Tarum canal has max. capacity 24 m3/s, other conveyance systems are need to be built or through rivers

Optimization Result:							
0.420	0.173	0.065	0.031	0.145	0.000	0.000	0.005

Result of the model with specific objective as option 1 as described above can be summarized as follow:

- Degree of water demand fulfillment (percentage) for each demand cluster is almost the same.
  It is shown from Table 1 that water demands for supply for all demand clusters (Jakarta, Bogor, Depok, Tangerang and Bekasi) could reach at about 84% of water demand, and all from surface water sources. As total water demand for Jabotabek, 84.1% of estimated water demand in 2025 could be fulfilled, or 113.90 m^3/s of 135.40 m^3/s.
- Additional reservoirs that need to be build.
  At Citarum river system (in the east part of Jabodetabek), there are three existing reservoirs, meanwhile there is no reservoir that has been built yet in the west and in the south. From column at actual release in the Table 1, it shows that there are actual releases from Karian reservoir, and unregulated releases from Ciujung, Cidurian and Cisedane rivers. This means that reservoir and free intake at those areas should be build. If actual release is equal to zero, no reservoir or water infrastructures need to be build.
- Operational management of the Citarum river system.
  The operational management should include flow prediction, drought management, and on-demand irrigation. There is no need to raise Cirata dam.

- Discharge flows in the conveyance system.
  There is information of discharge flows of each section of the conveyance system (e.g., discharge flow at section E1-E2 is 29.17 m^3/s, etc.). Information of these flows will lead to the determination of flow design capacity as well as the cost of each section of the conveyance system.

All of these data lead to information where reservoirs and the conveyance system are needed to be build to fulfill the water demand. Cost to build reservoirs and number of people need to be relocated are estimated based on these data, meanwhile cost of the conveyance system also depends on its flow capacity.

4. The objective is to increase water supply and no groundwater abstraction in areas of land-subsidence.

This means to fulfill water demands in area of land-subsidence (i.e., Jakarta, Tangerang and Bekasi) from surface water and build additional reservoirs that require little dislocation. The result is presented in Table 3 as below.

Table 3. Result of the model with strategy no groundwater abstraction in area of land-subsidence..

Supply_sim Model

Developed by: Edy Anto Soentoro

Raw Water Supply Allocation for Jabodetabek

Urban center	Serang Ser	Tanggerang Tng	Jakarta Jkt	Bekasi Bks	Karawang Krw	Depok Dpk	Bogor Bgr	Bogor West BoW	Total
Water demand	**17.3**	**22.2**	**42.1**	**16.2**	**18.1**	**5.4**	**10.8**	**3.3**	**135.40**
Surface water supply	*14.05*	*22.20*	*42.10*	*16.20*	*14.65*	*4.35*	*8.69*	*2.66*	*124.90*
Groundwater supply	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	***0.00***	***0.00***	***0.00***	*0.00*
Total water supply	***14.05***	***22.20***	***42.10***	***16.20***	***14.65***	***4.35***	***8.69***	***2.66***	***124.90***
Supply /demand (%)	**81.2**	**100.0**	**100.0**	**100.0**	**80.9**	**80.5**	**80.5**	**80.5**	**92.2**

Source of raw water supply :		**Surface raw water**					**Groundwater**		
(from actual release)		West-1	West-2	East-1	South	Retr. flow	GW	**Total**	
	(in m3/s)	31.00	7.00	75.00	5.90	6.00	0.00	**124.90**	
Fraction of flow	w3-sr/w1-3	w5-tng/w4-5	e1-2/e1	e2-3/e12	e3-jkt/e2-3	e4-5/e1-4	e4-bo-n/e4-5	e5-jkt/e4-5	s2-boe/s2
Fract. estimation	0.453	0.000	0.411	0.525	0.000	0.823	0.053	0.499	0.563

River	Reservoir	Max. Release	Act. Release	Canal	Flows	Canal	Flows	Grounwater pumping:	
Ciujung:	Karian	15	15	**West :**		**East :**		max /location	
	Pasirkopo	7	7	W1-W3	31.00	E1-E2	30.85	(m3/s):	**0**
	Unregulated	9	9	W3-Ser	14.05	E2-Krw	14.65	(mgd):	0.00
Cidurian:	Tanjung	7	0	W3-W4	16.95	E2-E3	16.20	**City/Area:**	
	Cilawang	4	4	W2-W4	7.00	E3-Bks	16.20	**Dpk :**	
	Unregulated	3	3	W4-W5	23.95	E3-Jkt	0.00	# of location:	1
Citarum:	Jatiluhur	50	50	W5-Tng	0.00	E1-E4	44.15	max (m3/s):	0
	* flow prediction	10	10	W5-Jkt	23.95	E4-E5	36.35	actual (m3/s):	**0**
	* drought mngmt.	10	10			E4-Dpk	2.35	**Bgr :**	
	* on demand irrigation	5	5	**South :**		E4-Bgr	5.45	# of location:	2
	* raised Cirata dam	15	0	S1-BoW	2	E5-Jkt	18.15	max (m3/s):	0
Cisedane:	Genteng	6.5	0	S2-BoW	0.66	E5-Tng	18.20	actual (m3/s):	**0**
	Unregulated	1.5	1.5	S2-Bgr	0.84			**BoW :**	
	Salak canal	2	2	S3-Bgr	2.00	**Return flow:**		# of location:	1
	downst.flow-W	3	3	S4-Bgr	0.40	Bgr-Dpk	2.00	max (m3/s):	0
	downst.flow-E	1	1			Bgr-R1	1.00	actual (m3/s):	**0**
Ciliwung :	upstream flow (S3-Bgr)	2	2			BoW-R1	3.00		
	spring	0.4	0.4			R1-Tng	4.00		
	downst.flow (Bgr-Dpk)	2	2						

Note:
: initial data, based on objective and optimization strategies
: optimization data
: Jatiluhur-Cirata-Saguling (E1) are the only existing reservoirs in the network right now, the others are need to be built.
: Present West Tarum canal has max. capacity 24 m3/s, other conveyance systems are need to be built or through rivers

Optimization Result:							
38.285	18.772	0.000	0.000	19.050	0.450	0.013	0.000

From Table 3, the result of the model with specific objective as option 2 as described above can be summarized as follow:

- Degree of water demand fulfillment (percentage) is 100% for some demand clusters in areas of land-subsidence.
  It is shown from the table that water demands for Jakarta, Tangerang and Bekasi could be fulfilled 100% (see % of supply/demand row in the table). The model could only supply about 80.5% to 81.2% for other demand clusters. As total water demand for Jabodetabek, 92.2% of demand could be fulfilled.
- Additional reservoirs that need to be built.
  Table 3 shows that there are actual releases from Karian, Pasirkopo, and Cilawang reservoirs. This means that these reservoirs and their conveyance system should be built. There is no need to raise Cirata dam, however, operational management of the Citarum river system has to be applied. Information of discharge flows of each section of the conveyance system will lead to the determination of flow design capacity of each section of the conveyance system.

- No groundwater abstraction in areas of land-subsidence.
  With degree of water demand fulfillment for Jakarta, Tangerang and Bekasi are 100% from surface water source, so there are no groundwater abstraction on those areas. Thus, this condition is expected to stop or at least reduce the ongoing land subsidence on those areas.

5. Result of the Study

Based on two example result of the model presented above, the spatial optimization model could be used to optimize water allocation with a specific objective such as water demand fulfillment is balance in all locations (e.g., 84%), fulfilling 100% of water demand in some locations while in other locations are balance at a certain level, or other specific objectives. The model could determine on which location an additional reservoir needs to be build. Besides that, the model could determine the conveyance system and their capacities required to supply raw water to fulfill the demand up to a particular level. Constrains such as fund provided, environmental condition, political situation, and possible environmental damages due to water shortage will influence decision on how high the level of water demand fulfillment should be achieved. All these information will help decision-making proses in Jabodetabek raw water supply development.

Results of this study could give other valuable information for decision-making process, such as:

- Assessment for reliability of water supply is mostly depends on the level of water demand fulfillment, although other factors such as management also influences. If no data of water supply reliability is available, the level of water demand fulfillment (percentage) can help to assess the reliability of water supply. A high level of water demand fulfillment will also represent a high level of raw water supply reliability.
- The level of water demand fulfillment can also be used as indicator for supporting economic growth (i.e., fulfillment of industrial water demand will keep the industry runs and grows), supporting regional development, and assessing employment opportunity.
- A high percentage (or 100%) of water demand fulfillment and with strict regulation on groundwater management leads to reduce groundwater abstraction. This will result in a reduction of environmental damage. Thus, the high level of water demand fulfillment can be used to assess reduction of land-subsidence rate in pertinent areas, and reduction of groundwater pollution and sea water intrusion.
- Information about additional reservoirs that need to be built will lead to information of number of people need to be relocated, land-area to build new reservoirs and cost of land acquisition. In the era of democracy, moving a large number of people and taking their land for building a new reservoir is not an easy job for the government with limited fund. There will be some people who will provoke the displaced people to ask for a high price land-compensation, or to oppose the project, and then, political difficulties will emerge. The information of additional reservoirs that need to be built can be used to assess the political difficulties that will emerge.
- Information of additional reservoirs that need to be built, how many reservoirs and their location are used to assess the ecological impact due to trans-basin water transfer.

6. Conclusion

Spatial optimization model for raw water supply allocation has been developed and applied for raw water supply development in Jabodetabek to solve problems occurred due to shortage of clean water. Based on results obtained, the model could be used to optimize water allocation with a specific objective. The model could determine where an additional reservoir needs to be built. Besides that, the conveyance system and their capacities needed to supply raw water to fulfill the demand up to a particular level can be determined. Results of this study are optimal selection to build additional water infrastructures which related to degree of water demand fulfillment (supply/demand) at each of the growth centers. Adding with constrains such as fund provided, environmental condition, political situation, and possible environmental damages due to water shortage, all these information will help decision-making proses to result in a better development plan of raw water water supply for Jabodetabek.

References

Bauman, D. D., J. J. Boland and W. M. Hanemann, 1998. Urban Water Demand Management and Planning, McGraw-Hill Inc., New York.

Breuser, H. N. C, 1992. Planning of Integrated Water Resources Development, Technical Note, Joint Research of Delft Hydraulics (the Netherlands), Bina Program Pengairan, and Puslitbang Pengairan, Bandung, Indonesia.

DGWRD, 1992. Jabotabek Water Resources Management Study, Joint Research of Delft Hydraulics, DHV Consultants, Iwaco, TNO (the Netherlands), and PT Indah Karya, PT Kwarsa Hexagon, PT Wiratman & Associates (Indonesia), Directorate General of Water Resources Development, Indonesia.

Easter, K. W., and J. E. Nickum, 1994. Alternative Approach to Urban Water Management, in : Metropolitan Water Use Conflicts in Asia and the Pacific, J. E. Nickum and K. W. Easter., eds., Westview Press, Boulder, pp. 187-211.

Edworthy, 1993. Technical and Management Aspects of the Sustainable Use of the Groundwater Resources in Urban Areas, in: Proceeding of the Regional Seminar in Urban Areas, Bangkok, Thailand.

Fellizar, Jr., Francisco P, 1994. Urban water management in Metropolitan Manila, Philippines, in : Metropolitan Water Use Conflicts in Asia and the Pacific, J. E.Nickum and K. W.Easter., eds., Westview Press, Boulder, , pp.:79-99.

Foster, S. S. D, 1990. Impact of Urbanization on Ground water, in: Proceedings of International Conference on Hydrological Processes and Water Management in Urban Areas, Duisberg., IAHS Publication, no 198.

Grigg, N. S, 2004. Assessment and Renewal of Water Distribution Systems, Awwa Research Foundation publication, Denver, Colorado.

Khan, Shakeel Ahmed, 1988. Measuring the Advantages of Cooperation and Integration in Regional Water Supply Management, Ph.D dissertation, Colorado State University, Fort Collins, Colorado.

Lanti, A, 2006. A Regulatory Approach to the Jakarta Water Supply Concession Contracts, *International Journal of Water Resources Development*, Vol. 22, No.2, pp. 255-276.

Lee, Donna J., and A. Dinar, 2002. Review of Integrated Approaches to River Basin Planning, Development, and Management, in: Water Resources and Economic Development, ed.by R.Maria Saleth, Edward Elgar Publishing Inc., Northampton, MA, pp. 458-475.

Nickum, J. E, 1994. Beijing's Maturing Socialist Water Economy, in : Metropolitan Water Use Conflicts in Asia and the Pacific, J.E.Nickum and K.W.Easter., eds., Westview Press, Boulder, pp. 37-60.

Rice, T. A., L. MacDonnell, 1993. Agricultural to urban Water Transfers in Colorado: An Assessment of the Issues an Options, NRLC Research Report Series, Natural Resources Law Center, University of Colorado School of Law.

Srivardhana, R., 1994. Water Use Conflicts in Bangkok Metropolitan Region, in : Metropolitan Water Use Conflicts in Asia and the Pacific, J.E.Nickum and K.W. Easter., eds., Westview Press, Boulder, pp. 131-152.

Tampa Bay Water, and CH2M HILL, 2006. Decision Process and Trade-Off Analysis Model for Supply Rotation and Planning, Awwa Research Foundation, Denver.

Tortajada, Cecilia, 2010. Water Governance: Some Critical Issue, *International Journal of Water Resources Development*, Vol. 26, No.2, pp. 297-307.

Triweko, Robertus Wahjudi, 1992. A Paradigm of Water Supply Management in Urban Areas of Developing Countries, Ph.D dissertation, Colorado State University, Fort Collins, Colorado.

Wert, van der, and Sugyanto Amirwandi, 1989. Cisadane-Cimanuk Integrated Water Resources Development, Technical Note 32, Joint Research of Delft Hydraulics (the Netherlands) and Puslitbang Pengairan, Bandung, Indonesia.

Wiwoho, L. H., "Terbukti, Jakarta ambles hingga 1 meter" (Jakarta is sinking up to 1 meter), based on data from Dinas Perindustrian & Energy of DKI Jakarta, Kompas online news, accessed: 10/01/2010.

Yoffe, S. B., and B. S. Ward, Water Resources and Indicators of Conflict : A Proposed Spatial Analysis, in : Water International, IWRA, Vol. 24, No.4, 1999, pp. 377-384.

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

The 3rd SCESCM

Special Topics in Public Works Research and Technology

Hydraulic characteristics analysis on Cipanas dam spillway

Galih H. Sundoro[a,b,*], Rahmat S. Lubis[a], Dian Sisinggih[b], Kirno[a], Asep Sulaeman[a, b]

[a] *River Research Center, Ministry of Public Works and Housing, Surakarta*
[b] *Master of Water Resources, Department of Water Engineering, University of Brawijaya , Malang*

Abstract

Cipanas dam will be built to meet water needs in Indramayu and Sumedang Regency, West Java. Its design has been completed by *Balai Besar Wilayah Sungai Cimanuk - Cisanggarung* in collaboration with PT. Indra Karya (Persero). An hydraulic physical model test carried out to test the hydraulic reliability of the design. Results of running the design model (model series-0) shows that: capacity and free-board of dam and spillway is already safe, but fairly large eddy's current occurred on the side-chanel and cross-flow occurred along the chuteway and affects the water-jump in the plunge-pool. Besides that, the dimentions of plunge-pool is too long and its position is too far from the end of chuteway. To overcome these problems, the modification of the design model was performed such as: a) modify the sharp angle shape of the spillways at the right wing wall with a 9.00 m diameter curved shape and sharp angle of the spillways right wing wall with a 4.00 m diameter curved shape (model series-1); b) puts a sill in upstream of chuteway with sloping sill as high as 2.00 m on the right side and 3.00 m on the left side (model series-2); and c) move plunge-pool toward the upstream 12.00 m and reduce its dimensions from 50.00 x 79.00 m to 40.00 m x 73.00 m (model series-3). With the modifications made, the eddy's current on side-channel significantly reduced and flow distribution on chuteway has been evenly distributed. The negative pressures still exist on the chuteway but not causing harmful cavitation. The flow from plunge-pool to the original river channel is relatively calmer, so it cannot cause bed scouring in downstream.

Keywords: dam, spillway, hydraulic physical model test, capacity, free-board, flow patern, cavitation, water jump

1. Introductions

One of the government's efforts to utilize and manage the water resources potential in order to meet water needs of community is to build a dam used for various purposes. One of the dams to be built by the government, in this case the *Balai Besar Wilayah Sungai Cimanuk – Cisanggarung*, is Cipanas dam in Indramayu and Sumedang Regency, West Java.

Cipanas reservoir at Cipanas river will have a number of functions. Its main function is to meet irrigation requirements of 4,600 ha service area in Sumedang and indramayu. Cipanas reservoirs will also be utilized to supply raw water to Sumedang, and West Java International Airport in Kertajati, Majalengka. In addition, Cipanas reservoir will also be used as hydroelectric, tourist sites, and flood control in Indramayu.

Cipanas dam planned by PT. Indra Karya (Persero) has dam crest elevation at +136.00 m with side spillway type ± 60.00 m wide. Cipanas reservoirs have a catchment area ± 288.00 km^2 with a dead storage volume of ± 10 million m^3 at +100.00 m. The total storage volume potential in alternative 1 with HWL at +123.00 m are ± 90 million m^3 and in alternative 2 with HWL +137.50 m are ± 201.20 million m^3.

Considering that the implementation of Cipanas dam construction will have a strategic function and high economic value, so the Cipanas dam designs must obtain a safety certificate. One of the safety requirements is the need for an assurance that the design meets safety requirements in both aspects of structures and hydraulic factors.

Some hydraulic problems sometimes difficult or cannot be solved with the theoretical approach or analytical calculations. One of the approach to complement theoretical analysis is hydraulic physical model test. Using 3D physical model test, it can check and test the hydraulic performances of a design. Some shortcomings were not/is not expected to occur can be identified and avoided by modifying the design as necessary.

One of the most important components of the Cipanas dam design is the spillway. To test and refine the design of Cipanas dam spillway, a hydraulic physical model test then conducted towards Cipanas dam spillway designs. The objective of hydraulic physical model test is to study the hydraulics behavior of spillway (side-channel, chuteway, and plunge-pool). Results of the model will be used to provide recommendations for the improvement in hydraulics aspects of in the form of design alternatives based on an existing design.

2. Methodology

Study on hydraulic characteristics of Cipanas dam spillway is done with hydraulic physical model test, with the following stages: a) data collections; b) model scales determination; c) model preparation; d) running models; e) model modifications; f) analysis and recommendations.

The data used for modeling is secondary data obtained from hydraulic design of Cipanas dam spillway by PT. Indra Karya (Persero), while the data for analysis using primary data from the model test results. Secondary data were used as a reference, among others:

a.Dams Technical data

- Dams type : CCRD
- Dams length : 516.00 m
- Dams crest elevation : +136.00 m
- Highest water level : +134.50 m
- Normal water level : +131.00 m
- Lowest water level : +109.50 m
- Max Dam Height : 60.50 m
- Inflow discharge : 2,074.46 m^3/s
- Outflow discharge : 1072.52 m^3/s

b.Spillway technical data

- Spillway
  - Crest elevation : +129.50 m
  - Crest length : 60,00 m
- Side-channel
  - Width : 9,00 ~ 15,00 m
  - Length : 76,00 m
  - Upper bed elevation : +124.50 m
  - Lower bed elevation : +120.50 m
  - Side wall elevation : +136.00 m
  - Slopes : 1/20
- Chuteway
  - Width : 15.00 m
  - Length : 120.00 m
  - Slopes : 1/2,25
  - Side wall height : 8,75 m
- Energy dissipaters
  - Type : USBR 2
  - Bed elevation : +65.40 m
  - Width : 41,00 m
  - Length : 84,00 m

Flood discharge data used as a reference in design and hydraulic physical model test presented in Table 1 as follows:

Table 1. Cipanas dams flood discharge.

Discharge	Max Inflow (m^3/s)	Max Outflow (m^3/s)	Max Elevation (m)
Q_2	126.87	54.56	130.07
Q_5	188.58	78.63	130.23
Q_{10}	230.08	96.03	130.33
Q_{25}	282.63	119.07	130.46
Q_{50}	321.71	136.83	130.56
Q_{100}	360.54	154.94	130.65
Q_{500}	453.95	195.48	130.84
Q_{1000}	501.51	218.54	130.94
Q_{PMF}	2074.06	1072.52	133.67

The hydraulic physical model is an imitation of the prototype into a miniature model with a certain scale, and satisfy the principle of similarity between the prototype and the scaled model. The Model's scale is determined based on the dimension of the prototype, laboratory facilities and the desired results accuracy. The greater the scale giving accurate results, but requires higher laboratory facilities and costs. If the relationship between scale and similarity has been fulfilled, then before setting a model scale, must consider the level of accuracy first. Based on that condition, the hydraulic model test is created in 3D model with the scale of 1:50 (undistorted). The dynamic similarity between the model and prototype is defined using Froude number (Fr) criteria. Scale for the parameters to be assessed based on the Froude number is presented in Table 2.

Table 2. Model scale based on froude number criteria

Parameters	Notations	Equations	Ratios ($n_h = n_L = 50$)
Flow velocity	*v*	$n_v = n_h^{1/2}$	$n_v = 7.071$
Time	*t*	$n_t = n_h^{1/2}$	$n_t = 7.071$
Discharge	*Q*	$n_Q = n_h^{5/2}$	$n_Q = 17677.67$
Diameters	*d*	$n_d = n_h$	$n_d = 50$
Volume	*V*	$n_V = n_h^3$	$n_V = 12500$
Chezy coefficient	*C*	$n_C = 1$	$n_C = 50$
Manning coefficient	*n*	$n_n = n_h^{1/6}$	$n_n = 1.919$
Pressure height	*P*	$n_p = n_h$	$n_p = 50$

Some parts of the prototype which are modeled among others are: a). reservoir with an area of ± 0.15 km^2; b). dams along to ± 300 m; c). side-channel spillway; d). chuteway; e). plunge-pool; f). River's channel downstream of the dam along to ± 900 m; g). support buildings (Fig. 1).

Fig. 1. Physical model: (a) reservoir; (b) side-channel spillway; (c) chuteway; (d) plunge-pool

To test the reliability of spillway, side-channel, chuteway, and plunge-pool of Cipanas dam design, model simulation carried as follows:

- Model series-0: is a model with conditions as in the original design. Tests carried out on: spillway capacity and rating-curve; flow pattern in upstream of spillway, side-channel and chuteway capacity; flow conditions at the spillway, side channel, and chuteway; the flow pattern in side-channel and chuteway; effectiveness of plunge-pool; examining the possibility of the occurrence of cavitation.
- Model series-1: is a modification to improve the flow pattern around the spillway.
- Model series-2: is a modified design for the improvement of the flow patterns along the side-channel and chuteway.
- Model series-3: is a modified design for energy reduction improvements.

3. Result and discussions

3.1. Model series-0

Model series-0 is a model running test with conditions as in the original design, with objective to test the reliability of the design in terms of hydraulic.

3.1.1. Spillway capacity and rating curve

This running test done with serial flood discharges outflow from the reservoir. In this study carried observations of water level in the reservoir at any certain flood discharge. The observations of water level are presented in Table 3 below:

Table 3. Water level in upstream of spillway, model series-0.

Discharge (m^3/s)	Water Level (m)	Free-board (m)	Water Depth (m)	Information
Q_2	130.200	5.800	0.700	
Q_5	130.392	5.608	0.892	
Q_{10}	130.500	5.500	1.000	Dam crest elevation: + 136.00
Q_{25}	130.600	5.400	1.100	
Q_{50}	130.700	5.300	1.200	
Q_{100}	130.898	5.102	1.398	Spillway crest elevation: + 129.50
Q_{500}	131.008	4.992	1.508	
Q_{1000}	131.100	4.900	1.600	
Q_{PMF}	134.300	1.700	4.800	

Spillway capacity is considered acceptable when the water level at the dam satisfies minimum free-board of 2.00 m in discharge Q_{1000} and the water level does not surpass the dam crest in Q_{PMF}. Table 3 above shows that the free-board for Q_{1000} is 4.90 m and for Q_{PMF} is 1.70 m (Fig. 2). Thus, the dimension of the spillway dam meets the requirements. Graphically rating-curve flow over the spillway is presented in Fig. 3. While the rating curve can be expressed mathematically in the form: $Q = 98.35\ H^{1.549}$ or $Q = 98.35\ (Z\text{-}129.50)^{1549}$. Where Q is discharge, H is water level on spillway crest and Z is the water elevation.

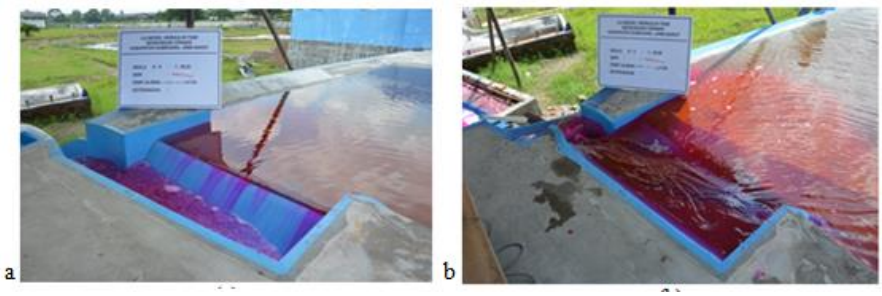

Fig. 2. Spillway flow conditions in model series-0: (a) Q_{1000}, (b) Q_{PMF}.

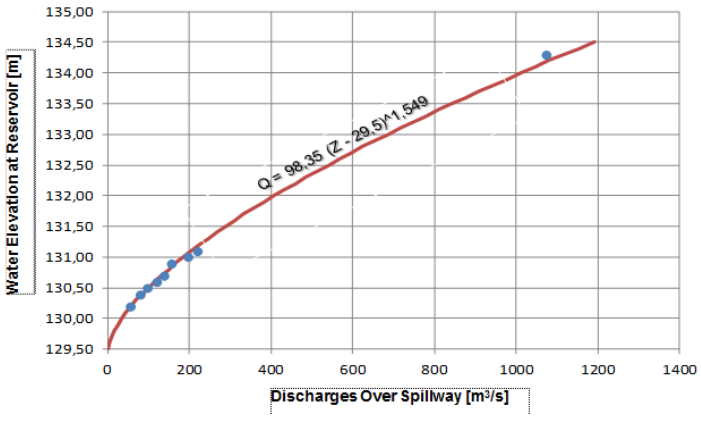

Fig. 3. Rating-curve spillway, model series-0

3.1.2. Flow conditions in upstream of spillway

Flow in the reservoir leading to the spillway is expected to be evenly distributed and considered safe if flow velocity at the side of the dam on Q_{1000} below 1.00 m/s. The results of flow velocity measurements are presented in Table 4. In Q_{1000} the largest flow velocity average is in the middle (0.646 m/s) and the smallest on the right side (0.575 m/s), with the difference between both of them is only 11%.

Table 4. Flow velocity in upstream of spillway, model series-0.

Position		Velocity (m/s)								
		Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}	Q_{1000}	Q_{PMF}
Right	0,2 h	0,027	0,245	0,293	0,649	0,713	0,636	0,782	0,844	3,126
	0,4 h	≤ 0,025	0,177	0,203	0,464	0,460	0,460	0,586	0,664	2,697
	0,6 h	≤ 0,025	0,181	0,190	0,196	0,269	0,357	0,430	0,415	1,736
Average		**≤ 0,025**	**0,201**	**0,228**	**0,436**	**0,481**	**0,484**	**0,599**	**0,641**	**2,520**
Middle	0,2 h	≤ 0,025	0,293	0,552	0,396	0,717	0,855	0,687	0,782	2,592
	0,4 h	≤ 0,025	0,200	0,370	0,314	0,477	0,561	0,571	0,664	2,232
	0,6 h	≤ 0,025	0,177	0,177	0,239	0,355	0,316	0,451	0,492	1,550
Average		**≤ 0,025**	**0,223**	**0,366**	**0,316**	**0,516**	**0,577**	**0,570**	**0,646**	**2,124**
Left	0,2 h	≤ 0,025	0,282	0,606	0,445	0,694	0,689	0,576	0,668	1,901
	0,4 h	≤ 0,025	0,177	0,421	0,338	0,490	0,520	0,503	0,571	1,728
	0,6 h	≤ 0,025	0,177	0,181	0,237	0,282	0,366	0,415	0,486	1,142
Average		**≤ 0,025**	**0,212**	**0,403**	**0,340**	**0,489**	**0,525**	**0,498**	**0,575**	**1,590**

3.1.3. Capacity and flow pattern in side-channel

From the test results for Q_{1000}, the highest water level in side-channel is +127.10 m. With the elevation of spillway crest at +129.50 m and reservoir water level for the Q_{1000} at +131.10 m, the critical water level is calculated by the following equation: EL_{cwl} = 129,5 + 2/3 (131,10-129,5) = +130.83.

The water level in the side-channel in Q_{1000} still far below the spillway critical water level and there are still high free-board by 8.90 m towards the channel wall (Fig. 4a). So from this test can be seen that the side-channel capacity is sufficient. During the Q_{PMF}, the water level in side-channel is higher than the critical water level at the spillway and just 1.70 m below the side wall (Fig. 4b). This condition will affect the flow over spillway, so that the water level on the spillway crest will be higher. However, due to the high of free-board, the effect will not endanger. From the flow patterns observation, it can be seen that the eddy's current occurred on the right side of the downstream end of the side-channel due to hit the side wall spillway that its shape and position block the flow.

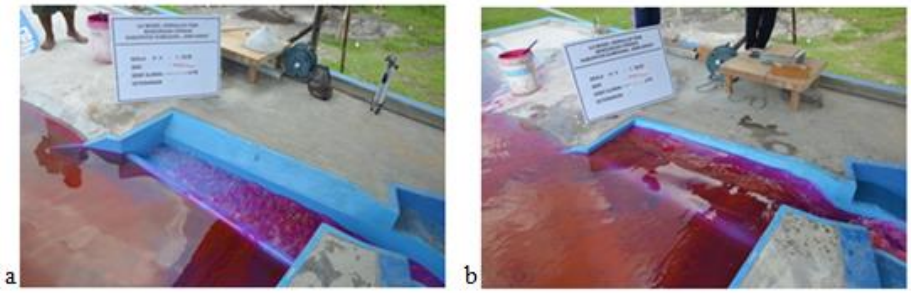

Fig. 4. Flow condition on side-channel model series-0: a) Q_{1000}, b) Q_{PMF}.

3.1.4. Capacity and flow pattern in chuteway

This test carried out with serial outflow discharge from the reservoir and the chuteway water level was observed at some point of observation for certain discharge. The observation of water level is presented in Table 5. From the test results known that the highest water level on the Q_{1000} that occurred is +123.52 which gives a free-board of 4.87 m height in the chuteway. In Q_{1000} it is

observed a cross-flow pattern in the chuteway resulting from Eddy's effect from upstream that makes the flow hit into the chuteway wall. The thicknesses of flow in chuteway are uneven (Fig. 5).

Table 5. Water level in chuteway, model series-0.

Position	Bed el. (m)	Wall el. (m)	Water level el.[m]					
			Q_2	Q_{10}	Q_{25}	Q_{100}	Q_{1000}	Q_{PMF}
Sta 1	120.28	128.39	121.36	122.02	122.15	122.46	123.52	128.00
Sta 2	118.71	126.43	119.40	119.75	119.92	119.58	120.45	124.30
Sta 3	100.98	107.85	101.21	101.47	101.61	101.60	101.96	105.23
Sta 4	83.03	89.63	83.31	83.73	83.64	83.90	84.27	86.73
Sta 5	78.87	85.74	78.99	79.08	79.46	79.39	79.55	81.59

Fig. 5. Flow condition on chuteway, model series-0: (a) Q_{1000}, (b) Q_{PMF}

3.1.5. Plunge-pool dimensions adequacy

This test is carried out with serial outflow discharges from the reservoir. The observations on the jump water length to plunge-pool was carried out with particular discharge. The observation result of water jump length presented in Table 6. In Q_{1000} the longest water jump occurred on the right side (67.5 m) and the nearest occurred on the left side (45 m). With a length of plunge-pool at 79 m, there is a difference of 11.5 m to the farthest water jump (Fig. 6). From the observations known that the dimensions of plunge-pool is too long and too far from the position of an end of chuteway, so in the small discharge the water jump falls in front of the plunge-pool.

Table 6. Water jump Length on plunge-pool, Model Series-0

Discharge	Water Jump Length (m)			Plunge-pool Length	Max. Water jump height
	Right	Middle	Left	(m)	(m)
Q_2	20	-	-	79	+81.10
Q_5	39	-	-	79	+83.900
Q_{10}	40	-	-	79	+84.025
Q_{25}	45	-	-	79	+84.825
Q_{50}	50	40	35	79	+84.700
Q_{100}	55	45	40	79	+85.650
Q_{500}	65	60	50	79	+86.800
Q_{1000}	67.5	60	45	79	+86.350
Q_{PMF}	75	80	75	79	+87.450

Fig. 6. Water jump condition in plunge-pool, model series-0: (a) Q_{1000}, (b) Q_{PMF}

3.1.6. Flow in downstream of plunge-pool

In this investigation, observation of flow velocity and water level in the downstream of plunge-pool were performed with certain discharge. Examination of the bed channel stability in downstream of plunge pool is performed by comparing the flow conditions in this channel with flow in the original river, assuming that the original river channel basis on equilibrium condition (balanced).

Using shear velocity (v*) as an indicator for erosion force, it can defined a criteria: if v* on the downstream channel of plunge pool is smaller than the v* in the original river channel, so the bed channel in downstream of plunge pool will be stable. The magnitude of v* is calculated by the following formula [5]:

$$v^* = (g \times h \times I)^{0,5} \quad (1)$$

$$I = \left(\frac{v \times n}{h^{\frac{2}{3}}}\right)^2 \quad (2)$$

Where :
g = gravity acceleration (m/s^2)
h = water depth (m)
I = water surface slope
v = flow velocity
n = Manning roughness coefficient

The original river channel condition estimated by the approach: channel width (b) = 20 m; slope (i) = 0.01, water surface slope I = i = 0.01; and manning roughness coefficient (n) = 0.04. Assuming the original river is a width channel, then from the amount of discharge Q can be calculated magnitude of h and v by the following equation:

$$Q = v \times b \times h = \left(\frac{1}{n \times h^{\frac{2}{3}} \times I^{\frac{1}{2}}}\right) \times b \times h = \frac{1}{n} \times b \times h^{\frac{5}{3}} \times I^{\frac{1}{2}} \quad (3)$$

Where :
Q = discharge (m^3/s)
h = water depth (m)
I = water surface slope
v = flow velocity
n = manning roughness coefficient

From the flow observation in downstream of plunge-pool and original river flow conditions estimations, the magnitude of v* and Froude numbers calculations presented in Table 7. From the results of analysis, the v* in downstream channel of plunge-pool is smaller than the v* in the original river channel. So it can be guaranteed that the downstream channel of plunge-pool secures against scour. In the terms of Froude numbers ratios (Fr), Fr prices in the downstream channel of plunge-pool is smaller than Fr in the original river channel (which means the channel is safe), except for Q_{PMF}. On Q_{PMF} gives Fr = 2.38, while in the river flow Fr = 1.16, but in the analysis of security, Q_{PMF} is not a consideration.

Table 7. Shear velocity, Model Series-0

Discharge	Plunge pool downstream					Original river stream			
	h	v	I	v*	Fr	h	v	v*	Fr
	[m]	[m/det]		[m/det]		[m]	[m/det]	[m/det]	
Q 2	1,35	1,50	0,0006	0,089	0.41	1,75	3,628	0,414	0,88
Q 5	1,97	3,45	0,0019	0,193	0.78	2,22	4,252	0,466	0,91
Q 10	2,22	4,34	0,0026	0,238	0.93	2,50	4,604	0,495	0,93
Q 25	2,4	4,34	0,0023	0,235	0.90	2,83	4,998	0,527	0,95
Q 50	2,41	4,23	0,0022	0,229	0.87	3,06	5,264	0,547	0,96
Q 100	2,79	4,60	0,0022	0,243	0.88	3,48	5,738	0,584	0,98
Q 500	3,07	4,84	0,0021	0,252	0.88	3,76	6,042	0,607	0,99
Q 1000	3,46	5,42	0,0022	0,276	0.93	3,99	6,287	0,626	1,01
Q PMF	4,92	16,53	0,0131	0,794	2.38	9,35	11,094	0,958	1,16

3.1.7. Cavitation possibility

Cavitation is an event that occurred when the flow has very high speed, so that the water pressure on the bottom surface becomes smaller than the maximum water steam pressure. It causes water steam bubbles generated. When these bubbles are brought down to the flow with high pressures, it can explode that can potentially cause erosion on construction [2]. Intensive cavitation could damage building materials such as concrete. It results in rough surface of the channel, giving more and more irregularity and vibration to the structures.

This investigation carried by observations of pressure on the chuteway with certain discharge by using piezometers. The observation results are presented in Table 8. From the observation known tha the extreme negative pressure the occur is -3.37 t/m^2, if the concrete tensile strength is 0.5 kg/cm^2 or equal to 5 t/m^2, then there is no danger of cavitation along the chuteway bed channel.

Table 8. Water pressures on the chuteway, Model Series-0

Positions	Water Pressures (ton/m^2)		
	Q_2	Q_{100}	Q_{1000}
Sta 1	1.04	1.28	1.56
Sta 2	0.81	0.89	0.91
Sta 3	0.68	0.76	1.08
Sta 4	0.42	-0.09	-0.05
Sta 5	-2.02	-3.37	-3.29
Sta 6	-1.99	-2.47	-2.44

3.1.8. Model Series-0 Evaluastions

Based on the results of hydraulics physical model test Model Series-0, concluded that the design as following:

- Dam free-board is very secure, in Q_{1000} at 4.90 m and in Q_{PMF} at 1.70 m.
- Side spillway design provides the perfect over flow on Q_{1000} (side spillway dimensions are sufficient), but imperfect overflow occurred during QPMF.
- Spillway right wing wall causing Eddy's current flow that needs to be streamlined (with rounded corners shape). Modification of it will be made on Model Series-1.
- At the end of the downstream side-channel, Eddy's current occurred due to the spillway lateral flow. Modifications with the addition of a spill at the end of the downstream of side-channel to overcome the Eddy's flow will be performed on Model Series-2.
- Capacity of chuteway is sufficient.
- The uneven thickness flow resulting by Eddy's flow effects from upstream.
- Negative pressure occurred in the chuteway, but does not cause cavitation danger.
- Dimensions of plunge-pool is too long and wide. Modifications to the plunge-pool dimensional reduction will be carried out on Model Series 3.

3.2. Model series-1

Model series-1 carried out by modify the model to repair the hydraulic behavior around side-channel spillway. Modifications were made to the model series-1 includes (Fig. 7): a) modifying the spillway downstream right wall with a radius of 9.00 m; b) modifying the spillway upstream left wall with a radius of 4 meters.

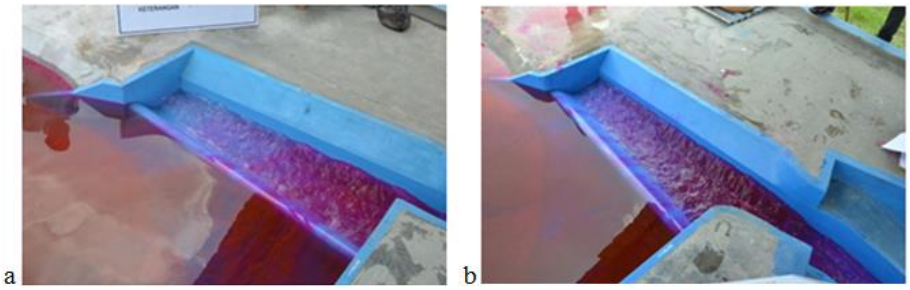

Fig. 7. Side wall modify: (a) Model series-0, (b) Model series-1

From the results of model series-1, known that for debit Q_{1000}, the highest water level in the side-channel is still below the critical water level at the spillway and 10.40 m below crest side wall (Fig. 8a). Eddy flow at the downstream end of the side-channel has been reduced significantly.

In the model series-1 also tested the capacity and flow pattern on chuteway. The observation of water level is presented in Table 9. The water levels on Q_{1000} is still below the channel walls elevation, with a height of free-board over 5.00 m. From the observation of flow patterns on Q_{1000} is known that there had been cross-flow in the chuteway resulting from upstream eddy effect that makes the flow hit into the wall. The thickness of the flow in chuteway is uneven (Fig. 8).

Table 9. Water level on chuteway, Model Series-1.

Position	Bed Elevation (m)	Wall Elevation (m)	Water Surface Elevation [m]					
			Q_2	Q_{10}	Q_{25}	Q_{100}	Q_{1000}	Q_{PMF}
Sta 1	120.28	128.39	121.53	122.12	122.65	121.65	122.20	128.32
Sta 2	118.71	126.43	119.30	119.58	119.87	120.05	120.41	124.90
Sta 3	100.98	107.85	102.10	102.21	102.44	102.46	102.73	105.04
Sta 4	83.03	89.63	83.38	83.49	83.72	83.64	83.88	86.03
Sta 5	78.87	85.74	78.97	79.18	79.24	79.27	79.42	81.42

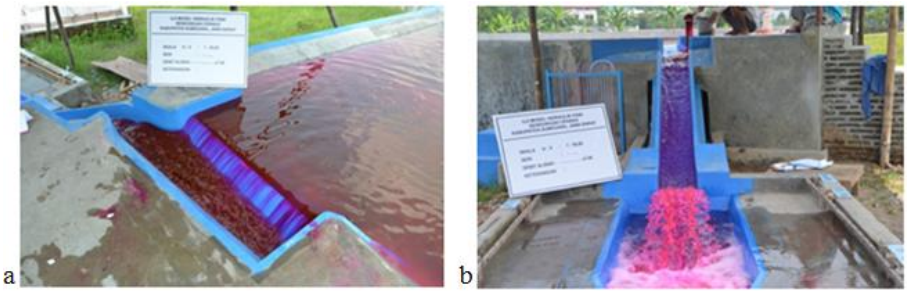

Fig. 8. Flow condition Model Series-1 during Q_{1000}: (a) side-spillway, (b) chuteway.

Based on the model series-1, with the modification of the model, obtained some of the following: a) after the right-wing corner of the spillway wall become streamlined, eddy flow side-channel reduced significantly; b) chuteway has a sufficient capacity; and c) the flow thickness on chuteway is still uneven.

3.3. Model series-2

Model series-2 is a physical model changes aimed at improving flow pattern and the velocity distribution in the chuteway. Modifications done by the addition of a sill on upstream chuteway. Dimensions of the sill is determined by trying some alternative with high and slope sill variation, then sill alternative that give the best effect on the velocity distribution in the chuteway were selected.

Based on the experimental alternatives, uniform velocity distribution (flow speed deviation to the left and right less from 3%) resulted when sill installed with a sloping base elevation of the left +122.75 and right +122.50. Uniform flow in upstream chuteway resulting flow patterns that occur along the chuteway has been streamlined and cross flow no longer occurs. With the addition of sill, in Q_{1000} the chuteway capacity still qualify with a high free-board over 5.00 m (Fig. 9). The negative pressure on chuteway still occurred, but the number and the magnitude was smaller than the model series-0 (Table 10).

Fig. 9. Flow condition on side-channel and chuteway, Model Series-2 Q_{1000}.

Table 10. Water pressures on the Chute-way for model Seri-2.

Position	Water Pressures (ton/m^2)		
	Q_2	Q_{100}	Q_{1000}
Sta 1	0.72	0.92	1.19
Sta 2	0.67	0.67	0.67
Sta 3	0.59	0.59	0.53
Sta 4	0.47	0.52	0.49
Sta 5	-1.98	-2.30	-2.33
Sta 6	-0.45	0.00	0.29

Based on the model series-2 with a modification of the model, obtained some of the following: a) the flow distribution in chutewayhas been evenly distributed; b) capacity of chuteway is sufficient; and d) negative pressure still occur in the chuteway, but does not cause danger cavitation.

3.4. Model series-3

Model Series-3 was model by move plunge-pool toward the upstream 12.00 m and reduce its dimensions from 50.00 x 79.00 m to 40.00 m x 73.00 m. In this series, water jump length in the plunge-pool was observed (Table 11). On Q_{1000} the farthest water jump was occurs in the middle (65.00 m) and the nearest on the right side (35.00 m). With plunge-pool Length of 73.00 m, there is a difference of 8.00 m to the farthest water jump (Fig. 10). So it can be concluded that the dimensions of the plunge-pool are still sufficient.

Table 11. Water jump on plunge-pool, Model series-3

Discharge	Water Jump Length (m)			Plunge-pool Length	Max. Water Jump Height
	Right	Middle	Left		
Q 2	15,500	18,500	22,500	73	+ 81.08
Q 100	27,500	55,000	37,500	73	+ 86.34
Q 1000	35,000	65,000	46,000	73	+ 87.18

Fig. 10. Water jump on plunge-pool, Model Series-3, Q_{1000}

4. Conclusion

From the hydraulic physical model test results to the original design conditions and its modifications, the following conclusions can be drawn:

- Design of dam and spillway dimensions resulted in a high free-board with a reasonable safety margin (Fb=4.90 m at Q_{1000} and Fb=1.70 m at Q_{PMF}).
- Outflow rating curve can be expressed in the formulation: $Q = 98.35\ H^{1.549}$ or $Q = 98.35\ (Z\text{-}129.50)^{1549}$, where Q is discharge, H is water level on spillway crest. and Z is the water elevation.
- The tip of the spillways right wing walls design causes disturbing Eddy's flow on side-channel. By modifying the shape of right-wing wall corner with curved shapes in 9.00 m diameter and modify the angle of the upper left wing wall with a curved shape in 4.00 m diameter, eddy's current and its disturbance can be eliminated.
- That designed shape of side-channel and chuteway, encouraging cross-flow along the chuteway, resulting flow velocity in chuteway and an uneven jump plunge pool. The addition of sill as high as 2.00 m on the right side and 3.00 m on the left side capable to leveling the flow velocity in chuteway with deviation of less than 3.00%.
- Based on the water jump on model series-0, the plunge-pool moved toward the upstream 12.00 m and reduce its dimensions from 50.00 x 79.00 m to 40.00 m x 73.00 m.
- In flood discharge design (Q_{1000}) the flow from plunge-pool to the original river channel is relatively calmer compared to the flow in the original river channel, so it cannot cause bed scouring in downstream.

References

De Vries, M, Scale Model in Hydraulics Engineering. IHE Delft: Delft, 1997.

Patty, O. 1995. Tenaga Air. Erlangga: Jakarta.

Sharp, J.J,. 1981. Hydraulic Modelling. Butterworth & Co. (publishers) Ltd: London.

Triatmodjo, B. 2013. Hidraulika II. Cetakan kesembilan. Betta Offset: Yogyakarta.

Yiniarti, F. 2014. Pelatihan Desain Bendung Dalam Rangka Pemanfaatan dan Pengelolaan Sumber Daya Air: Hidraulika da Angkutan Sedimen. Tidak Dipublikasikan, Pusat Litbang SDA, Bandung.

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

Special Topics in Public Works Research and Technology

Study of the requirement and availability of water in cultivation areas based on urban planning of Bener Meriah District 2012-2032

Isma Arsyani[a], Alfiansyah Yulianur[b], Azmeri[b]

[a]*Magister Teknik Sipil Program Pascasarjana Universitas Syiah Kuala Banda Aceh*
[b]*Prodi Magister Teknik Sipil Universitas Syiah Kuala, Darussalam, Banda Aceh 23111, Indonesia*

Abstract

According to the national regulation number 26 of 2007 about the urban planning, in order to arrange pattern and structure of spaces it must consider natural resources, human resources, and other resources by conducting zonal or regional scoring. Currently, the problem faced is how much water required to meet the cultivated areas and other needs must be considered to be fufilled for long term, so that the region will continues to sustain its existence in accordance with the mandate layout. The other problem is how to determine the availability of water based on water resources that are available around the zone or area of cultivation. It used data from digital elevation model (DEM) of the highlands region in 2010 and processes using geographic information system. The analysis results in 37 catchment area/ Sub-catchment areas. Then, each cultivation area in the spatial was overlaid with data from catchment area/sub-catchment area. The results of the value of irrigation water requirements, drinking water, river maintenances, plantations and livestock are adapted to the watershed area where the region is located. The value of water availability depended on the area of watershed and can be predicted using Mock method. The Mock method uses rainfall data from Takengon station during the period of 1980-1989 as one of inputs. The needs of Irrigation water demand in each watershed is 2.07 liters/second/Ha. This water requirement cannot be fulfilled by a probability of 80% availability of water in some watersheds. The needs of drinking water in residential areas could not be fulfilled due to some deficit on the availability of water with probability of 99%, except in residential of Samar Kilang. For river maintenance, it needs to conduct a comparison of 95% water availability, almost all settlements not covered except Samar Kilang. Furthermore, the plantation and livestock water needs cannot be fulfilled with a probability of 95% water availability and 99%. The strategy of solving these problems is through the conservation of water resources by i) constructing reservoirs or *Embung* in watersheds and ii) intervention for vegetation (rehabilitation) in upstream area. Additionally, it is also important on reviewing the spatial planning document.

Keywords: water requirement; water availability; watersheds; Urban Planning; cultivated area.

1. Introduction

According to the regulation number 26 of 2007 on Spatial Planning, chapter 17, paragraph 1 said that: "The coverage of spatial planning includes its structure and pattern plans". The chapter explains that every spatial planning district or municipality must contain patterns Space (*pola ruang*) and Structure (*struktur ruang*) as the core spatial planning district or town. The structured spaces nclude the central settlement system plans and infrastructure network system, while the pattern of space include protected areas and cultivation area.

Bener Meriah is one of the districts that is located in the central region of Aceh Province, the area of the district is about 190.400 km^2. It has been set in the spatial planning of the district in accordance with the mandate of Law No. 26 of 2007. These regulations had been set forth in the Qanun (regional regulation) number 22 of 2013 on Spatial Planning Regency Period 2012-2032 highlands. In Qanun, it states that planning for the spatial pattern at *Bener Meriah* district is divided into two parts, namely the protected and cultivated area.

The regions that belonging to protected areas including protection forest, hunting parks, dams/reservoirs border, and the border river. Even though, the cultivation area includes production forests, plantations, dry land farming, livestock, agriculture, wetlands, urban settlements, and other areas.

Cultivation area is one of the important areas that must be preserved from land use change for the next 20 years (the age of spatial planning districts). This region has not only expanded the existing land, but also it will become the center of economic growth as a result from the population growth. Cultivation area should be able to accommodate the growth of population in need

in order to develop and to boost economic sector. This area is dynamic in terms of changes that require appropriate actions to achieve sustainable development for a period of 20 years and beyond.

One of the elements that must be taken into account for sustainable development in the area of cultivation is the needs and the water availability for every part of the region. The study of the requirements and the availability of water is quite important because it can be used as a reference in the implementation of spatial plans and other strategic planning document for the next 20 years.

The aims of this study are: to determine how much water requirements in several areas such as the cultivation of wetlands rule in this case represented by the irrigated areas or fields. Also, the cultivation areas such as settlements, plantations and farms. Second, to find out how much water availability in the watershed region inhabited by cultivating area referred to priority. Third, to know how the conservation of water resources when it is in the area of water availability run into water deficit.

The results of the study will be used as a reference or the first step in the planning. So that, that strategic area in the district, particularly the Bener Meriah district, reviewing requirements and water availability of a region. Another benefit becomes the basis for more detailed planning of the nature of spatial planning such as spatial planning districts or detailed spatial plan with small-scale work with more measured.

2. Study References

2.1. Water Requirement

2.1.1. Irrigation Water Requirement

Irrigation water requirement is the total amount of water that required to be given to the rice fields or irrigations. The amount of water requirement in rice fields is influenced by the amount of water for its growth and tillage (Sosrodarsono and Takeda, 1976). The water requirements for paddy (NFR = Net Field Requirement) is influenced by factors such as land preparation, effective precipitation, the water requirements for the plant's growth, characteristics of each of area and seepage, and replacement of the water layer. Irrigation water demand can be calculated using the formula (Anonymous, 2002):

$$NFR = IR - R_{EF} \quad (1)$$

$$IR = \frac{M \times e^k}{e^k - 1} \quad (2)$$

$$M = E_0 + P \quad (3)$$

$$K = \frac{M \times T}{S} \quad (4)$$

$$R_{ef} = \frac{R_{80}}{15} \times 70 \quad (5)$$

$$ET_c = K_c \times ET_0 \quad (6)$$

$$DR = \frac{NFR}{ef \times 8.64} \quad (7)$$

$$ef = ef_1 \times ef_2 \times ef_3 \quad (8)$$

$$Q = \frac{DR \times A}{1000} \quad (9)$$

NFR : the need of water for rice in the field (mm/day);
IR : irrigation requirements during land preparation and during each growth period (mm/day);
M : water replacement requirements (mm/day);
E_0 : open water evaporation (mm/day);
P : percolation, 1-3 (mm/day);
K : parameter of water function;
T : land preparation period, 30 days and 45 days each for mechanical and manual;
S : water requirement for saturation (mm);
e : number of natural number (Napir) e= 2.71828;
R_{ef} : effective precipitation (mm/day);
R_{e80} : dependable rainfall by 80% satisfaction (mm);
ET_c : consumptive water requirements (mm/day);

K_c : rice crop coefficient;
ET_0 : potential evapotranspiration (mm/day);
WLR : replacement of the water layer (mm);
DR : making requirements (lt/s/Ha)
ef : total irrigation efficiency
ef_1 : efficiency on the main/primary network (90%)
ef_2 : the efficiency of the secondary network (80%)
ef_3 : the efficiency of the tertiary network (80%)
Q : discharge (m^3/s)
A : acreage of paddy (ha)

2.1.2. Drinking Water Supplies

The amount of water depends on the requirements of the population, consumption patterns which are in line with the increase in wellfare, as well as the magnitude of the city that can be assumed to depend on the population (Linsley, 1986). Several statistical methods can be used to predict the rate of population growth is (Kimsan, 2012):

- Arithmetic method
- Geometric method
- Linear regression method
- Exponential method
- Logarithmic method

The formula for calculating the drinking water requirements are:

$$Q_a = P_n \times K_a \quad (10)$$

Qa : raw water requirement (liter/capita)
Pn : number of pupulation in period of n (people)
Ka : Basic raw water requirement (liter)

Table 1. The requirement of raw water.

Number of Projected Population	Basic raw Water requirement (Liters/Person/Day)
>1 Million	190
500K-1 Million	170
100K-500K	150
20K-100K	130
<20K	30

Source: Linsley, 1986

2.1.3. Water Requirements for River Maintenance

Water demand for river maintenance were estimated by multiplying the number of residents with water requirements for its maintenance (Azizah, 2012).

According to the management of Water Resource Integrated (IWRM) the amount of water requirements for maintenance of river/current canal is 330 liters/capita/day. In 2000, it is expected to increase to 360 liters/capita/day. In 2015, estimated to be reduced to 300 liters/capita/day with consideration given out in 2015 slightly improves and many peoples who have waste treatment systems.

The equation used is:

$$Q_f = \frac{365_{hari} \times q_f}{100} \times P_n \quad (11)$$

Q_f : the amount of water requirements for maintenance (m^3/year)
q_f : water requirements for maintenance (liter/capita/day)
P_n : number of population (people)

Table 2. Water need for river maintenance.

The annual projection	Water Need (Liter/Capita/Day)
1990-2000	330
2000-2015	365
2015-2020	300

Source: IWRM, 2002

2.1.4. Water Requirements for Livestock

Water need for livestock requirements to be estimated by multiplying the number of cattle with water consumption for each cattle type (Yulistiyanto et al, 2008). The equation used is:

$$Q_p = 356 \times \sum q_n \times P_n \quad (12)$$

Q_p : water requirements for livestock (m^3/year)
q_n : water requirements for each types of livestock (liter/cattle/day)
P_n : number of each type of livestock

Table 3. Water need for livestock.

Type of Livestock	Water Need (Liter/cattle/Day)
Cow/Buffalo	40
Sheep/Goat	5
Pig	6
Fowl	0.5

Source: SNI, 2002

2.1.5. Water Requirements for Plantation

In the spatial plan on the pattern of the space, Bener Meriah showed some areas are planted by oil palm. It requires water about 1,500-1,700 mm of rainfall per year to meet the requirements of growth and production. Compared to other crops, this oil palm plants require relatively large water. Water demand for palm oil is similar to the water requirements for cane, which is 1,000-1,500 mm per year and banana 700-1,700 mm per year. However, these needs are not as high as the water requirements for paddy crops which range from 1,200 -2,850 mm per year or per growing season, such as rice, corn, and soybeans (Pasaribu, 2012).

2.2. Water Availability

The availability of water is basically coming from rainwater (atmospheric), surface water, and groundwater. The rain falls on the surface at a Watershed (DAS) or Basin will partially evaporate to the sky again, while the majority will flow through the land surface and land sub-surface into a canal, river or lake, and some will seep fell to the ground as replenishment (recharge) the existing soil water content (Anonymous, 2006). Overall, the amount of water on this planet is relatively fixed from time to time (Suripin, 2002).

2.2.1. Average Rainfall

Areal average rainfall is obtained by taking the average value (arithmetic mean) of rainfall data recorded in some rain stations in the area (Soemarto, 1990). It uses the following formula.

$$d = \frac{d_1+d_2+d_3+\cdots+d_n}{n} \quad (13)$$

d : average rainfall (mm)
d_n : rainfall on station n (mm)

2.2.2. Average Monthly Discharge

The F. J. Mock method is used to calculate the average monthly discharge of the river, based on water balance explaining the relationship between surface runoff with monthly rainfall, evapotranspiration, soil moisture, and storage in the soil (Mock, 1973).

Through several steps, the Mock method is explained below:

$$Q_{total} = Q_{base} + Q_{direct} + Q_{storm} \quad (14)$$

$$Q_s = Q_{total} \times A \quad (15)$$

A : The area of the watershed (km^2)
Q_s : average monthly discharge (m^3/month)

2.3. Weibull's Plotting Position

The formula used to determine the probability of occurrence or the availability of the water is given in Weibull's as follows (Soemarto, 1999):

$$P = \frac{m}{n+1} \times 100\% \quad (16)$$

P : The probability of occurrences of each data (%)
m : The sequence number of the data (the data has been sorted ascendingly)
n : The number of data.

3. Research Methodology

3.1. Research Preparation

The research object is the cultivation area, in addition to the forest as settlements, wetlands, plantations, farms, and urban settlements are included in the pattern space on the district spatial plan stated in the Qanun number 22 of 2013 on RTRWK of Bener Meriah in 2012-2032.

The required data for the calculation are topographic data; SRTM to be used as a digital elevation model, the station rainfall data of Takengon in 1980-1989; climatological data of Cot Girek in 1991-2000; RTRWK space pattern data of Bener Meriah; and population data of the BPS 2009-2014. Various software such as Office Spreadsheet for tabulation and calculation of Geographic Information Systems for spatial data analysis and printing were used for analyzing data.

3.2. Research Process

The research process was divided into two parts. First, calculating water requirements based on cultivation area. As mentioned, the cultivation area covers an area of wetlands, in this case the rice fields; settlement to determine the water requirements and the water requirements of maintenance of the river; breeding areas; as well as the plantation area.

Second, it needs the calculation on the availability of water on each catchment area or watershed (watershed/sub-watershed). The area of watershed/sub-watershed was analyzed by using ARCGIS on digital elevation data manipulation mode. After that, it will then calculate the monthly average discharge using the input of rainfall data and climatological data. Thus we pointing the intake in each watershed. From the intake we will know the availability water for each cultivation area.

These two values on the water requirements and water availability are compared. So, it will be able to identify whether the available water in each basin /sub-watershed is deficit or surplus compared to the water requirements in the area. If there is a deficit, i needs the strategies for conservation of water resources that could be implemented in the watershed/sub-watershed.

4. Research Result

4.1. Irrigation Water Requirements

4.1.1. Withdrawal Debit

The resulted irrigation water requirements can also be used to define the possible Irrigation Area. It is usually to manage such that the beginning of the growing season is in coincidence with the early of the rainy season. The growing season in the Bener Meriah start from September. So, the requirements of irrigation water for paddy fields will start in September as well.

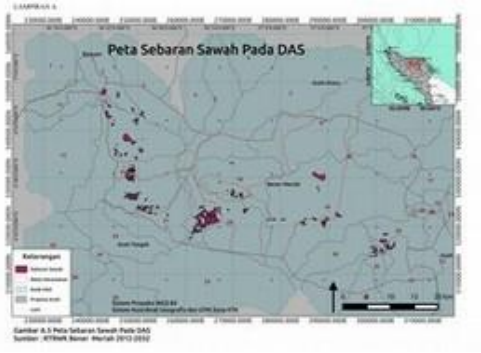

Fig. 1. Distribution of paddy fields in the catchment area.

The results of the analysis showed that the distribution of rice are in the DAS/Sub-DAS with code 2; 3; 12; 14; 16; 18; 20; 21; 29; 30; 31; 32; and 35. Thus, the calculation of paddy field delineated DAS/Sub-DAS that the rice fields are located. The calculation result of discharge decision are;

Table 4. Water need for rice fields.

No	Intake D.I	Area of Paddy Field (Ha)	DAS Code	DR (l/s/Ha)	Q (m^3/second)
1	Intake 0	16	21	2.07	0.03
2	Intake 2	520	20	2.07	1.08
3	Intake 3	52	20	2.07	0.11
4	Intake 4	9.23	18	2.07	0.02
5	Intake 5	86.69	18	2.07	0.18
6	Intake 7	22.83	16	2.07	0.05
7	Intake 8	37.53	16	2.07	0.08
8	Intake 9	48.72	16	2.07	0.10
9	Intake 10	87.43	16	2.07	0.18
10	Intake 11	14.11	16	2.07	0.03
11	Intake 12	34.26	35	2.07	0.07
12	Intake 13	50.82	32	2.07	0.11
13	Intake 14	73.53	31	2.07	0.15
14	Intake 15	77.89	30	2.07	0.16
15	Intake 16	85.32	29	2.07	0.18
16	Intake 17	206.89	16	2.07	0.43
17	Intake 18	415.21	21	2.07	0.86
18	Intake 19	209.76	14	2.07	0.43
19	Intake 20	239.7	14	2.07	0.50
20	Intake 21	77.27	14	2.07	0.16
21	Intake 22	53.59	14	2.07	0.11
22	Intake 23	1.7	14	2.07	0.004
23	Intake 24	144.13	14	2.07	0.29
24	Intake 25	221	14	2.07	0.46
25	Intake 27	98.03	14	2.07	0.20
26	Intake 28	77.92	2	2.07	0.16
27	Intake 29	25.48	14	2.07	0.05
28	Intake 30	125.49	14	2.07	0.26

The size of Q result or discharge decision is very influential in the rice area DAS/Sub-DAS. While the similar DR value resulting from the same value of effective rainfall in September because of the postal station that is used only a single rain.

Collective discharge or the biggest rice needs occur in areas in Intake 2, which the area is 520 Ha. The large discharge of flowing through the rice fields are about 1,08 m^3/s. The irrigation area is located in Bukit District. Intake put in Wih Ni Delon River.

4.2. Water Supply Requirements

4.2.1. Projected Population

Drinking water requirements reach great value and it depends on the number of residents in a settlement. It is necessary to forecast the number of people in the coming year through understanding the number of pepople in a settlement within a certain time. The method used to determine the projected number of people in the future is statistics method. There are five statistical methods used and the selection of appropriate methods to use methods that correlate to approach the value "1". If the correlation is too far, it should have seen the value of the standard deviation of each method.

After calculation through this study, statistical method used to be exponential statistical methods. All calculations projection of all districts in the Bener Meriah is close correlation "1" an exponential method. the display of statistical method of calculation results in one of the districts can be seen in the table 5 below.

Table 5. Statistical Calculation Model for Timang Gajah district.

Yr	Pop	Arith	Geom	Reg	Exp	Log
2010		17,758	17,758	17,546	17,550	17,698
2011	17,758	17,918	17,875	17,721	17,722	17,947
2012	17,813	18,077	17,992	17,896	17,895	18,092
2013	18,124	18,237	18,110	18,070	18,069	18,195
Sum	18,237	71.990	71.735	71.233	71.237	71.932
	71.932					
Std		*206.13*	*151.53*	*225.67*	*223.37*	*215.80*
Cor		*0.9654*	*0.9656*	*0.9654*	*0.9657*	*0.9232*

Using a statistical exponentially method of Population growth until 2032, it can be seen in picture 2 below.

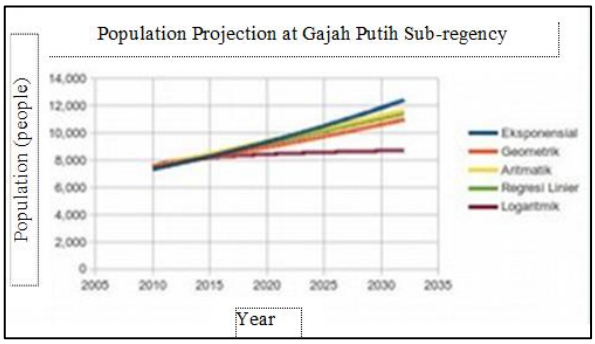

Fig. 2. Population growth in the Timang Gajah district.

4.2.2. Calculation of Water Supply Requirements

The population growth in every district in 2032's overlaid on DAS and distributed based on location of settlements that shown on the map spatial patterns RTRWK of *Bener Meriah* in 2012-2032.

Fig. 3. Population map on watershed area.

Based on the projection and distribution, it can be determined that the amount of water requirements in every settlement. The calculation result can be seen as stated in the Table 6. The need for clean water is also added the calculation with the account of

maximum and the loss factor of water. The value used by Technical Direction of Settlements Planning Directorate-PERA Ministry of Public Works on Water Supply System. The range for the maximum value (FM) are at 1.05 to 1.15. For the calculation, the value of 1.15 is able to be taken while the loss of a predetermined value is 20% of 1.25. The result is:

Table 6. Calculation of Water need for each settlement.

No	Intake Code	Population	Requirement water (l/day)	Water Requirement (m^3/day)
1	0	34,419	6,432,088	6. 433
2	1	8,605	371,091	0.372
3	2	16,867	727,389	0.728
4	3	5,534	238,654	0.239
5	4	37,373	6,984,079	6.985
6	5	22,134	4,136,291	4.137
7	6	4,441	191,518	0.192
8	9	1,127	48,602	0.049
9	16	1,127	48,602	0.049
10	18	28,111	5,253,243	5.254
11	19	8,977	387,133	0.388
12	20	4,489	193,588	0.194
13	21	4,489	193,588	0.194
14	22	4,489	193,588	0.194
15	23	8,295	357,722	0.358
16	24	2,717	117,171	0.118
17	25	8,150	351,469	0.352
18	26	2,717	117,171	0.118
19	27	5,434	234,341	0.235
20	29	2,717	117,171	0.118
21	30	4,148	178,883	0.179

The data will be accumulated into the water requirements in a DAS/Sub-DAS, in order to be able to compare the water availability of probability with 99% of the monthly average discharge.

4.3. Water requirements for River Maintenance

River maintenance of water demand in the calculation also requires a projected population. Such as the need for clean water, population growth of projections using the same statistical methods.

The method which used is exponential and the amount of data that equal to the projected results of the calculation for water requirements. The calculation result can be seen in the Table 7.

The calculated result will be accumulated into the water requirements of maintenance streams in a DAS/Sub-DAS. The figures will be compared with the number of availability of 95% of the monthly average discharge.

Table 7. The Calculation of River Maintenance.

No	Intake Code	Population	Requirement water (m^3/yr)	Requirement water (m^3 /day)
1	0	34,419	3,768,902	10,326
2	1	8,605	942,248	2,582
3	2	16,867	1,846,937	5,061
4	3	5,534	605,973	1,661
5	4	37,373	4,092,344	11,212
6	5	22,134	2,423,673	6,641
7	6	4,441	486,290	1,333
8	9	1,127	123,407	339
9	16	1,127	123,407	339
10	18	28,111	3,078,155	8,434
11	19	8,977	982,982	2,694
12	20	4,489	491,546	1,347
13	21	4,489	491,546	1,347
14	22	4,489	491,546	1,347
15	23	8,295	908,303	2,489
16	24	2,717	297,512	816
17	25	8,150	892,425	2,445
18	26	2,717	297,512	816
19	27	5,434	595,023	1,631
20	29	2,717	297,512	816
21	30	4,148	454,206	1,245

4.4. Water requirements for Plantation

The results of water need calculation are as shown in Table 8.

Table 8. The Calculation of River Maintenance.

No	Intake Code	Area (m^2)	Numbers	Requirement Water (m^3/sec)
1	3	50,983,287	726,780	3,385
2	12	4,905,542	69,930	325.7

4.5. Water requirements for Livestock

The calculation results can be seen on Table 9 below.

Table 9. The calculation of water for livestock.

No	Livestock	Numbers	Requirement Water (m^3/sec)
1	Cows	7,700	0.0036
2	Buffaloes	3342	0.0015
3	Horses	613	0.0003

4.6. Water Availability

The value of water availability varies depending on the extent of the DAS/Sub-DAS. To produce a monthly average discharge of rainfall data analyzed Takengon station in 1980-1989 and climatological data from the climatology station at Cot Girek in 1990-1999.

4.6.1. The Relation Between Water Availability and Need

Table 10. Comparison of Water Availability - Water need for Irrigation.

No	Intake No.	Service Area (Ha)	Q (m^3/sec)	Q_{80} (m^3/sec)
1	Intake 0	16	0.03	0.051
2	Intake 2	520	1.08	0.334
3	Intake 3	52	0.11	0.054
4	Intake 4	9.23	0.02	0.091
5	Intake 5	86.69	0.18	0.045
6	Intake 7	22.83	0.05	0.063
7	Intake 8	37.53	0.08	0.117
8	Intake 9	48.72	0.10	0.945
9	Intake 10	87.43	0.18	0.717
10	Intake 11	14.11	0.03	0.12
11	Intake 12	34.26	0.07	0.212
12	Intake 13	50.82	0.11	0.063
13	Intake 14	73.53	0.15	0.062
14	Intake 15	77.89	0.16	0.019
15	Intake 16	85.32	0.18	0.086
16	Intake 17	206.89	0.43	0.056
17	Intake 18	415.21	0.86	0.043
18	Intake 19	209.76	0.43	0.239
19	Intake 20	239.7	0.50	0.066
20	Intake 21	77.27	0.16	0.059
21	Intake 22	53.59	0.11	0.2
22	Intake 23	1.7	0.004	0.099
23	Intake 24	144.13	0.29	0.103
24	Intake 25	221	0.46	0.277
25	Intake 27	98.03	0.20	0.039
26	Intake 28	77.92	0.16	0.242
27	Intake 29	25.48	0.05	0.068
28	Intake 30	125.49	0.26	0.284

The highlight rows are indicated that catchment area is insufficient for watering paddy field.

4.6.2. The Relation Between Water Availability and Need

The availability of water needed to fulfill clean water is to look debit mainstay with a probability of 99%. The results can be seen in Table 11 below.

Table 11. The comparison of Water Supply - Clean Water Need.

No	Intake Code	Population	Requirement Water (m^3/d)	Q_{99} (m^3/d)
1	0	34,419	6,432.09	86.4
2	1	8,605	371.09	86.4
3	2	16,867	727.39	172.8
4	3	5,534	238.65	86.4
5	4	37,373	6,984.08	86.4
6	5	22,134	4,136.29	86.4
7	6	4,441	191.52	86.4
8	9	1,127	48.60	432
9	16	1,127	48.60	86.4
10	18	28,111	5,253.24	86.4
11	19	8,977	387.13	172.8
12	20	4,489	193.59	86.4
13	21	4,489	193.59	86.4
14	22	4,489	193.59	172.8
15	23	8,295	357.72	86.4
16	24	2,717	117.17	86.4
17	25	8,150	351.47	172.8
18	26	2,717	117.17	86.4
19	27	5,434	234.34	86.4
20	29	2,717	117.17	86.4
21	30	4,148	178.88	172.8

Looking at the results of Table 11 as above, only two areas of inhabitants have sufficient water in their catchment areas (highlight row).

4.6.3. The link of Water Supply and River Maintenance of Requirements

The results of the relationship between water availability and maintenance of the river with 95% probability as shown in Table 12.

Table 12. The comparison of Water Supply – Water Need for River Maintenance.

No	Intake Code	Population	Requirements Water (m^3/d)	Water availability Q_{95} (m^3/d)
1	0	34,419	10,326	173
2	1	8,605	2,582	432
3	2	16,867	5,061	778
4	3	5,534	1,661	173
5	4	37,373	11,212	432
6	5	22,134	6,641	259
7	6	4,441	1,333	173
8	9	1,127	339	2.074
9	16	1,127	339	259
10	18	28,111	8,434	173
11	19	8,977	2,694	518
12	20	4,489	1,347	173
13	21	4,489	1,347	173
14	22	4,489	1,347	518
15	23	8,295	2,489	259
16	24	2,717	816	259
17	25	8,150	2,445	605
18	26	2,717	816	86
19	27	5,434	1,631	86
20	29	2,717	816	173
21	30	4,148	1,245	691

As requirement water of clean water the requirement for maintenance river, only a inhabitant has a sufficient water from catchment area.

4.6.4. The relation between Water Supply and Water requirements for Plantation

Table 13. The Comparison of Water Supply - Water Need of Plantation (Palm Oil Tree)

No	Intake Code	Area (m^2)	Number of trees	Req. Water (mm^3/d)	Water Availability (Q_{95}) (mm^3/d)
1	19	50,983,287	726,780	3,385	518
2	19	4,905,542	69,930	325.7	518

As shown as above table, availability water in catchment area is insufficient.

4.6.5. Relation of Water Availability and water need of Livestock

The Relations of livestock water requirement with the availability of water with of 95% probability. The results can be seen in the Table 14 the relations between water availability and water need for livestock.

Table 14. The Comparison of Water Availability and Water for Livestock (m^3/s).

No	Intake Code	DAS Code	Water Requirements	Water Availability (Q_{99})
1	17	16	0.0054	0.001

Availability water in this catchment area is deficit for supplying water requirement for Livestock area in Mesidah Sub-District.

5. Conclusion and Suggestions

5.1. Conclusion

- Based on the calculation results, the availability of water in the DAS/Sub-DAS cannot fulfill the water requirements for irrigation, water supply, river maintenance, plantation and farms. Except for particular areas such urban settlements, in Samar Kilang.
- To fulfill water requirements for the future, it has been planned by Embung or Redeleong's reservoirs that can satisfy the requirements of raw of water for the *Bukit district, Bandar, and Permata*. For *Timang Gajah* District, it requires to identify both rivers and creeks that can be build a dam or a reservoir to meet the water requirements in the particular region.
- Apart from the reservoir, in the area which requirements for clean water and the surplus river maintenance of water availability can be maximized by maximizing the existing of rivers and creeks.

5.2. Suggestion

- To evaluate the RTRW document for every five years to incorporate the water availability in the area of zoning in addition to some other evaluation elements.
- To check the availability of water is necessary to create a data system, either from rain data and flow in some representative rivers in the watershed area.
- In the future, the government of *Bener Meriah* requires to provide a tool to calculate the river discharge and rainfall in order to build a new system and to improve the function of rainfall stations in each district.
- It is important for the future and is more in-depth and specific research to examine the requirements and the availability of water in the areas, so that all aspects of the determinants can be seen and tested analytically.

References

Azizah, C., 2012. The study of River Water Potential in Bireuen, ISSN: 2085-Volume 3 Number 9, Majalah Ilmiah Unimus, Bireuen.

Balitbang Kimpraswil, 2002. Guidelines / Instructions Engineering And Manual, Chapter 2: Irrigation (Standard of Irrigation Planning), Jakarta.

Initiative Strategy of Water Resources Management WS. Sampean Baru, The office of Provincial Irrigation East Java, Surabaya, 2006.

Linsley Jr., R. K. and Franzini, J. B., 1991. Water Resources Engineering, Terj. Saso, D., Volume 2, Fourth Edition, publisher, Jakarta.

Mock, F.J, 1973. Land Capability Appraisal Indonesia, Water Availability Appraisal, UNDP / FAO, Bogor, Indonesia.

Sari, I.K. , Limantara, L.M, Priyantoro, D., The Analysis of Water Availability and Requirements In Sampeyan DAS, Journal of Irrigation UB, Malang.

Settlement and Regional infrastructures of Ministry, 2000. Guidelines for Water Resources Planning River Region, General Directorate of Water Resources, Jakarta.

Sjarief, R., 2002. Water Resources Management, Litbang Kimpraswil, Infrastructure and Design ITB Journal, No. 1, Volume 1, pp. 64-76.
SNI, The Balance Preparation of Water Resources, Part 1: The Spatial Water Resources, Bakosurtanal, Jakarta, 2002.
Soemarto, 1999. Engineering Hydrology, Edition 2, Erlangga, Jakarta.
Sosrodarsono, S, Takeda, K., 1976. The Hydrology For Irrigation, PT. Pradya Paramita, Jakarta.
Suripin, 2002. Konservasi Tanah dan Sumber Daya Air, Andi, Yogyakarta.
The Law of the Indonesian Republic Number 7 of 2004, Jakarta, 2004.
Triatmodjo, B., 2009. Hidrologi Terapan, Beta Offset, Yogyakarta.
Yulistiyanto, B., Kironoto, B.A., 2008. Analysis of Water Resource Utilization In WS Paguyaman With RIBASIM, Media Engineering, No. 2 Th. XXX, Malang.

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

The 3rd SCESCM

Special Topics in Public Works Research and Technology

The analysis of channel type combination alternative of "Klambu-Kudu" raw water channel

Heny Krisyani[a], Suseno Darsono[b], Pranoto Samto Atmojo[b]

[a]*Balai Besar Wilayah Sungai Pemali Juana, Kementerian Pekerjaan Umum dan Perumahan Rakyat, Jl. Brigjen S. Sudiarto No. 375* Semarang
[b]*Magister Teknik Sipil Universitas Diponegoro, Jl. Hayam Wuruk N0. 5-7 Semarang*

Abstract

"Klambu Kudu" raw water channel is a 40.558 km channel which conveys raw water from Klambu Weir to Kudu Water treatment plant (WTP). The water flow measured in the Intake at Klambu Weir and at Kudu WTP has some discrepancies to the planned. This discrepancies are partly caused by use of different types of channel on various locale conditions. This research describes the selection to the policy maker in deciding which raw water channel type suitable for each area by using Decision Making Supporting System (DSS) with an approach of Analytic Hiearchy Process (AHP) Method. It integrating the criteria of construction cost, operation and maintenance cost, the ease of operation and maintenace implementation as well as benefit/profit.

Keywords: Decision Making Supporting System (DSS); Analytical Hierarchical Processes (AHP); Klambu Kudu; KuduWTP

1. Introduction

1.1. Background of the Research

"Klambu Kudu" channel conveys raw water from Intake in "Klambu" Weir, Grobogan District to "Kudu" WTP in *Kelurahan* Kudu, *Kecamatan* Genuk, Semarang City. It is 40,558 km length stretching from East at Grobogan to West at Semarang and passing through 3 (three) districts/cities, that are Grobogan District, Demak District and Semarang City.

Most of "Klambu Kudu" channel are open channel which passes through farming areas so that there is a possibility for the raw water to be 'stolen' for farming during dry season. On the other hand, during rainy season, there is a potential of rain water overflowing "Klambu Kudu" channel which causing high concentration of mud in the standard. Furthermore, the flow rate arrived at "Kudu" WTP can be reduced or even stopped when the channels at some locations are broken or when the raw water flows is obstructed by rubbish. Therefore, the amount of water rate of flow from Intake at "Klambu" Weir to "Kudu" WTP has discrepancies compared to the planned one. This situation raises some questions on the selection of the channel type with consideration on each locale conditions.

1.2. Problem of Research

Alonf the 40,558 km length, "Klambu Kudu" channels is managed into of 7 (seven) working areas called '*kemandoran*'. Each of *Kemandoran* has different channel types which brings its own problems. It is necessary to evaluate the appropriateness on the type of channels's selection. As there are many channel type combinations, a model of Decision Making Supporting System (DSS) is required to help the selection on which alternative on channel type combinations is suitable for "Klambu Kudu".

1.3. Aim of the Research

This research objective is developing a model of Multi Criteria Decision Making System by using AHP model to help the selection of channels types combination at Klambu-Kudu.

1.4. Purpose of the Research

The purpose of this research are as follows:

- Deciding the most influencing factor in selecting the most suitable channel combination type for "Klambu Kudu" system.
- Analizing "Klambu Kudu" alternative channel type combinations which is suitable with the areas it passed through based on the criteria of development implementation cost, operation and maintenance cost, the ease of operation and maintenace implementation as well as benefit/profit.
- Analizing the sensitivity of the criteria of the channel type combination selection.

1.5. Location of the Research

The scope of the research is the location of "Klambu Kudu" system from "Klambu" Weir at Grobogan District to "Kudu" WTP in Semarang City.

2. Literature Study

Turban, et.al., (2001) said that the concept of Decision Supporting System (DSS) is firstly emerge on the early of 1970's by Scott Morton. According to (Turban, et.al., 2005), DSS is an approach to support the decision making. It is one of software products specifically developed to help the management for the decision making process (Nazibu, 2009). The term DSS is made on 1971 by G Anthony Gorry and Michael S. Scott Morton to direct the computer application in managing the decision making (Nazibu, 2009).

A decision making means choosing several available alternative actions to reach one or several decided goals (Turban, et.al., 2005). The act of determining a criterion on a decision making process is one of important factors as the criterion itself shows the problem's definition in a concrete form and sometimes it is considered as the achieved target (Sawicki, 1992 in Marimin, 2004). (Hasan, 2002) stated that, the concept of DSS is marked with a computer based interractive system which help a decision maker to make use of data and model to solve unstructured problem. According to (Sobriyah, 2005), the analysis of DSS is initiated by identifying problem along with determining activity goals and decision support parameter. In (Nazibu, 2009), there are many DSS application. It can be used independently like Expert Choice, Super Decision and similar applications. It can also be made in an environment together with the existing applications such as Spreadsheet MS Excell, based on the spreadsheet itseld or by creating the macro function of Visual Basic Application (VBA).

In "AHP to Take Decision in A Complex Situation" book (Saaty, 1986), AHP means a simple and flexible method which accommodate creativity on approaching a problem. AHP collaborates consideration and personal judgement in a logical way, influenced by imagination, experience and knowledge to arrange a hierarchy of a problem based on logic, intuition, and experience to give consideration (Tominanto, 2012). AHP has many strengths in describing the decision making process as it can be shown in graphic so that it can be easily understood by many people involved in the decision making (Atmaja, 2008).

Compared to another multi criteria method, AHP has a structural hierarchy as a consequence of the chosen criteria and the detailed sub-criteria (Makkasau, 2012).

The steps of a decision making using AHP (Suryadi and Ramdhani, 1998) are as follows:

- Arranging a hierarchy of the problem, started with the general goal, continued by criteria and sub-criteria and followed by alternative choices which is needed to be ranked.
- Determining element of priority.
    - Shaping paired comparison matrix describing the influence of each element on the criteria and sub-criteria used.
    - Filling paired comparison matrix using numerical score which describes relative importance of one to another element. The comparison score is 1 to 9 (Saaty, 1986).
    - Normalizing data by dividing score of every element in the matrix which is paired with the total score of each column.
    - Calculating Eigen Value score by adding the score of each matrix and dividing it with the total element to get the average score. Eigen Value provides consistency measurement of comparison process (Nugraheni, 2012).
    - Calculating Eigen Vector of each paired comparison matrix. Eigen Vector score is the amount each element. Eigen Vector determines the rank of chosen alternative (Nugraheni, 2012).
    - Calculating Index Consistency under the following formula:

$$CI = (\lambda mak - n)/(n - 1) \quad (1)$$

Where,
CI = Consistent Index
λmax = maximum Eigen Value
n = the number of parameter

- Calculating Ratio Consistency under the following formula:

$$CR = CI / RI \quad (2)$$

Where,
CI = Consistent Index
RI = Random Index
CR = Consistency Ratio

$$CR = \frac{((\lambda mak - n)/(n-1)}{RI} \quad (3)$$

The Random Index Score (RIS) can be obtained in Saaty's table (1994).

It must be lower than 5% for 3x3 matrix, 9% for 4x4 matrix and 10% for bigger matrix. If RIS is higher than that, the matrix comparison score must be re-calculated (Tominanto, 2012). Moreover, there should be score revision as higher inconsistency level leads to error (Saaty, 1994).

The weakness of AHP lays on its dependence of its main input because the main input is someone's perception so that it involves an expert's subjectivity where this model can be meaningless when the expert gives wrong judgement (Putri, 2011).

Sensitivity Analysis is a dynamic element of a hierarchy. It means that the score which was done for the first time is maintained for a certain period of time where any change of policy change is done by using Sensivity Analysis to see its effect (Mora, 2009).

Sensitivity Analysis is aimed at seeing the influence of every element on the priority hiearchy which was built (Makkasau, 2012).

Population Score is all good score, resulted from the calculation and measurement as well as the quantity of certain characteristics of all member of complete and explicit group whose features needs to be observed (Hasan, 2003). Based on the number of a group member, (Usman, et.al., 1996) said that population can be divided into Restricted Population (limited) and Unrestricted Population (unlimited).

According to (Sugiyono, 2009 in Putri, 2011), Sampling Collection Technique is a technique to collect sample in a research so that the sample is representative for the population it represents. They divided it into 2 (two), Probability and Non-Probability Sampling Technique. The first one collects sample where each sample has the same chance for each item/member of population (for a quantitative research), while the second one collect sample where each sample has different chance for each item/member of population (for a qualitative research) (Sugiyono, 2009 in Putri, 2011).

3. Method of Research

There are 2 (two) kinds of data in this research, Primary and Secondary Data. The first one were obtained by distributing questionnaire/question containing choices of opinion to respondents who are competent in their job. The data were also taken by holding a discussion with the respondents to get more accurate data. The second one were collected from offices.

(Sugiyono, 2009 in Putri, 2011) defined Sampling Collection Technique as a technique to get sample in a research in order to get a representative sample for the population it represents. This research use Purposive Sampling Technique, that is a technique of collecting sample under certain consideration, based on the research requirements which will be done where not all of respondents understand the topic of the research.

According to (Sugiyono, 2009 in Putri, 2011), respondents who are considered as an expert are they who are competent in their field. They can be competent in their authority/policy to make a decision, competent in their daily job (routine duty)/profession or they can have an academic competency suitable with the topic of this research. The respondents in this research are officers in The Office of *Balai Besar Wilayah Sungai Pemali Juana*, The Office of PSDA *Propinsi Jawa Tengah* and *PDAM Tirta Moedal* Semarang who are competent in their field. The questionnaire was distributed directly where respondents directly filled the form and held a discussion with the researchers. The numbers given from respondents' perception becomes the comparison scale of each factor of criteria and sub-criteria. The score of the respondents' answer is drawn based on the score of the camparation scale/range given by the respondents in the questionnaire. In this research, the respondents' education background should be observed as (Sugiyono, 2009) stated that one of important factors of competent respondent is their academic competence which is suitable with the topic of this research. The procedures of this research can be obtained in the research flow chart in Fig. 1.

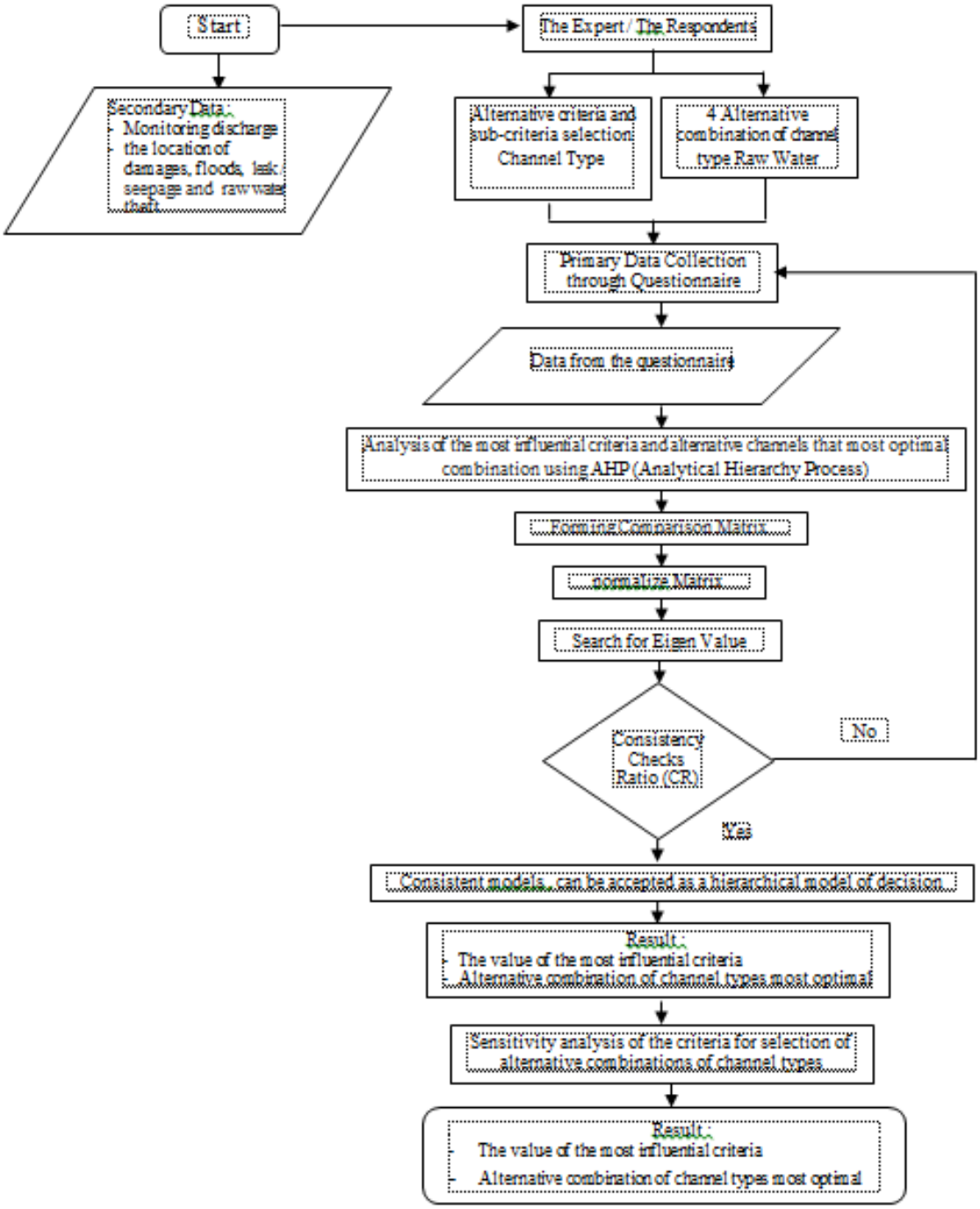

Fig. 1. The research flow chart.

4. Result of The Research and Discussion

The scores on criteria and sub-criteria were obtained from the score of scale/range of comparison scoring on respondents' questionnaire result. The score of comparison scale can be varied from important to more important. The standard score for comparison is 1 to 9 based on Thomas L. Saaty scoring number.

The first highest comparison score on the criteria of choosing channel type combination for "Klambu Kudu" system is the criteria of operation and maintenance implementation cost (0.291). The second highest score is operation and maintenance implementation cost (0.248). The third highest score is development implementation cost (0.177). The fourth highest score is the ease of development implementation (0.176). The fifth highest score is benefit/profit (0.107).

Based on the result of using AHP Method on each sub-criteria of choosing the alternative of channel type combination of "Klambu Kudu" system , the researchers obtained 4(four) most optimal result as follows:

- The first priority is alternative channel type 4 (0.448), that is a closed channel of clean water pipe on WMI near "Klambu" Dam, Grobogan District.

- The second priority is alternative channel type 1 (0.186), that is the existing channel with repairmen/improvement in several locations.
- The second priority is alternative channel type 3 (0.195), that is the alternative channel 3 (km 0,600 – km 24,007), the piled channel should use lining concrete contruction and the channel dike should use the power of concrete pole. The excavated channel (km 24,007) should use sheet pile construction, concrete lining and single tee concrete cover. This alternative channel type is used for "Kudu" WMI in Semarang City where the location of channel km 26, 902 – km 39, 275 is moved to the north of the street.
- The second priority is alternative channel type 2 (0.187). On the alternative channel 2, the piled channel (km 0,600 – km 24,007) should use concrete lining construction and the channel dike should use concrete pole reinforcement. Meanwhile, the excavated channel (km 24,007 – km 40,558) should use sheet pile construction, concrete lining and single tee concrete cover. This alternative channel type is used for "Kudu" WMI in Semarang City while building drainage for farming on km 26,902 – km 39,275 to channel excessive water in rainy season from farming areas.

The following picture shows "Klambu Kudu" system.

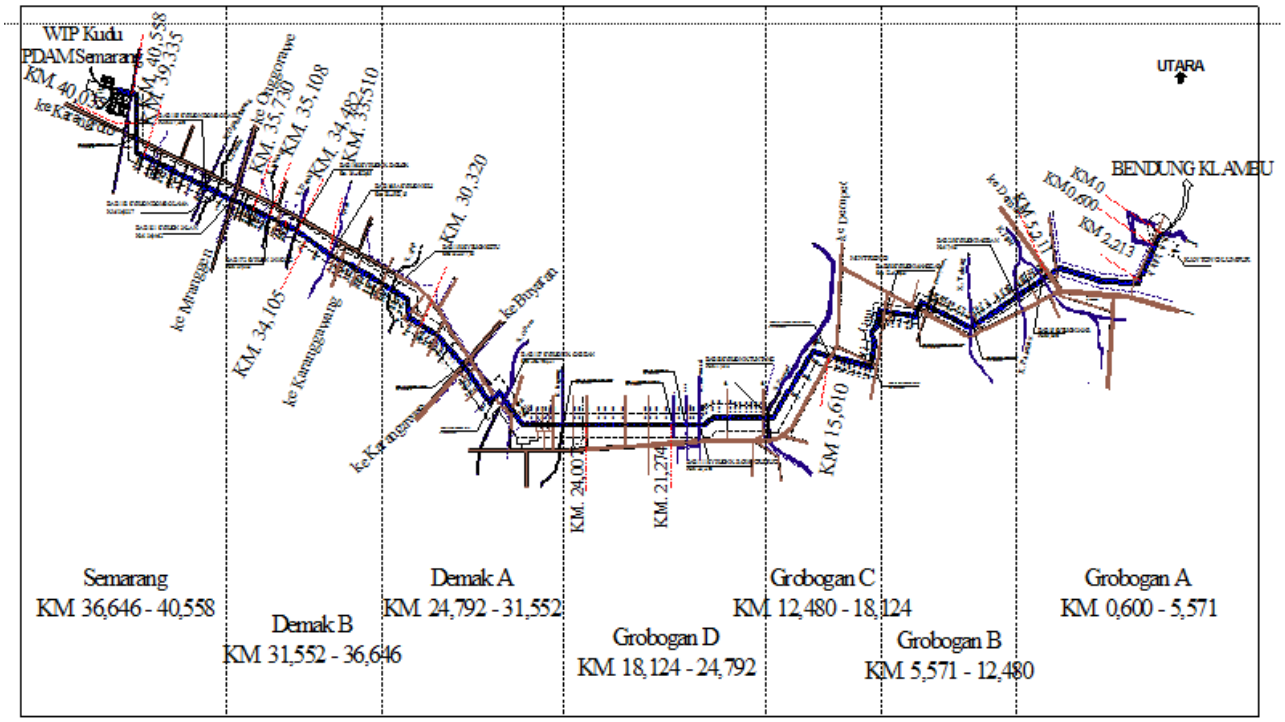

Fig. 2. "Klambu Kudu" system.

The chosen criteria and channel type alternative is tested by using Sensitivity Analysis by changing the score (by adding or subtracting the score). If the score of the operation and maintenance cost is raised by 3% from 0.291 to 0.300, the priority is globally unchanged, that is the alternative channel 4 still becomes the first priority. If the score of the operation and maintenance is raised by 20% from 0.291 to 0.350, the priority is still globally unchanged. It will stay the same when the score of the operation and maintenance cost is 31% or 40% lower, that is the priority remain the same.

5. Conclusion of The Research

From the result of the data analysis in this research, the researchers draw 3 (three) conclusion as follows :

- By using AHP Method, the alternative 4 of raw water channel type combination is obtained as the suggested alternative to be used, that is a closed pipe channel of clean water.
- The most important criteria in choosing the alternative raw water channel type combination is the operation implementation and maintenance cost criteria.
- After testing the result by using Sensivity Analysis, is can be concluded that criteria and sub-criteria in choosing the alternative raw water channel type combination in "Klambu Kudu" is not sensitive. That the conclussion in (a) is unchanged.

References

Akbar, Usman, H. dan Setiady, P. 1996. Metodelogi Penelitian Sosial. Jakarta: Bumi Aksara.

Atmaja, I. T. 2008. Evaluasi dan Peningkatan Kinerja Jaringan Irigasi Bapang Kabupaten Sragen. Surakarta. Program Studi Magister Teknik Sipil. Universitas Sebelas Maret.

Hasan. M. I. 2002. Pokok-pokok Materi Pengambilan Keputusan. Jakarta: Ghalia Indonesia.

Hasan. M. I. 2003. Pokok-pokok Materi Statistik. Edisi Kedua. Jakarta: PT Bumi Aksara.

Makkasau, K. 2012. Penggunaan Metode Analytic Hierarchy Process (AHP) dalam Penentuan Prioritas Program Kesehatan (Studi Kasus Program Promosi Kesehatan), Dinas Kesehatan Kota Ternate Provinsi Maluku Utara. J@TI Undip. Vol: VII No 2 Mei 2012.

Marimin. 2004. Pengambilan Keputusan Kriteria Majemuk. Jakarta: PT Grasindo.

Mora, M. 2009. Analisis Sensivitas dan Pengaruhnya terhadap Urutan Prioritas dalam Metode Analytic Hierarchy Process (AHP). Medan. Fakultas Matematika dan Ilmu Pengetahuan Alam. Universitas Sumatera Utara.

Nasibu, I. Z. 2009. Penerapan Metode AHP Dalam Sistem Pendukung Keputusan Penempatan Karyawan Menggunakan Aplikasi Expert Choice. Jurnal Pelangi Ilmu. Volume 2 No. 5.

Nugraheni, S. D. 2012. Menentukan Waduk Prioritas di Daerah Aliran Sungai Cisanggarung. Semarang. Program Pascasarjana. Universitas Diponegoro.

Putri, I. D. A. N. A. 2011. Penentuan Skala Prioritas Penanganan Jalan Kabupaten di Kabupaten Bangli. Denpasar. Program Pascasarjana. Universitas Udayana.

Saaty, T. L. 1986. Proses Hirarki Analitik untuk Pengambilan Keputusan Dalam Situasi yang Kompleks. Jakarta: PT Pustaka Binman Pressindo.

Saaty, T. L. 1994. Fundamental Of Decision Making and Priority Theory With The Analytic Hierarchy Process. University of Pittsburgh: RWS Publication.

Sobriyah. 2005. Sistem Pendukung Keputusan Pada Penentuan Prioritas Rehabilitasi Jaringan Irigasi di DIY. Surakarta. Gema Teknik Fakultas Teknik Universitas Sebelas Maret.

Sugiyono. 2009. Metode Penelitian Kuantitatif. Bandung: Alfabeta.

Suryadi, K. dan Ramdhani, M. A. (1998). Sistem Pendukung Keputusan. Bandung: PT. Remaja, Rosda Karya.

Tominanto. 2012. Sistem Pendukung Keputusan dengan Metode Analytical Hierarchy Process (AHP) untuk Penentuan Prestasi Kinerja Dokter pada RSUD Sukoharjo, Jurnal Ilmiah Rekam Medis dan Informatika Kesehatan. Infokes, Vol. 2 No. 1 Agustus 2012.

Turban, E. & Aronson, J. E. 2001. Decision Support Systems and Intelligent Systems. New Jersey: Prentice Hall, Upper Saddle River, 6th edition. Copyright 2001.

Turban, E., Aronson. J. E. & Liang. T. P. 2005. Decision Support Systems and Intelligent Systems (Sistem Pendukung Keputusan dan Sistem Cerdas). Yogyakarta: Andi Yogyakarta.

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

The 3rd SCESCM

Special Topics in Public Works Research and Technology

Monitoring system of river morphological changes for supporting river structures maintenance

Asep Sulaeman[a, b], Rahmat S. Lubis[a], Ery Suhartanto[b], Galih H. Sundoro[a, b]

[a] *River Research Center, Ministry of Public Works and Housing, Surakarta*
[b] *Master of Water Resources, Department of Water Engineering, Brawijaya University, Malang*

Abstract

Rivers has a dynamic nature and will change continuously in response to changes in the components that affect it. In general the changes that occur in rivers are changes in the quantity and quality of river water as well as river physical changes, where both the changes are influenced each other. The changes that occurred in the river both vertically and horizontally are very influential to changes in cross-section and shape of the entire river. The shape of the river can be generally classified into three (3) types, namely; straight river, meandering river, and braided river. In reality, many natural river's conditions show the transition from three (3) classification forms of the river. The pattern of a river is determined by the characteristics of its watershed, i.e.: runoff and its hydrograph; sediment loads, characteristics of sediment material; and boundary conditions such as the topography of the valley, geological structure, and soil composition of the channel and banks. For most alluvial rivers, boundary conditions play a significant role in the formation of river patterns. The fluvial processes in both planar and longitudinal directions significantly affect river's behavior and stability, especially for large rivers, which play very important roles in a country's sustainable development of its economy, ecology and environment. The fluvial processes may cause or aggravate the disasters. Sometimes the river physical changes can cause damage to structures and infrastructures along the river stream. The damage that occurs due to changes in river morphology is not monitored well. Therefore in river maintenance, it is necessary for monitoring changes in river morphology continuously to obtain morphological characteristics of a river. With monitored morphological changes of the river, then the damages due to changes in river morphology can be identified and anticipated. Monitoring of river morphological changes include the following aspects: river geometry, *sediment transport*, river structures and human activities. Monitoring locations divided into river characteristics are: Straight river, Meander river, River structure (Bridge, Weir, Cut off, Reinforcement/protection river bank, Groyne). Monitoring can be carried out at least once a year, which is done after the rainy season. For the river that experience active morphology changes that endanger the surrounding structures, the monitoring can be performed more extensive. Measurement result are manage using SPPMS program. SPPMS able to know geometry cross section and the length of the long section. SPPMS able to overlay cross section and long section on the same station name in different years so it can notice changes in each the cross section and long section and its widespread. By using SPPMS measurement data will be stored in a structured and incorporated in an online system with unlimited space access.

Keywords: morphology; river; monitoring system; straight river; meander; braided; local scour

1. Introduction

Rivers are area or basin as well as the drainage network of water from the spring to the estuary with restricted with river border at right and left along the river banks. A river is a system consisting of many components and are complex but orderly, where the components are interrelated and influence in a synergistic.

Rivers has a dynamic nature and will change continuously in response to changes in the components that affect it. In general the changes that occur in rivers are changes in the quantity and quality of river water as well as river physical changes, where both changes influenced each other. Physical changes in the river may occur in geometric parameters in the horizontal direction and the vertical direction.

Changes may occur due to a series of river evolution itself or due to human activities directly or indirectly. The river as a source of water has attracted humans to approach him. Human activity in utilizing the river makes the symbiosis between river and man intertwined and affect each other. The science that describes land forms and processes as well as investigating reciprocal influence between landforms and processes in the context of spatial is called Geomorphology. Processes that lead to physical changes in a landform called geomorphic processes. Geomorphic processes can be distinguished into exogenous, endogenous, and extraterrestrial processes.

Changes in the shape of the river flow are strongly influenced by these geomorphic processes. The process of endogenous and extraterrestrial occurred in a river is very unpredictable on which/what will happen and when it will happened. While exogenous process occurs slowly over a relatively long time, so it is easier to learn and predict its effect. Many factors can influence the occurrence of exogenous process in river basins, among others; weathering, sedimentation, erosion, and soil movement. The existence of this exogenous process will eventually result in a change in the flow, and face the river.

River morphological changes caused by the exogenous process, i.e.:

- Aggradation and degradation
  Aggradation is an increase in a river bed elevation. River bed aggradation can occur when flow energy is not sufficient to carry sediment's material so that sediment material settles in the river bed and lead to higher elevation of the river bed. River aggradation often occurs in:

  - River with gentle bottom slope that flows slowly so that flow energy is not sufficient to carry sediment loads.
  - In the flow of the obstructed river by inline river structure (such as weirs, dams, groundsill, etc.) as well as by natural obstruction (such as river rock landslide, piles of garbage, etc.) so that the flow is slow.
  - At estuary that river flow is retarded by the tides so the flow is slow.

- Riverbed Degradation: namely the decline of river bed elevation of a river segment. Riverbed degradation generally occurs on a fast velocity flow at river segment that flow energy is able to erode the river bed. Degradation can occur due to several things as follows:

  - The amount of sediment supply from upstream stopped/reduced because it was blocked by river's structures such as weirs, dams, groundsill, groyne, etc.
  - Sand mining from river bodies.

- Horizontal river morphological changes
  River will change continuously influenced mainly by variations in discharge flowed at certain moments which can cause river changes either retreat or advance of the riverbank.

  - The withdrawal of the river bank can be caused by a landslide/erosion. The resignation of the river bank is common in outside bend areas of the river because the water flow at the outside corner is strong enough to erode the river banks. Besides the flow of water, water waves hit either caused by wind or waterway can cause erosion of the river banks. The occurrence of landslide on riverbanks caused by instability of the bank. This instability occurs when the force conditions which will result in an erosion of the bank is greater than the force that held him back.
  - The advancement of the river bank can be caused by sedimentation. Advancement of river banks is common in the inner bend area. Because water flow around the bend in not too strong, so causing the sediments transported by water flow settles in that location.

The changes that occurred in the river both vertically and horizontally are very influential on changes in cross-section and shape of the entire river. The shape of the river can be generally classified into three (3) types, namely; meandering river, straight river, and braided river, although in reality, many natural river conditions that the transition from three (3) classification forms the river. Illustration rivers form presented in Figure 1.

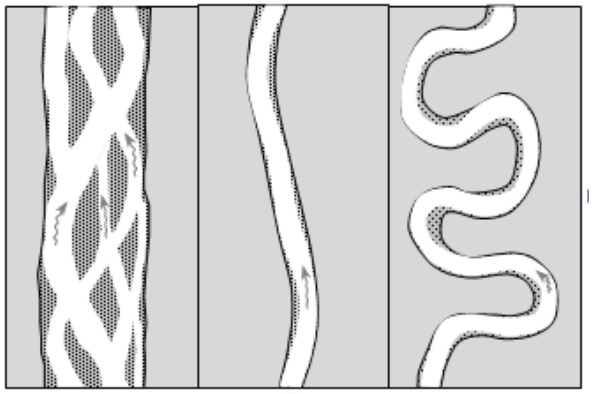

Fig 1. Type of River; (a) Braided river, (b) Straight river, (c) Meandering river.

The pattern of a river is determined by the characteristics of its watershed, i.e.: incoming runoff and its hydrograph; incoming sediment load and its hydrograph, and size distribution of sediment; and boundary conditions such as the topography of the

valley, geological structure, sediment particles, and soil composition of the channel and banks. For most alluvial rivers, boundary conditions play a significant role in the formation of river patterns. If the boundary, including channel bed and banks, is composed of sand or silt, a braided occurs. When the channel bed is composed of sand and silt and the banks have some clay or sandy clay, a meandering river occurs.

During floods, the channel bed may increase and decrease in elevation as a result of the variation in sediment supply and transport capacity natural in dynamic watersheds. Erosion of sediment, sometimes termed "scour" or "degradation" and deposition of sediment, sometimes termed "fill" or "aggradation," occurs at various magnitudes during individual floods. Over the long-term, this variation in erosion and deposition may essentially balance over time—yielding a stable channel elevation, or a trend toward either scour of fill (Shilling, F., 2005).

Assessment of fluvial processes and morphology and documentation of changes over time are often conducted at the scale of a "reach". Selecting a channel reach length of about 10 to 20 times the average channel width (Leopold et al., 1964) is commonly used—others have suggested reach lengths of at least 6-30 times the channel width and including two complete riffle-pool sequences (Simon and Castro, 2003).

Assessment of morphology at the reach scale is intended to document some of the variability inherent in natural systems, and helps ascertain fluvial characteristics that are representative of that section of the river—so definition of a reach depends on the particular river being considered. For example, in order to characterize a meandering river, a reach might need to be longer than 10 or 20 times the channel width so that the reach encompasses complete meander wavelengths—instead of truncating them mid way—and with enough up- and downstream length to provide context for the areas of interest. In other words, it is important to look outside of the channel banks. In contrast to the reach scale that may include multiple cross sections, data from a single cross section, say over the deepest part of one pool, or across one riffle, lacks the context to understand the natural variation inherent in rivers (Shilling, F., 2005).

Many rivers today are confined into single channels, whereas, prior to human activities and land use changes they were multiple channel systems where the floodplain was an integral component of the system. Investigations that compare historical to current maps or photographs are invaluable in inferring dominant processes prior to human activities and documenting changes.

Some important parameters to measure plan form include:

- Sinuosity
  Sinuosity (s) is a measure used to quantify the difference between meandering and straight channels. Sinuosity of a channel is defined as the channel length (L) measured along the center of the channel divided by the valley length (Lv) measured along the valley axis (Schumm, 1963 in Shilling, F., 2005):

$$\boldsymbol{S} = \frac{\boldsymbol{L}}{\boldsymbol{Lv}} \tag{1}$$

  Sinuosity of natural rivers generally varies between 1.0 (straight channels) and 3.0 (highly sinuous, or "tortuous" meanders).

- Migration Rate
  The migration rate is a measure of how quickly a meandering channel erodes through floodplain sediment on the outside of a bend while maintaining a relatively constant channel width--and is defined as the distance a channel moves divided by the time it takes. However, over a certain length of channel, such as around the outside of a meander bend or a longer reach, the rate of migration is variable, with some portions eroding faster than others. Thus, the migration distance is often averaged by measuring the area (A) that is eroded by the migrating river divided by the length of channel considered (L). The migration rate here given as the variable (Mr), is determined by dividing the ratio (A/L) by the time period of measurement (t):

$$\boldsymbol{Mr} = \frac{\left(\frac{\boldsymbol{A}}{\boldsymbol{L}}\right)}{\boldsymbol{t}} \tag{2}$$

- Number of channels and Floodplain Drainage Density
  The interrelation between channels and the floodplain in multiple channel systems can be quantified using morphometric parameters that characterize the branching system attributes: 1) the number of channel segments (n); 2) the length of channel segments (L); and 3) floodplain drainage density (D):

$$D = \frac{\sum L}{A} \tag{3}$$

  Where:
  $\sum L$ is the sum of the lengths of all channel segments within a measured floodplain area, A. In particular, floodplain drainage density is a useful parameter used in his context to quantify changes in channel-floodplain interactions in lowland river systems where channel floodplain connectivity sustains floodplain ecology (Florsheim and Mount, 2003 in Shilling, F., 2005).

The fluvial processes in both planar and longitudinal directions significantly affect river behavior and stability, especially for large rivers, which play very important roles in a country's sustainable development of its economy, ecology and environment. The fluvial processes may cause or aggravate the disasters (Rosgen, David L., 2001).

Sometimes the river physical changes can cause damage to structures and infrastructures around the river stream. The damage that occurs due to changes in river morphology are not monitored well. Therefore in river maintenance necessary for monitoring changes in river morphology is performed continuously to obtain morphological characteristics of a river. With monitored morphological changes of the river, then the damages due to changes in river morphology can be anticipated. For monitoring of river morphology changes need to be made a monitoring system that can facilitate implementing in recognizing and investigating the morphological characters of the river.

2. Methodology

Formulating monitoring system activity took place is done by a theoretical approach, and based on the results of the study on changes in river morphology.

3. Result and Discussions

3.1. River Morphological Changes

3.1.1. Straight River

- Feature straight river
  In alluvial rivers, straight rivers have straight outlines with a relatively short length, such as the straight reach between two bends of meandering rivers or the single straight river between two branched reaches. Straight rivers have the following main features.

  - Alternate side bars. Alternate side bars cause the main current line to be sinuous. The size of side bars depends on the size of river channels.
  - Side bars alternate with pools along the river.
  - Riffles and pools occur alternately along the thalweg. In low water seasons, sprays can be found on the surface downstream near the riffles.

- Features of flow and sediment transport
  Straight rivers have pools and crossings with a sinuous main current. Straight rivers also have circulating flows, but the flow intensity is weaker than that of meandering rivers. The sediment transport rate of bed load on crossings is lower than that in pools. Obvious sorting of sediment particles can be found. The coarse particles are concentrated on crossings and the sediment composition in pools is fine. Sediment sorting also exists vertically on the crossings. The coarse sediment is located near the surface, while Fine sediment is situated in the deep layers.
- Feature of pluvial prosess straight river
  The migration of alternate side bars downstream and the corresponding shifting of pools are the major characteristics of the fluvial processes of straight rivers. Therefore, the river, including the side bars, pools and crossings, as a whole moves some distance downstream after a certain time period.

The river channel is widened periodically. When the side bars move down, the erosive banks on both sides are covered by the side bars. Correspondingly, the formerly covered banks are exposed and re-eroded by the flow. Thus, the bank lines recede, causing the channel to be gradually widened. Then, the wide side bars are cut off by the flow and become mid-bars or islands. Once one branch is blocked, the island connects with the bank and the channel becomes narrowed once again.

3.1.2. Meandering river

- Feature of meandering river
  Meandering rivers consist of a series of bends of alternate curvatures connected by straight crossing reaches. The terms used to describe stable meanders are defined in Figure 2. Essential elements of meandering rivers include: meandering wave length (Lm); meandering belt width (Tm) (H m); curvature radius (R); width of straight reach (crossing) (B); length of curve line (s); Central angle (θ□□); and length of crossing (L).

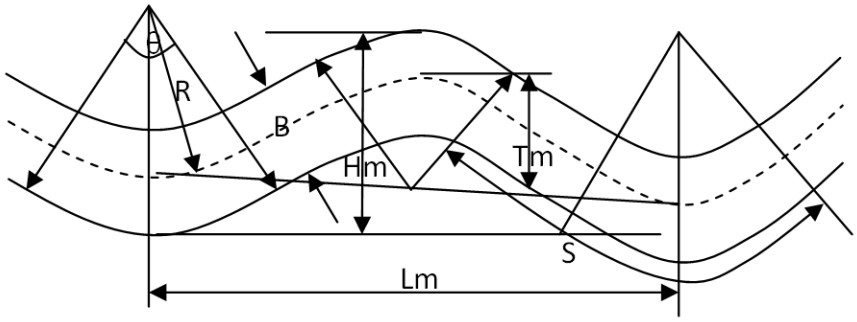

Fig. 2. Meander River.

- Transversal slope of bed surface and distribution of sediment particles
  Under the action of circulating flow and channel bed, the transversal transport of sediment particles occurs and the transversal slope of the channel bed surface is thereby formed. Because of the complicated Exchanges of sediment between the transported particles and bed sediment, the distribution of bed sediment also becomes non-uniform. Coarse particles appear near the thalweg line.
- Sediment transport in meandering rivers

  - Transport of suspended load
    In general, the distribution of suspended load is not uniform along the depth. The sediment concentration is higher and the grain size is coarser near the channel bed. In a bend reach, because of the influences of spiral flow, water with high concentrations and coarse particles is concentrated along the convex bank, and that with low sediment concentrations and fine sediment particles is in the concave bank. The distribution of sediment concentration through the depth near the concave side is also more uniform. In a straight (crossing) reach, the distribution of sediment concentration along depth is uniform, and the transversal distribution of vertical average concentration corresponds to the transversal distribution of vertical average velocity.
  - Transport of bed load
    The transport of bed load in meandering rivers is characterized by the following two phenomena (Xie, 1987 in Xiaoqing, Yang, 2003):

    - According to experimental data, the sediment particles eroded from the concave bank of a bend are carried by flow and partly deposited at the crossing and convex bank of the next bend. The remaining particles are further carried and deposited at the downstream sections and convex banks of downstream bends. However, when the circulating flow is strong, the sediment particles eroded from the concave bank are carried directly to the opposite convex bank and settle there. The former is called same side transporting of sediment and the latter, different-side transporting. For meandering rivers, same-side transporting of sediment is more common than different-side transporting.
    - Bed load particles often move in a transporting belt along the river instead of spreading all over the channel bed. The transporting belt is situated near the point bars of convex banks. The transversal transport of bed load caused by spiral flow is controlled by the transversal slope of the bed surface.

- Characteristics of fluvial processes
  Characteristic of pluvial river meander as Xioqing (2003) mentioned were:

  - Collapse of concave banks and growth of convex banks
    Generally, meandering rivers are in the equilibrium state of sediment transport. Under the action of spiral flow, the sediment deposited at convex banks is mainly from erosion of the concave side. As a result, the channel has a continuous migration over the years.
  - Meander migration
    The shear stresses acting on the bank and channel bed reach a maximum at the position downstream of the apex of the bend, and the eroded sediment particles deposit at the convex bank, causing the point bar to develop. With the collapse of the concave bank and the growth of the convex bank, the channel bend, as a whole, gradually migrates downstream. During the migration process, the outside of the bend is changed, but the center part of the crossing may remain basically unchanged. Therefore, the adjacent bends move around a fixed point, and an S-shaped meander may form.
  - Cutoffs
    As the S-shaped bend develops, the apex of the two adjacent bends located on the same side come closer, and the difference of water surface at both ends of the neck becomes larger. Once the overbank flood occurs, the neck may be scoured. A new channel may be formed, widened and deepened, and the old bendway may become separated from the river by deposition, surviving as an oxbow lake. This phenomenon is called natural cutoff. Subsequently, the channel

upstream of the cutoff is eroded because of the steep slope, and the channel downstream of the cutoff is deposited because of the lower slope. If the pilot channel is not protected from erosion, a new meander (bend) is formed again.

3.1.3. Braided river

The river downstream from the dam was originally a wide, shallow and braided channel with a rapidly shifting thalweg and lots of well developed unstable mid-channel bars, and was regarded as a typical meandering braided river. Bank erosion was fast because of quite high flood peaks, frequent and rapid channel shifting, and low silt-clay content in the bank material.

Braided rivers have steep slopes, small water depths and high flow velocities in wide and shallow channels with fragmented, broken and disorganized channel beds. Special water surface phenomena, corresponding to bed forms such as dunes and anti-dunes etc., often occur because the Froude numbers of its flow are far greater than those in ordinary alluvial rivers.

- Morphological features
  The static features of braided rivers include the following: (1) There are dense mid-bars, branches and scattered flows in the channel. (2) The channel configurations are more smooth and straight, with a sinuous coefficient (total length of branches)/(length of channel) of 1–1.3, which is smaller than that of meandering rivers (1.5–2.5). (3) The channel beds are wide and shallow.
  The dynamic behavior of braided rivers may be described as follows: (1) The mid-bars move quickly and the river bed can be easily eroded and deposited. (2) The positions of main currents change constantly. Sometimes, the position of the main current can change completely during a flood. (3) The range of main current shifting is large and the shifting rate is high. (4) There are two types of migration of the main channel — gradual shifting and sudden shifting in channel evolution. Gradual shifting often occurs in flood-rising periods, and sudden shifting occurs in flood-falling periods.

3.1.4. Local scour at Bridge

From (Sulaeman, Asep and Supriyanto, 2015) River morphology encompasses a group of characterizations affecting any waterway crossing. The two most important river morphology parameters are stream classification and flow habit. Meandering streams are subdivided into *stable* and *active*.

Other major characteristics derived from river morphology are curvature, lateral movement, and stream stability. Curvature is a local variable at the bridge site that describes how much the stream direction is turning. Erosion on the outer bank of the bend and deposition on the inner bank is a general trait in meandering rivers and can have devastating effects on a bridge if it crosses at a bend. Additionally, lateral migration adversely affects structures by attacking portions of the bridge not initially designed to be threatened by erosion, changing the angle of attack on piers and abutments, and/or contracting the waterway with deposition on the inner bank.

Local bridge hydraulics describes the flow that moves bed material during the scour process. Water depth and velocity are the two most important characteristics of this flow with regard to local scour. Generally, as the depth decreases and approach velocity increases, the flow becomes more turbulent when encountering an obstruction. This in turn increases vortices and bed scouring.

Depth and velocity also affect other hydraulic aspects of a bridge site besides local scour. The water depth relative to the bridge geometry can have significant effects. If the water surface rises above the low chord of the bridge, the additional component of a plunging pressure flow can deepen the maximum scour depth and drag debris deeper into the flow. High water velocities produce significant drag forces on fixed monitoring related structures. Among other effects, these forces may cause removal or flow induced vibrations of instrumentation, resulting in monitoring system failure. The amount of entrained air and debris in the flow are examples of other characteristics that affect the use of fixed scour monitoring instrumentation. Sonar does not work in bubbly flows and debris in the water may also have adverse effects on sonar and other types of instrumentation.

3.2. Monitoring system for river morphological changes

Identification of changes in river morphology is done by observing the change of some parameter such as monitoring aggradation, degradation and geometry changes in horizontal direction of the river and sediment transport.

3.2.1. Monitoring parameter

Monitoring parameters that are undertaken include:

- River geometry
  River geometry changes parameters required are: length, width, slope, altitude (elevation). These parameters can be obtained by field measurements whose results compared with the previous geometry data. Signs of morphological changes of the river commonly found among others:

- Degradation/decrease in base flow or riverbed, with parameters: length, width, and depth.
- Aggradation/sedimentation parameters: length, width and height / thickness.
- Local Scouring as a result of disruption to the flow of the river by the structure of the natural / artificial parameters: length, width, depth, and place.
- River bank erosion due to a Hellical flow or eddies flow, which can lead to landslide riverbank, with parameters: length, width, and deep.
- Meander, i.e. symptoms of rivers curvatures in the area are elongated, with parameters: length, width, depth and site.
- Braided, namely the combination of symptoms meanders and numerous local precipitation, with parameters: length, width, depth and site, the amount is generally longer than the meanders.

- Sediment transport
  On the river upstream in general basic sediment load is part of the total sediment transport. The quantity and quality of the material carried by the flow along the riverbed dependent than the spread of erosion in mountainous areas and also depends on the degree of slope, geology and vegetation structure.
  Indication about sediment transport problems is usually found among other things:

  - Obvious degradation/decline or the bottom of the groove and the riverbed, with parameters: length, width, and depth.
  - Aggradation/sedimentation with parameters: length, width and height / thickness.
  - Local scour as a result of disruption to the flow of the river by the structure of the natural / artificial parameters: length, width, and depth, as well as place.
  - River bank erosion due to a Helical flow or eddies flow, which can lead to landslide riverbank, with parameters: length, width, and deep.
  - Meander, i.e. symptoms of rivers curvatures in the area are elongated, with parameters: length, width, depth and site.
  - Braided, namely the combination of symptoms meanders and numerous local precipitation, with parameters: length, width, depth and floor plans, the amount is generally longer than the meanders.

- River Structures
  Changes in the value of the function in the operation of the river structure, as well as the security and stability of the structure. This condition is characterized by damage at river structure that have constructed.

- Human activities
  Activities which affect river morphology changes include: sand mining, dredging, repair river basins, and river transport.

3.2.2. Monitoring location

- Straight river
  Monitoring location of river morphology changes on straight line made in the location that represent of the beginning, middle and end of the straight river. Monitoring location focused on structure close to the river or near the bridges or roads or other infrastructure.
- Meander river
  Monitoring location on meandering river focused on structure close to the river or near the bridges or roads or other infrastructure. In the meanders are monitored, the measurement is made at least three measurements performed on the horizontal meander at the beginning, at the point of tangency and the end of the meander. In addition to the horizontal measurement was also monitored on a bank above the ground between bench mark/ monument each at least 20 m.
- River structure
  Monitoring location In the area of the structure is made at upstream and downstream of the structure. At least 3 point monitored site. River structure in question are:

  - Bridge: On the bridge, the location of the monitoring carried out at axis of bridge as cross section. Additional locations are points around pier.
  - Weir: the river which has a weir, monitoring location carried out in the upstream and downstream of the weir. For upstream weir location monitoring points located in the area immediately surrounding the inlet. While the downstream weir, monitoring location is done at the downstream of weir end-sill.
  - Cut off: The river which has cut off or short cut, place the monitoring conducted in the upstream of short cut, beginning of short cut, middle, end and the downstream of the short cut.
  - Reinforcement / protection river bank: on strengthening the banks, the location was monitored at least three locations that represent the beginning, middle and end of reinforcement.
  - Groynes: at Groynes structure, the location of the monitoring carried out at least at three locations which represent the beginning, middle and end of groyne.

- Dredging river: monitoring carried out in the dredged area, with a minimum of five monitoring sites in the monitoring point. Dredging monitoring location at the beginning, middle and end dredging location, and two monitoring sites upstream dredging area.
- Sand mining area: monitoring locations on the river experienced mining at least be in the upstream mining, on-site mining the middle and at downstream of river.

3.2.3. Frequency of Monitoring

Monitoring carried out at least once a year, which is done after the rainy season. And to the river that changed morphology aggressive that affect dangerous surrounding structure is monitored more extensive.

3.2.4. Monitoring Tool

- Geometry measurement
  Device for measuring the geometry of a river i.e. : theodolite, waterpass, total Station, signs measure Monument / BM, stakes. Measuring geometry of the river is conducted by terrestrial mapping.
- Sediment transport measurement tool
  Device for measuring Sediment transport of a river i.e. : Current Meter, suspended sediment load sampler, bed load sediment sampler, Bottled water samples with a minimum volume of 350 ml and 450 ml maximum.
- Local scour measurement
  Device for measuring local scours i.e. : sliding magnetic collars, float-out devices, tilt angle / vibration sensor devices, sounding-rod or falling-rod instruments, film piezoelectric devices, time domain reflecto-meter device that is used depend on characteristic local that will be monitored.

3.2.5. Monitoring System Database

Data base geometry measurement results and sediment can be accomplished using the river morphological changes monitoring system which has developed by the Experimental Station for River namely SPPMS. SPPMS a tool to see the trend of morphological changes of the river at the location of the river, especially near the building structure and infrastructure. Means used to compile some measurement data in a structured geometry river. Software monitoring morphological changes in the river is able to show the trend of the morphological changes of the river in this river changes direction transverse visually and software. Besides, this software is used for storing measurement data stream that different uptake time in one system are structured [6].

SPPMS can manage river morphological measurement data such as:

- River geometry data: shp file / DWG a form of river flow, name of station, year measurements, Coordinates (x, y), Cross section data (No, Distance and Elevation), long section data (distance between station)
- Water level recorder: name, Location: Latitude-Longitude, elevation, Rating Curve
- Riverbed sediment material: Name of location, Location: lat-long, and data as see in Table 1.

Table 1. Form for Riverbed sediment material observation.

Location	Diameter (mm)				Specific gravity
	D35	D50	D65	D90	Gs (ton/m3
……	…..	…….	…	……	……..

- River structure:
  - Bridge: Name, Location: lat-long, years of development, width of the bridge, Base floor elevation of the bridge, number of pillars.
  - Weir: Name, Location: latitude-longitude, weir type, years of construction, weir crest elevation, weir width.

SPPMS is able to know geometry cross section and the length of the long section. SPPMS able to overlay cross section and long section on the same station name in different years so it will be noticeable changes from the cross section and long section will be known and widespread changes of cross section area. By using SPPMS measurement data will be stored in a structured and incorporated in an online system with unlimited space access.

4. Conclusion

To anticipate the impact of morphological river changes to any infrastructure in the region, the monitoring needed are periodically. Monitoring of river morphological changes include the following aspects:

Monitoring parameter undertaken include: river geometry, *sediment transport*, river structures and human activities. Monitoring locations divided into river's characteristics are: Straight river, Meander river, River structure (Bridge, Weir, Cut off, Reinforcement / protection river bank, Groynes). With Monitoring carried out at least once a year, which is done after the rainy season. And to the river that changed morphology aggressive that affect dangerous surrounding structure is monitored more extensive. Measurement result are manage using SPPMS program. SPPMS able to know geometry cross section and the length of the long section. SPPMS able to overlay cross section and long section on the same station name in different years so it will be noticeable changes from the cross section and long section will be known and widespread changes of cross section area. By using SPPMS measurement data will be stored in a structured and incorporated in an online system with unlimited space access.

References

Lueker, Matthew. Marr, Jeff. Ellis, Chris. Winsted, Vincent and Akula, Shankar Reddy. 2010. Bridge Scour Monitoring Technologies: Development of Evaluation and Selection Protocols for Application on River Bridges in Minnesota. Minnesota Department of Transportation Research Services Section. Minnesota.

Rosgen, David L. 2001. A stream channel stability assessment methodology. Proceedings of the Seventh Federal Interagency Sedimentation Conference, March 25 to 29, 2001, Reno, Nevada.

Shilling, F., S. Sommarstrom, R. Kattelmann, B. Washburn, J. Florsheim, and R. Henly. 2005. California Watershed Assessment Guide. California Resources Agency. California.

Sulaeman, Asep and Supriyanto, Ibnu. 2015. Pengembangan software untuk pemantauan perubahan morfologi sungai. Proceeding Kolokium hasil Litbang Sumber Daya Air tahun 2015. Bandung.

Xiaoqing, Yang. 2003. Manual on sediment management andmeasurement. World Meteorological Organization. Geneva.

Zuidam, Van in Made, Atmaja Dewa. 1997. Peranan Geomorfologi Dalam Pengembangan Daerah Aliran Sungai, Aneka Widya STKIP Singaraja No, 1 Th XXXI Januari.

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

The 3rd SCESCM

Special Topics in Public Works Research and Technology

Trade-off analysis on reservoir operation for flood-control and benefit from raw water and hydropower (case study in Jatibarang reservoir)

Ferdian Agung Nugroho[a], Edy Anto Soentoro[b]

[a]*Master Program in Water Resources Management, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia, email: agung.engineer@gmail.com*

[b]*Master Program in Water Resources Management, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia, email: edyas209@gmail.com*

Abstract

The Jatibarang reservoir has multi-purpose functions as flood control, raw water supply for drinking water, and micro hydropower generation. Reservoir operation as flood control may reduce the benefit inccured from raw water and hydropower. This study is aimed to determine the trade-off of the reservoir's role as flood control and the benefit obtained from raw-water supply and hydropower generation. In this study, a reservoir volume factor (α) is introduced to anticipate and to reduce the peak flood downstream the reach. By varying the value of α during the flood season (i.e. the peak wet season), simulation and optimization are performed to find the trade-off between peak flood reduction and benefit obtained from raw-water supply and hydropower generation. Results of this study are that the trade-off between reservoir function as flood control and as a storage water to provide raw water supply and hydropower generation are in the range of 12.58% to 42.62% of peak flood reduction for range number of α from 100% to 50%. Considering property damages caused by flood in Semarang city area, however, the benefit of reservoir function as flood control surpassed the benefit obtained from water supply and hydropower generation.

Keywords: reservoir operation; flood control; simulation; trade off

1. Introduction

Semarang city is the capital of Central Java province that serves as the center of government, industry, commerce, education, tourism. Part of the Semarang city has been flooded almost every year. Like many big cities in Indonesia, most part of the city of Semarang is located on the coastal plain or delta, the Delta Garang (Suripin, 2004). Characteristics of flooding in the city of Semarang is flash flood which occured in the Garang River at 1961, 1963, 1974, 1976, 1981, 1982, 1985, 1987, 1988, 1990, 2001 and 2010. Flood that happened in January 1990 resulted in Kali Garang (West Canal Flood) overflowed so that the surrounding areas affected by the flooding. Several hundred homes at Sampangan area and surroundings were inundated by the flood elevation that reaches 2 meters. Flooding that occurred resulted in fatalities some 47 people, 25 homes damaged/collapsed and resulted in 126 homes and 15 public facilities were slightly damaged. Approximately 145 hectares of residential areas were inundated for more than three hours. (*SNVT Pembangunan Waduk Jatibarang*).

In addition to the problem of flooding, the problems that occur in many big cities in Indonesia, such as Semarang is with the movement of people from rural to urban areas (urbanization) cause problems in water supply and electricity. With the increasing population in urban areas and the addition of electrical energy needs will require a comprehensive solution of this question.

Efforts physical handling of problems that occur with the construction of the Multipurpose Dam Jatibarang built in Kreo Watershed time will contribute to flood control, raw water supply of Semarang and micro hydro power plant, 1.5 MW. Jatibarang Multipurpose dam has the function of reducing flood peak discharge 50 years at downstream from the annual meeting with Kali Garang or the West Flood Canal. Raw water system in Semarang City had needs are of 2.18 m^3/s and water availability there of 1.13 m^3/s. Require the addition for raw water supply for Region West Semarang 1050 l/s which will be supplied from the reservoir Jatibarang. And the need MHP produces 1.5 MW of electrical power required water discharge output 3 m^3/s.

The objective of this research is to examine the important role Jatibarang Reservoir in flood control. It needs to be simulated Jatibarang Reservoir in controlling flood discharge that will go to the West Flood Canal Semarang, assuming the reservoir in a state of full or effective volume maximum reservoir flood control. The flood control functions can still be maximized by providing extra volume in anticipation of flooding. The anticipation of flooding can be obtained by lowering the maximum

effective volume on the second half of the month of December until the first half of the month of February every year simulation period. So we will get an additional volume of flood control to reduce the risk of flooding. Through this study, it is expected to find simple formulation regarding the extent to which the role Jatibarang Reservoir as flood control and utilization of reservoirs to meet water needs for drinking water and power plants optimally by analyzing the Trade Off by performing simulation of operation of reservoirs. The resuslts can be used as a basis for reservoir management policies and it can be quickly and accurately compared to the Standard operation Procedure (SOP) for operating the reservoir.

The purpose of this study includes:

- Calculate how much the Jatibarang reservoir can reduce the flood peak discharge in the lower reaches of the Garang River (Semarang city area) by routing flood hydrograph.
- Perform a simulation model of Jatibarang reservoir operation taking into account the volume of flood and inundation for analyzing Trade Off to function as a flood control reservoir and to meet the needs of raw water for drinking water and electricity.

2. Location of Study

Watershed of Kreo is part of the Garang catchment area. Kreo Watershed is located on the northern slopes of Mount Ungaran extending from south to north with an area of 80.66 km^2. Jatibarang Reservoir is located in the middle range Kreo River, about 13 km upstream from the confluence to the main Garang River and about 23 km upstream from the Garang River mouth. Location of Jatibarang Reservoir covering four villages, namely Jatibarang, Jatirejo, Kedungpane, and Kandri in District Mijen and Gunungpati, Semarang city.

Kreo River flows through several districts and sub-districts in Semarang City, which includes Districts of West Semarang, Mijen, and Gunungpati. The Kreo River watershed extend also in Kendal regency (sub-District of Boja and Limbangan) and in Semarang District (sub-District of Klepu and Ungaran) (Puguh, 2009).

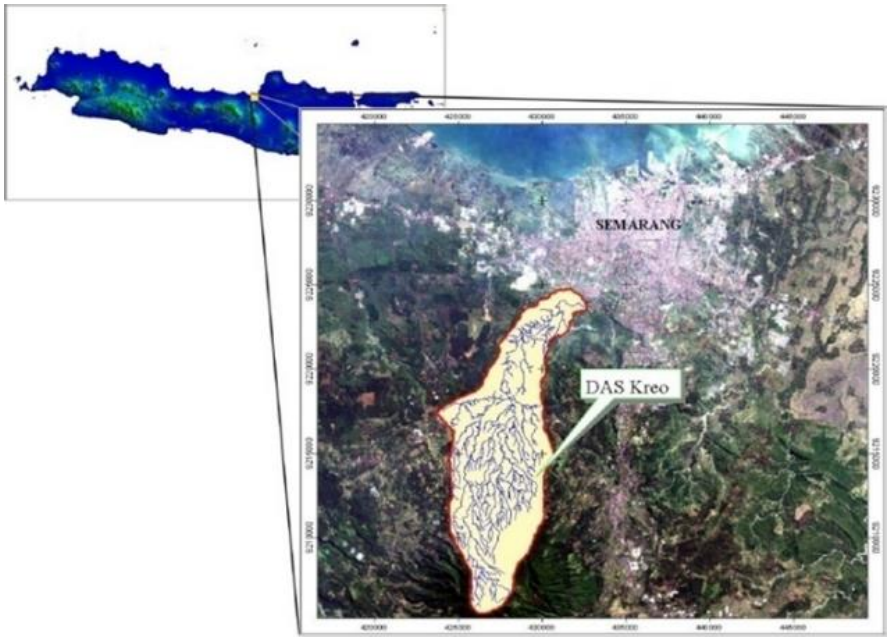

Fig 1. Location of Study.

3. Research Methodology

The trade-off between flood control versus raw water supply and electricity functions in Jatibarang Reservoir can be analyzed using simulation. At the beginning of simulation time, the reservoir state is assumed in a state of maximum volume (full stage), so that the amount of discharge inflow into the reservoir directly spill over the spillway. The next step out is to quantify the reduction of flood peak discharge passing through spillway when the reservoir is operated by performing hydrological flood routing.

In this study, a reservoir volume factor ($\boldsymbol{\alpha}$) is introduced to anticipate and to reduce the peak flood downstream to the reach. The $\boldsymbol{\alpha}$ (in percentage) is maximum reservoir volume which is set during the flood season (i.e. the peak wet season) divided by effective reservoir volume. The purpose of this allocation for flood control is to reduce reservoir volume during the peak of wet season in order to provide space for receiving flood water to the reservoir, so that it can reduce the peak flood flowing down-stream to Semarang City. By varying the value of $\boldsymbol{\alpha}$, simulation and optimization by linear program are done to find the trade-off between flood control allocation and benefit obtained from raw-water supply and hydropower generation. Varying the alpha is

conducted only during the peak wet season (second half of December to first half of February), meanwhile during other months the value alpha is set normal (**α** = 100%).

With the boundary condition in the simulation model of reservoir operation corresponding functions as a flood control reservoir which is still able to provide raw water for drinking water and hydropower generation. In this reservoir simulation model, the reservoir is expected to meet the needs of drinking water and electrical energy production as optimal as possible constrained with limited storage allowable during peak wet season. In this study it uses Microsoft Excel for the simulation. The simulation is perfomed for various values of flood storage allocation (by varying alpha value) while still satisfying raw water for drinking water and hydropower generation requirements. These series of simulation is used for analyzing the Trade Off between the decrease flood peak discharge versus raw water supply and hydropower generation.

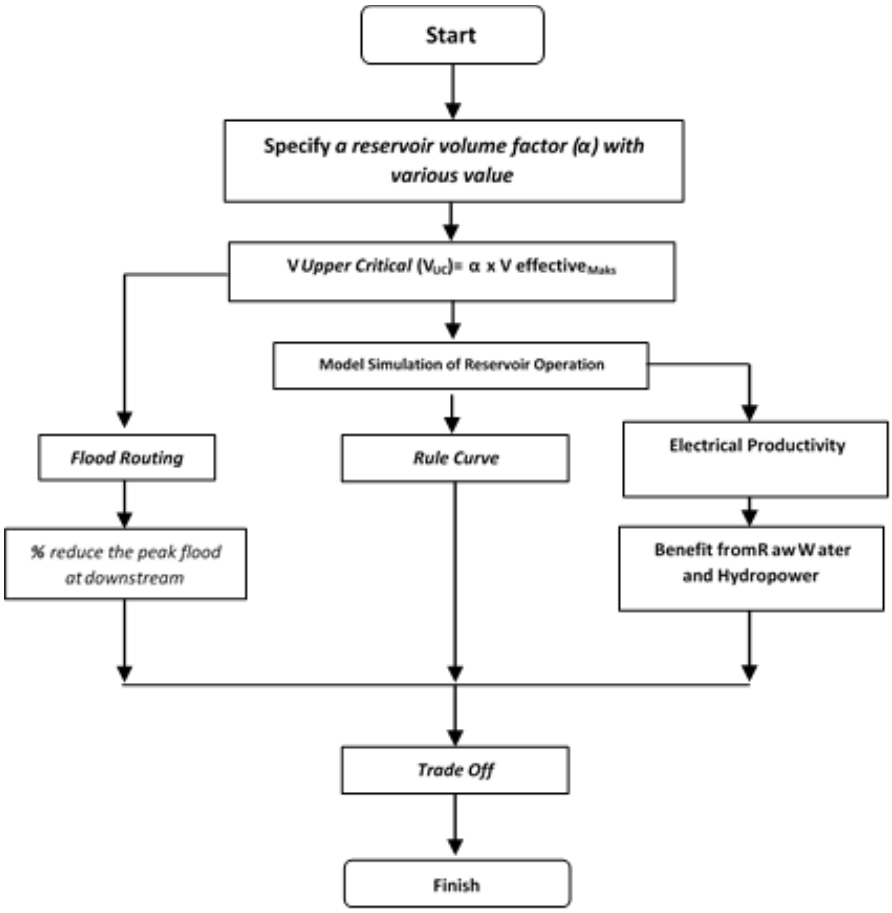

Fig. 2. Flowchart of Calculation.

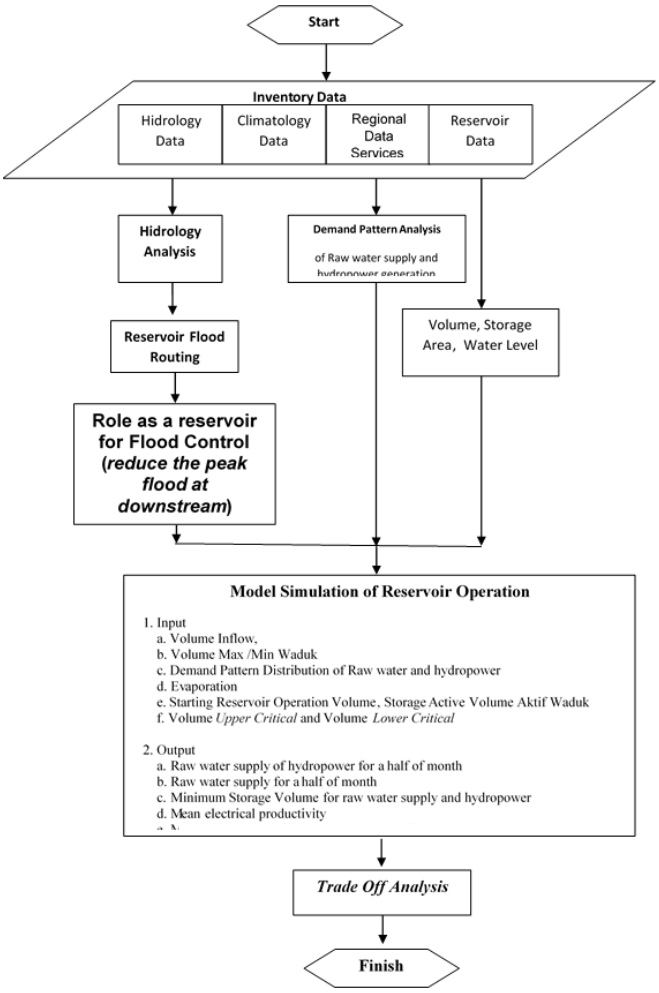

Fig. 3. Flowchart of Research.

4. Analysis

4.1. Hydrology Analysis

Hydrology analysis is performed to obtain the necessary design flood at Jatibarang Reservoir and to perform Reservoir Flood Routing. It is used to determine the discharge plan for each specific return period. In determining the map Garang catchment area it uses the result of previous study conducted by Bagus Adi Irawan (2015) who carried out Garang watershed map-making with the help of WMS software v.8.1 with topographical data input and outlet of the catchment is predetermined.

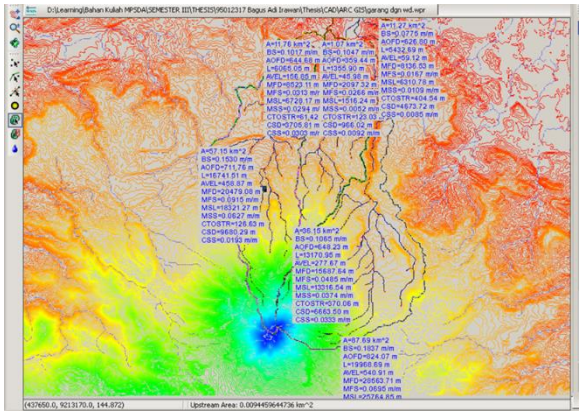

Fig. 4. Map and Parameter of Garang catchment area (Source: Bagus Adi I, 2015).

In the analysis of hydrological, rainfall data series is first tested for homogeneity and consistency test. Further analysis of the areal rainfall area can then be performed. So it can be continued on the preparation of the frequency distribution.

The analysis of the frequency of rainfall in order to obtain the design rainfall using common frequency distribution, such as Gumbel, Normal, Log Normal, Pearson, and Log Pearson type III. In frequency analysis, test on possible probability distribution is also conducted to test whether the distribution of frequencies can be used for further analysis or not. When it passes the test, the analysis can be continued in the calculation of design rainfall intensity.

For calibration purpose of the design flood, observation of river discharges from AWLR at Simongan Weir from the period of 1990-2011 are used. The data is used to perform the calibration of parameters of flood design discharge. From the data obtained one can get river flood hydrograph at Kreo which act as an inflow discharge to reservoirs. This flood inflow will be routed through the reservoir to obtained peak discharge flowing out of the reservoir.

Table 1. Result of Calculation Flood Routing with Q_{100} Years.

Time (Hours)	Inflow (m^3/sec)	Inflow (m^3/hour)	ΔStorage (m^3)	H (m)	ΔH (m)	Outflow (m^3/sec)	Outflow (m^3/hours)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
0,00	0,00	-	17.663.406,41	149,29	0,39	13,770	49.572,37
1,00	0,00	-	17.613.834,04	149,24	0,34	10,947	39.410,01
2,00	1,69	6.048,19	17.580.508,22	149,20	0,30	9,398	33.832,56
3,00	10,85	39.077,33	17.585.752,98	149,21	0,31	9,637	34.691,77
4,00	50,72	182.575,03	17.733.636,25	149,35	0,45	17,113	61.608,48
5,00	135,52	487.876,75	18.159.904,52	149,77	0,87	45,157	162.563,68
6,00	256,17	922.204,50	18.919.545,33	150,49	1,59	112,262	404.142,04
7,00	377,18	1.357.839,58	19.873.242,87	151,38	2,48	218,458	786.449,72
8,00	447,83	1.612.191,06	20.698.984,21	152,13	3,23	315,501	1.135.804,78
9,00	454,68	1.636.847,08	21.200.026,51	152,58	3,68	383,546	1.380.767,33
10,00	408,82	1.471.741,68	21.291.000,87	152,66	3,76	396,280	1.426.607,44
11,00	340,22	1.224.784,11	21.089.177,55	152,48	3,58	368,184	1.325.462,02
12,00	267,79	964.059,99	20.727.775,52	152,16	3,26	319,312	1.149.522,01
13,00	208,19	749.490,31	20.327.743,82	151,80	2,90	275,698	992.511,96
14,00	161,09	579.938,28	19.915.170,14	151,42	2,52	223,577	804.876,97
15,00	123,29	443.827,41	19.554.120,58	151,08	2,18	180,657	650.364,76
16,00	94,17	339.007,35	19.242.763,17	150,79	1,89	145,892	525.209,61
17,00	70,99	255.580,17	18.973.133,73	150,54	1,64	117,652	423.545,88
18,00	54,48	196.111,65	18.745.699,50	150,33	1,43	95,319	343.147,43
19,00	42,29	152.234,85	18.554.786,93	150,15	1,25	77,727	279.818,26
20,00	33,20	119.537,23	18.394.505,89	149,99	1,09	63,848	229.853,54
21,00	25,67	92.416,49	18.257.068,83	149,86	0,96	52,651	189.542,11
22,00	19,17	69.018,75	18.136.545,48	149,74	0,84	43,410	156.275,94
23,00	15,17	54.615,37	18.034.884,91	149,65	0,75	36,070	129.851,30
24,00	11,69	42.082,01	17.947.115,62	149,56	0,66	30,093	108.333,13
454,68						396,28	

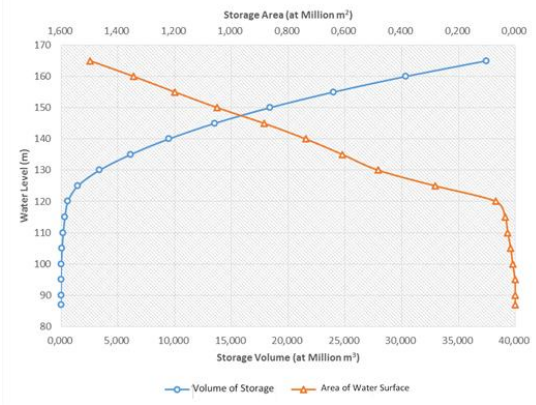

Fig. 5. The relationship between volume and area of reservoir.

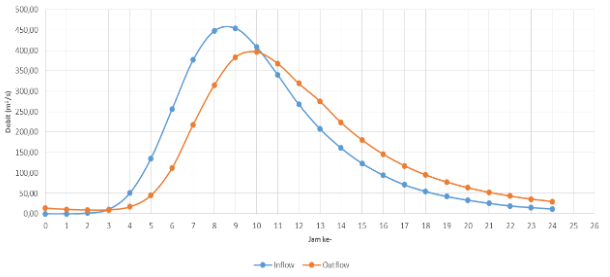

Fig. 6. Flood routing with Q_{100} years.

The result of flood routing (reservoir routing) for 100 years design discharge, it can be concluded that a reduction in flood peak discharge that occurs in the presence Jatibarang Reservoir, approximately 58.40 m^3/s or reduction of flooding is about 12.84%.

4.2. Simulation Model of Reservoir Operation

The formulation of reservoir operations model simulations by calculating the reservoir operation based on meeting needs in accordance with the reservoir as a function of flood control and water supply and electricity. In the simulation model of reservoir operations accounted for only evaporation loss, meanwhile for percolation and seepage are ignored. Evaporation occurs in the reservoir is influence by the area of reservoir inundation. The simulation and optimization model using Microsoft Excel software. Several factors are taken into account in the simulation such as an initial volume of reservoir, inflow discharge, evaporation loss, reservoir volume, and water demands for environmental flow, for raw water supply of drinking water, and for hydropower generation. Some of the conditions that exist in the calculation of the simulation is also to maximize the function of reservoir in flood control by lowering the maximum effective reservoir volume during the second half of the month of December until the first half of the month of February every year simulation period. So we will get an additional volume of flood control to reduce the risk of downstream flooding. In order to control the flooding ofthe reservoir while also meeting the water requirements it needs to conduct a trade off analysis.

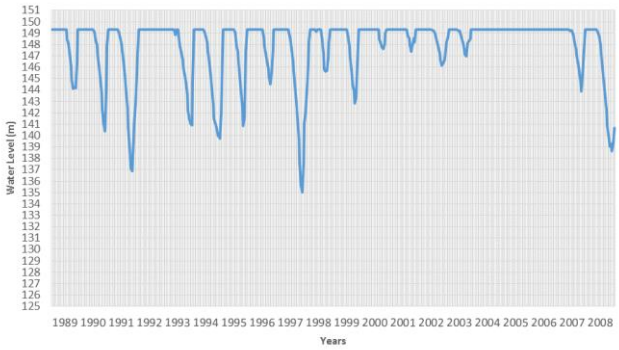

Fig. 7. Water Level Fluctuation Results from the Operations Reservoir Simulation Model Jatibarang in 1989-2008.

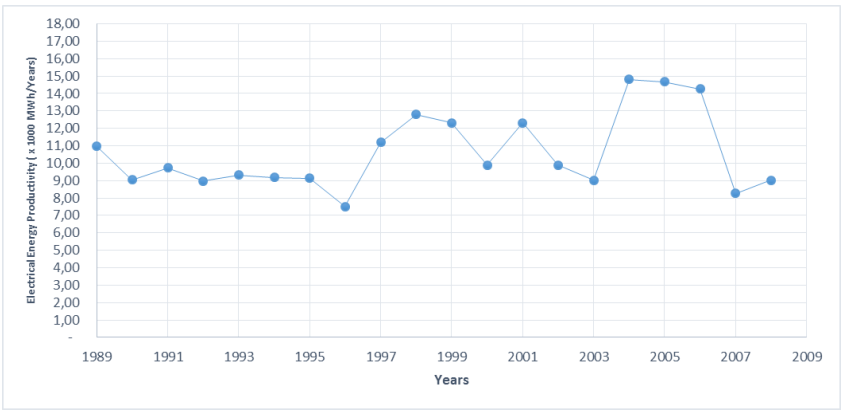

Fig. 8. Production of Electrical Energy produced from Jatibarang Reservoir Operation in 1989-2008.

4.3. Trade Off Analysis of Reservoir Operation

The calculation is performed on all year, from 1989 through 2008, the simulation is done with the assumption that the reservoir is at full condition or the effective volume maximum reservoir flood control still function can be maximized by providing extra volume in anticipation of flooding, namely by lowering the volume effective maximum inundation during the second half of the month of December until the first half of the month of February every year simulation period. After that, during the second half of February until the first half of the month of December, the reservoir is operated normally. So we will get an additional volume of flood control to reduce the risk of flooding. If from the reservoir simulation can still operate normally to meet the needs of drinking water and power generation and still can be optimized for flood control further. The simulation is done to find the best reservoir volume factor (α). With restrictions, the water level at the beginning of the period is equal to the height at the end of the period, the discharge can flow through the pipe-making for power generation is 4 m^3/s, the discharge minimum maintenance that should come out of the reservoir at any moment is constant, the discharge decision for drinking water is a constant in each period.

Stages of computation performed the same as in the calculation of reservoir operation of Jatibarang reservoir in 10 years (1989-2008). A trade-off between the benefit of reservoir as flood control and the benefit for raw water supply and hydropower generation is done by calculating peak flood reduction or preventing property damages, and benefit of water provided for raw water supply and hydropower generation. If the α is small, it means that maximum reservoir volume during peak wet season is limited, and volume of water provided for raw water supply and hydropower generation may be impacted as well as the benefit from them. On the other hand, small number of reservoir volume factor (α) will provide more volume space in the reservoir for flood water, and resulting more reduction of peak flood that flows to downstream (i.e., Semarang city area). By varying the value for reservoir volume factor (α), one can find the best reservoir operation.

Table 2. Results Flood Routing with various values α.

α	Peak Inflow Discharge	Peak Outflow Discharge	Reduction of Peak Flood Discharge		Time Lag
%	m^3/s	m^3/s	m^3/s	%	Hours
100	454.68	396.28	58.40	12.844	1.5
95	454.68	392.87	61.81	13.594	1.5
90	454.68	385.85	68.83	15.138	1.5
85	454.68	375.90	78.78	17.327	1.5
80	454.68	362.67	92.01	20.237	1.75
75	454.68	345.86	108.82	23.934	2
70	454.68	332.56	122.12	26.858	2
65	454.68	318.36	136.32	29.981	2.5
60	454.68	301.66	153.02	33.655	2.75
55	454.68	281.44	173.24	38.102	3
50	454.68	260.88	193.80	42.624	3

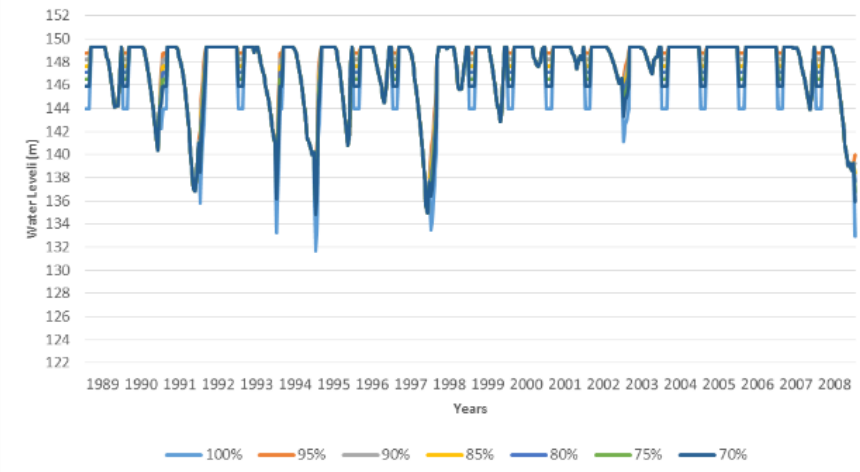

Fig. 9. Result of trade off analysis of reservoir simulation model with various value of α : 100%, 95% , 90%, 85%, 80% , 75%, and 70% based on the elevation of water surface reservoir.

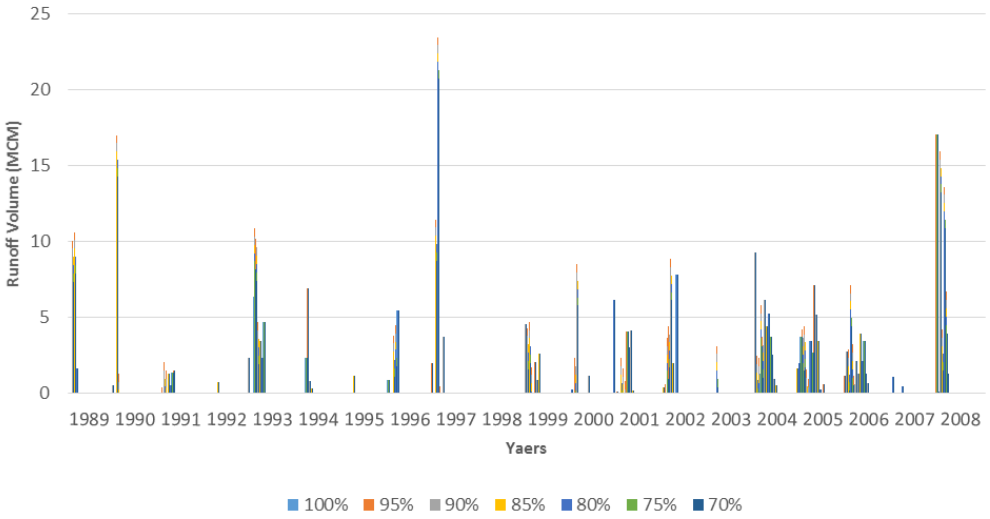

Fig. 10. Variation discharge through spillway from the result of trade off analysis from simulation model for reservoir operation with various value of α 100%, 95%, 90%, 85%, 80% , 75%, and 70%.

Based on Fig. 10 show variations in the volume of runoff through the spillway Simulation results analysis models Trade Off on the operation of the reservoir with varying α value of 100%, 95%, 90%, 85%, 80%, 75% and 70%. It can be concluded that by taking a critical upper volume variation which is the multiplication of the factor scores for the anticipated flood inundation volume (α) with a maximum effective volume puddle result the decrease of the volume of water passing through spillway. With reduced flow passing through the spillway indicates that with the use of critical upper volume variation can reduce flood discharge passing through spillway and reservoir function as flood control to be optimum.

If Simulation Model of Reservoir Operation has done, the next step of calculation is the preparation of Rule Curve reservoirs based Trade off Model Analysis Simulation on the operation of the reservoir with a value of α vary 100%, 95%, 90%, 85%, 80%, 75%, 70% , 65%, 60%, 55% and 50%. And the results compared with the Rule Curve of Standard Operation Procedure (SOP) has been prepared adapted to Reservoir Operation Model Simulation has done the calculations. And the results of this study note that the Rule Curve of Standard Operation Procedure (SOP) has been prepared after the Simulation Model of Operation Reservoir has a value of volume factor puddle in anticipation of flooding (α) is 53.69%, whose graph lies between the value of the volume factor puddle to anticipation of flooding (α) 50% - 55%. It can be seen in Fig. 13.

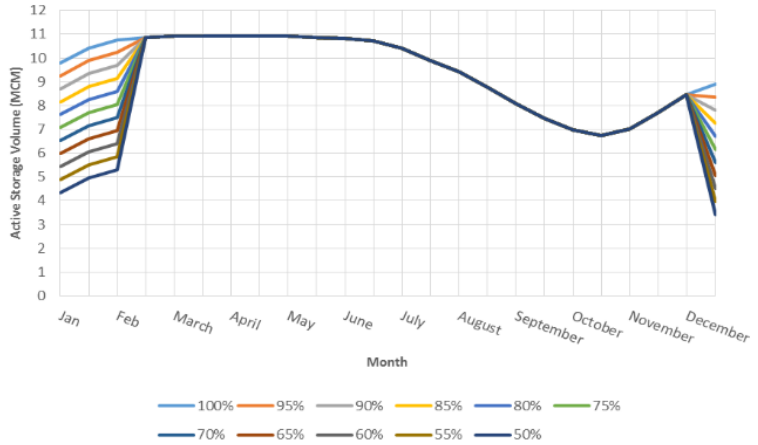

Fig. 11. Rule Curve Simulation Model of Trade Off Analysis with various value α 100%, 95% , 90%, 85%, 80% , 75%, 70%, 65%, 60%, 55%, 50% and Standart Operation and Procedure (SOP).

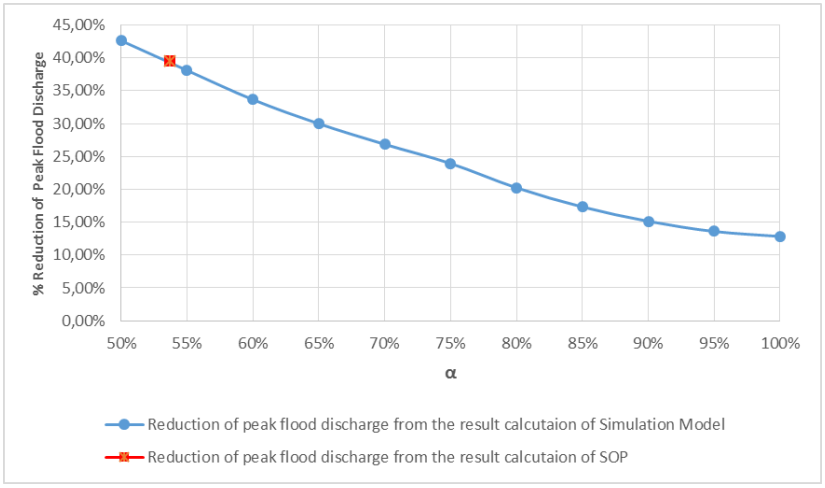

Fig. 12. Reduction of peak flood discharge from the result calculation of Simulation Model of Trade Off Analysis with various value α , 100%, 95% , 90%, 85%, 80% , 75%, 70%, 65%, 60%, 55%, 50% and Standard Operation and Procedure (SOP).

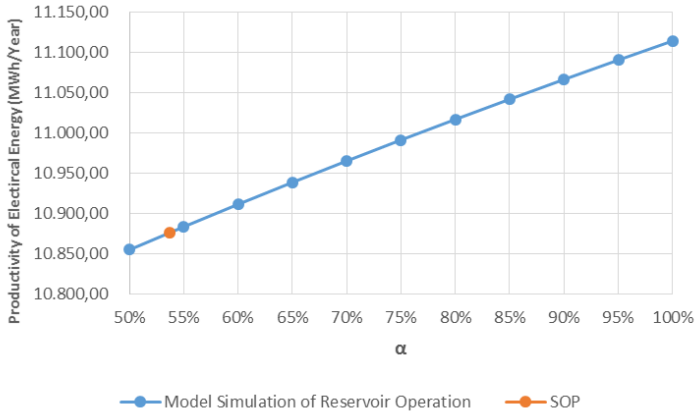

Fig. 13. Electrical Energy Productivity from the result calculation of Simulation Model of Trade Off Analysis with various value α , 100%, 95% , 90%, 85%, 80% , 75%, 70%, 65%, 60%, 55%, 50% and Standard Operation and Procedure (SOP).

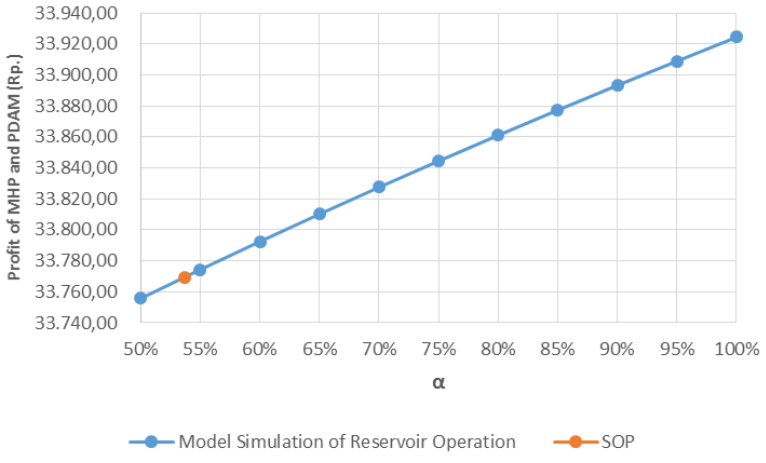

Fig. 14. Profit of MHP and PDAM from the result calculation of Simulation Model of Trade Off Analysis with various value α , 100%, 95% , 90%, 85%, 80% , 75%, 70%, 65%, 60%, 55%, 50% and Standard Operation and Procedure (SOP).

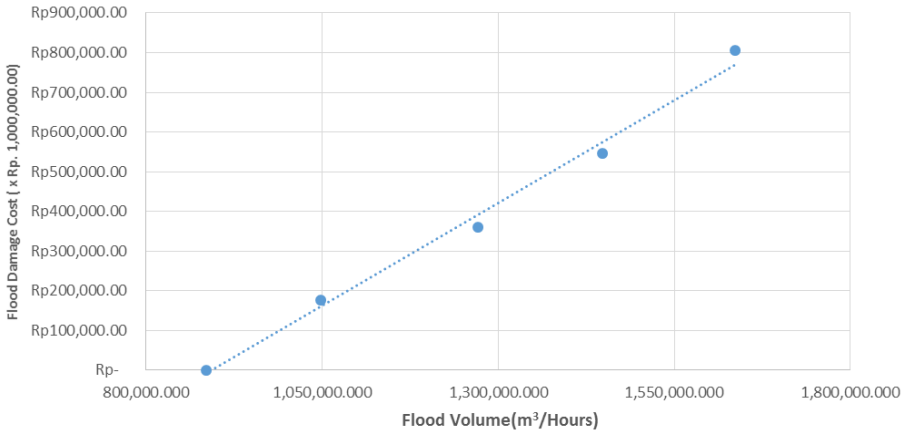

Fig. 15. Calculation of Flood Costs.

Table 3. Comparative Advantages of MHP and PDAM with Reduced Losses from floods.

α (%)	Advantage of MHP and PDAM (Rp.)	Reduced Losses from floods (Rp.)
100	33.924.374.187,21	60.958.738.978,93
95	33.908.964.616,23	73.706.273.144,25
90	33.893.284.894,68	99.939.458.735,55
85	33.877.318.398,45	137.137.057.652,60
80	33.861.046.958,59	186.579.699.924,06
75	33.844.450.776,90	249.391.445.005,48
70	33.827.508.341,47	299.087.983.675,13
65	33.810.196.342,08	352.155.459.130,89
60	33.792.489.585,53	414.584.498.630,88
55	33.774.360.910,91	490.150.794.870,84
50	33.755.781.104,72	566.987.058.551,10

Based on Table 3, the result of trade off analysis can be seen that the decreasing elevation allowed during peak wet season, or at the same word increasing the allocation for flood control, then the risk of flooding downstream is getting smaller as indicated by the decrease the flood peak discharge passing through spillway and resulting in an increase in the reduction of flood peak discharge. So from the trade off analysis it can be concluded that with the reduction in the allowed water level elevation of reservoir in order to increase the value of the reduction of flood peak discharge must sacrifice by reducing profits incurred from generating electrical power and water services. However, when compared to the profit of sales of drinking water supply and electricity, then its functions as a flood control reservoir is more profitable compared to function as a reservoir for drinking water supply and hydropower generation.

5. Conclusion

Based on the analysis and calculation, it can be concluded:

- Reservoir Jatibarang can contribute to reduce the 100-year peak flood discharge as much as 12.84% or 58.40 m^3/s with the normal reservoir operation.
- Introducing a reservoir volume factor (α) that varies 100% to 50%, a trade-off between reservoir function as flood control (reducing the peak flood) and as a storage water to provide raw water supply and hydropower generation are determined. The range is 12.58% to 42.62% of peak flood reduction for number of α from 100% to 50%.
- Considering property damages caused by flood in Semarang City area, however, the benefit of reservoir function as flood control surpassed the benefit obtained from water supply and hydropower generation.

References

Buras, N., 1975. Scientific Allocation of Water Resources, 2nd Edition, American Elsevier Publishing Company, Inc, New York.
Chow, Ven Te, and David R. Maidment, Larry W. Mays, 1988. Applied Hydrology, McGraw-Hill Book Company, Inc., Singapore.
De Neufville, R., 1990. Applied Systems Analysis Engineering Planning and Technology Management, McGraw-Hill Publishing Company, USA.
Departemen Pekerjaan Umum, 1993. Keputusan Menteri Pekerjaan Umum No. 98 Tahun 1993 tentang Organisasi Keamanan Bendungan.
Garg, S. K., 1982. Water Resources and Hydrology, Khanna Publishers, 2-B, Nath Market, Nai Sarak, Delhi.

H.K. Barrows, S. B., 1943. Water Power Engineering, McGraw-Hill Book Company, Inc., New York.
Hadihardaja, I.K., Fontane, D.G., Albertson, M.L, 2001. Trade Off Analysis of Reservoir Sediment-Control Modelling, Jurnal Telnik Sipil, Vol.8 No.3 Juli 2001, Institut Teknologi Bandung, Bandung, pp. 123-133.
Huang, W. C., 1997. Decision Support for Reservoir Operation, Water Resources Bulletin, Vol.32, No.6.
Sekretariat Negara, 2010. Peraturan Pemerintah Republik Indonesia No. 37 Tahun 2010 tentang Bendungan.
Venugopal, K., and Komarudin, I., 1991. ”Optimal Allocation of Citarum River Basin System”, Enviromental Hydraulic, Lee & Cheung (eds), 1991 Balkema, Rotterdam.
William P. Creager and Joel D. Justin., 1950. Hydroelectric Handbook, John Wiley &sons, Inc., New York.
Winston, W. L., 1987. Operation Research : Application and Algorithms, PWS-KENT Publishing Company, Boston.
Wurbs, Ralph A., 1996. Modelling and Analysis of Reservoir System Operation, Prentice Hall-USA.

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

The 3rd SCESCM

Special Topics in Public Works Research and Technology

Estimation of road network performance of Surakarta City

Syafi'i[a,*] , Slamet Jauhari Legowo[b] , Fika Zusanti[c]

[a]*Lecturer, Postgraduate Progam of Civil Engineering, Sebelas Maret University, Jl. Ir. Sutami No. 36 A, Surakarta, 57126, Indonesia*
[b]*Lecturer, Department of Civil Engineering, Sebelas Maret University,Jl. Ir. Sutami No. 36 A, Surakarta, 57126, Indonesia*
[c]*Student, Department of Civil Engineering, Sebelas Maret University, Jl. Ir. Sutami No. 36 A, Surakarta, 57126, Indonesia*

Abstract

There are some problems of urban transportation, two major problem i.e., congestion and accidents. Transportation planning is needed to anticipate/reduce the possibility of congestion in the future. One of indicator of road network performance is volume per capacity ratio (V/C) representing level of congestion. The aims of the study is to know road network performance represented by V/C on each link in 2035. Case study of this research is Surakarta City. Zoning system is based on administrative boundary. There are 65 zones consisting of 51 internal zones and 14 external zone. Traffic count data at 30 locations (point) is collected from survey the morning peak hours. EMME/3 software was used in calculating of OD matrix and trip assignment process. Before estimating OD matrix Surakarta city in 2035, we estimate OD matrix 2016 by traffic count data using the approach of Matrix Estimation by Maximum-Entropy (ME2). Estimation of the value of the parameter β which is a deterence function parameter on gravity models using the Newton-Raphson calibration methods with the help of Matlab software. Validity test of parameter β was done using coefficient of determination (R2). The scenario used is do-nothing i.e., assuming no changes in the road network. The result show that total trip of OD Matrix in the morning peak hour in 2035 is estimated 77520 pcu/hour, almost double that of 2016. The value of V/C in 2035 show that the road/link with stable condition (V/C< 0.8) is 80.2%, an unstable condition (0.8 <V/C <1.0) of 11.5%, and the critical condition (V/C>1) of 8, 3%.

Keywords: Road nework performance; Surakarta City; OD Matrix

1. Introduction

Problem of Urban transportation become more complex in line with rapid growth of vehicle that is not matched by proportionally increase in transportation infrastructure. There are some problems of urban transportation, two major problem i.e., congestion and accidents. Congestion contributes on the health of human being due to air pollution and also give significant impact on social / economic cost. Finally, productivity and economic growth will decline in line with increasing of congestion. Some efforts has been done to reduce congestion, either by implementing traffic management or increasing the road network capacity through widening highway, building flyover/underpass. However, the above efforts usually are done when severe congestion already occurred in the road network. Therefore, transportation planning is needed to reduce the possibility of congestion in the future.

Four steps model (FSM) is usually used in transport planning. Even though FSM is static model, till now it is still widely used to estimate the future condition of transport system. FSM consist of four steps, i.e., trip generation, trip distribution, modal choice, and trip assignment. Trip generation is a step to estimate number of trip produced from origin zone i or attracted to destination *zone d*. Trip distribution estimates number of trip movement from origin zone *i* to destination zone *d* (T_{ij}) represented by origin-destination (OD) matrix or desired line. Proportion of usage of one mode compared to the others mode is handled by modal choice step. Finally, assigning OD matrix to the road network called by trip assignment is a step to estimate on how road user's choice their route from origin zone *i* to destination zone *j*. The result of this final step we can know number of traffic volume (V) on each link. So if we know the capacity (C) of each link in the road network, we can estimate ratio of traffic volume per capacity (V/C) which representing level of congestion.

Two steps of FSM are needed to find V/C. .i.e., trip distribution (OD Matrix), and trip assignment. The aims of the study is to know road network performance represented by V/C on each link in 2035. Case study of this research is Surakarta City.

* Corresponding author. Tel.: +62-81329120988; fax: +62-271-634524
E-mail address: syafii@uns.ac.id

Knowing V/C on the network we can determine the development strategy of transportation system (including development of infrastructure). The study is limited only for do-nothing scenario.

2. Literature Review

The basic problem of OD matrix estimation by traffic count is to identify origin-destination pair using specific link as part of their travel, this variabel called P_{ij}^{a}, namely trip proportion from origin *i* to destination *j* travelling through link *a*. So, flow on link a is the summation of traffic flow contribution from each zone pair. Mathematically, it can be stated as follows.

$$V_a = \sum_{ij} T_{ij} P_{ija} \; ; \quad 0 \le P_{ija} \le 1 \tag{1}$$

The above equation model (1) will provide perfect result if flow on link a from model equal to observation.

$$W_a = V_a = \sum_{ij} T_{ij} P_{ija} \tag{2}$$

where:
T_{ij} = trip from zone *i* to zone *j*
P_{ija} = trip proportion from *i* to *j* travelling through link *a*
V_a = flow on link *a* from model
W_a = flow on link *a* from observation

In practice, traffic data from observation is far less than number of T_{ij} known. With this condition, it is impossible to find the unique solution of matrix estimation problem. Therefore, most of the metode try to find the most likely of trip matrix T_{ij} that fulfill the above equation. Van Zuylen, et al (1980) proposed two approach to solve equation (2). First, if there is no prior trip matrix; second if there is a prior trip matrix. This two approaches can be stated as mathematic formulation as follow.

$$T_{ij} = \prod_a X_a^{P_{ij}^a} \quad \textit{and} \quad T_{ij} = t_{ij} \prod_a X_a^{P_{ij}^a} \tag{3}$$

where t_{ij} is prior matrix estimation, whereas X_a is balancing factor which is selected as such a way so fulfill the constraint of equation (2). A set of all possibility of trip matrix that fulfill the constraint is known by "*set of feasible solution*". A specific characteristic of *set of feasible solution* is "*convex set*" namely if matrix R_{ij} and S_{ij} both is feasible, then each linear combination of R_{ij} and S_{ij} (i.e., $T_{ij} = x\, R_{ij} + (1-x)\, S_{ij}$) is also feasible with constraint $0< x < 1$.

Robillard (1975) classified trip assignment method to estimate trip matrix from traffic count into two groups: proportional and non-proportional assignment. Proportional assignment method assume that proportion of route choice is not depend on number of flow. All-or-nothing and pure stochastic assignment methods are included in this group. Whereas non-proportional assignment method expicitly consider effect of congestion, therefore proportion of route choice is depend on flow on corresponding link. Equilibrium and stochastic user equilibrium assignment method are included into this group. Non-proportional assignment technique is assumed more realistic for congested road network.

The objective function of matrix estimation consist of two type, first, traffic flow from model is close to flow from model; second, search matrix solution which is close to prior matrix. Related to this objective function, some methods that has been developed can be classified as follow.

- Entropy maximization model (Wilson (1970), Willumsen (1978), Bell (1983), and Brenninger-Gothe et al (1989). The objective function of this approach mathematically can be expressed as:

$$\underset{v,T}{Minimize} \quad \gamma_1 \sum_{ij} T_{ij} \left(\ln \frac{T_{ij}}{\overline{T}_{ij}} - 1 + \ln \overline{T} \right) + \gamma_2 \sum_{a \in A} v_a \left(\ln \frac{v_a}{\overline{v}_a} - 1 \right) \tag{4}$$

where γ is Lagrangian multiplier related to the constraint (traffic flow), $\overline{T} = (\overline{T}_{ij})$ is target of OD matrix.

- Information minimization model, this model is almost the same with point (a). OD matrix distribution on this model is adjusted to the information from trip distribution on each link in the network (Van Zuylen and Willumsen, 1980).
- Statistical approach. The model accomodates error and/or uncertainty on avaibility of information. The model also consider probability of traffic count. In this approach some models have been developed. Pursula and Pastinen (1993) proposed Bayesian inference method where OD matrix element assumed distributed multivariate normally.

Maher, et.al (2001) and Yang, et al (2001) try to combine between matrix estimation and optimisation of traffic light on congested network in the form of bi-level programming with stochastic user equilibirum (SUE) assignment as second-level programming. The developed model show convergent result. The drawback of this method lies in the use of Logit assignment that does not consider the cross-correlated.

Another method which seeks to take into consideration traffic conditions and can be applied on a large road network was proposed by Stathopoulus, et al (2003). Nie, et al (2005) developed estimates of OD matrix by inserting estimator variable of current path in the road network through the method of generalized least squares (GLS). This approach seeks to solve GLS to minimize errors in the traffic count from observations and OD matrix based on equilibrium assignment. However, the proposed model has the disadvantage that model produces good results when applied to the road network that is not too large. This model also does not consider trip production-attraction constraint. Mathematically, objective function of GLS method is stated as follows.

$$\underset{v,T}{Minimize} \quad \left(\overline{T}_{ij} - T_{ij}\right)^t U^{-1}\left(\overline{T}_{ij} - T_{ij}\right) + \left(\bar{v}_a - v_a\right)^t V^{-1}\left(\bar{v}_a - v_a\right) \tag{5}$$

In this study we use entropy-maximisation approach to estimate parameter of gravity model. Theoritically, entropy-maximisation approach try to find information from all micro states with the same probability and also consistent with information from macro states. Wilson (1970) stated that number of micro states $W\{Tid\}$ related to meso states T_{id} is as follow.

$$W[T_{id}] = \frac{T!}{\prod_i \prod_d T_{id}!} \tag{10}$$

Basic assumption of this approach is all micro states are equally likely, the most probable messo-state would be the one that can be generated in a greater number of ways. Therefore, what is needed is a technique to identify the values of *{Tij }* which maximise *W* in (10). For convenience we seek to maximise a monotonic function of *W*, namely log *W*, as both problems have the same maximum. Therefore:

$$\log_e W = \log_e \frac{T!}{\prod_i \prod_d T_{id}!} = \log_e T! - \sum_i \sum_d \log_e T_{id}! \tag{11}$$

By using *Stirling* approach $\log_e X! \approx X \log_e X - X$, the above equation can be simplified become:

$$\log_e W = \log_e T! - \sum_i \sum_d (\log_e T_{id} - T_{id}) \tag{12}$$

Due to **log*eTid*!** is a constant, so it can be deleted on the optimisation process. So, the above equation become entropy function**.**

$$\log_e W' = -\sum_i \sum_d (T_{id} \log_e T_{id} - T_{id}) \tag{13}$$

Mathematically, objective function of entropy-maximisation (EM) approach can be stated as follow:

$$Maximize \quad E_1 = \log_e W'' = -\sum_i \sum_d (T_{id} \log_e (T_{id} / \hat{T}_{id}) - T_{id} + \hat{T}_{id}) \tag{14}$$

3. Methodology

Case study of this study is Surakarta City located in the south part of Central Java. Zoning system is based on administrative boundary. There are 65 zones consisting of 51 internal zones (entire villages Surakarta) and 14 external zone (villages around outside Surakarta). Each zone is represented by a single center or a zone that can be referred to as centroid, which is then connected to one of the vertices of the road network (node) with the connector (centroid connector). The road network included in this study is arterial and collector road as shown in Fig. 1. Traffic count data at 30 locations (point) is collected from survey the morning peak hours (6:00 a.m. to 8:00). Beside primary survey, secondary survey is also conducted to find road network data and transportation system from government institution of Surakarta City.

EMME/3 software is used in calculating of OD matrix and trip assignment process. Some data are inputted to the network editor of EMM/3. i.e., mode, node, link, coordinate, link capacity, road width, lane type. Calculation of link capacity is based on Indonesian Highway Capacity Manual (IHCM). There are two mayor process in this study; first, estimation of OD matrix in

2035; second, assigning the OD matrix into the road network with do-nothing scenario. Before estimating OD matrix Surakarta city in 2035, we estimate OD matrix 2016 by traffic count data using the approach of Matrix Estimation by Maximum-Entropy (ME2). The next step is the estimation of the value of the parameter β which is a deterrence function parameter on gravity models using the Newton-Raphson calibration methods with the help of Matlab software. Validity test of parameter β is done using coefficient of determination (R2) which represent the comparison of traffic flow from observation (traffic count) and flow from model (using software EMME/3).

OD matrix in 2035 is obtained using gravity models with the parameter β obtained in the previous step. Number of trip at origin (O_i) and destination (D_j) in 2035 is calculated based on O_i and D_j in 2016 using growth factor. Final step is estimation of road network performance by assigning OD matrix in 2035 into the road network, known as trip assignment process with the help of software EMME/3. The scenario used is do-nothing i.e., assuming no changes in the road network. The end result of this process is that we can know the traffic flow in the future year (V). Assuming no change in capacity (C) on each link of the road network, we can obtained the value of V/C which is an indicator of the road network performance in 2035. The above steps is shown in Fig. 2.

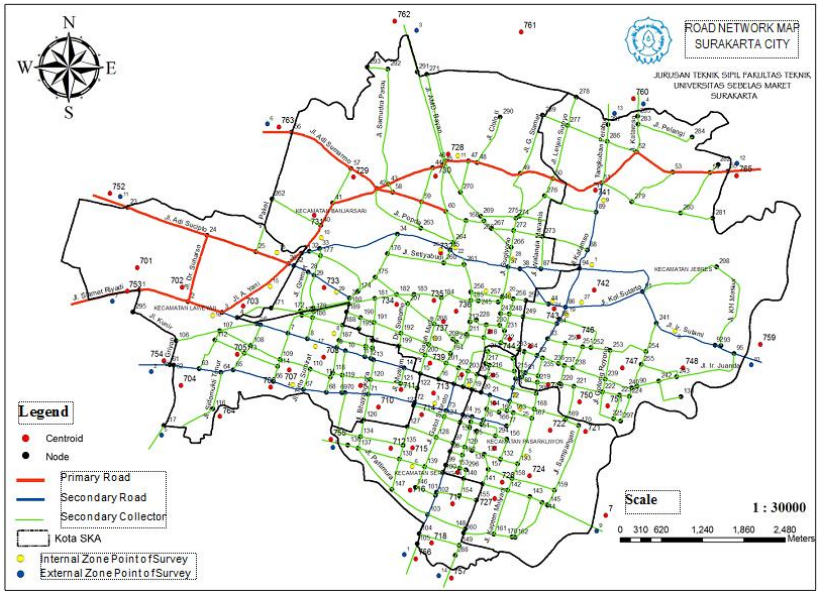

Fig.1. Road Network of Surakarta City.

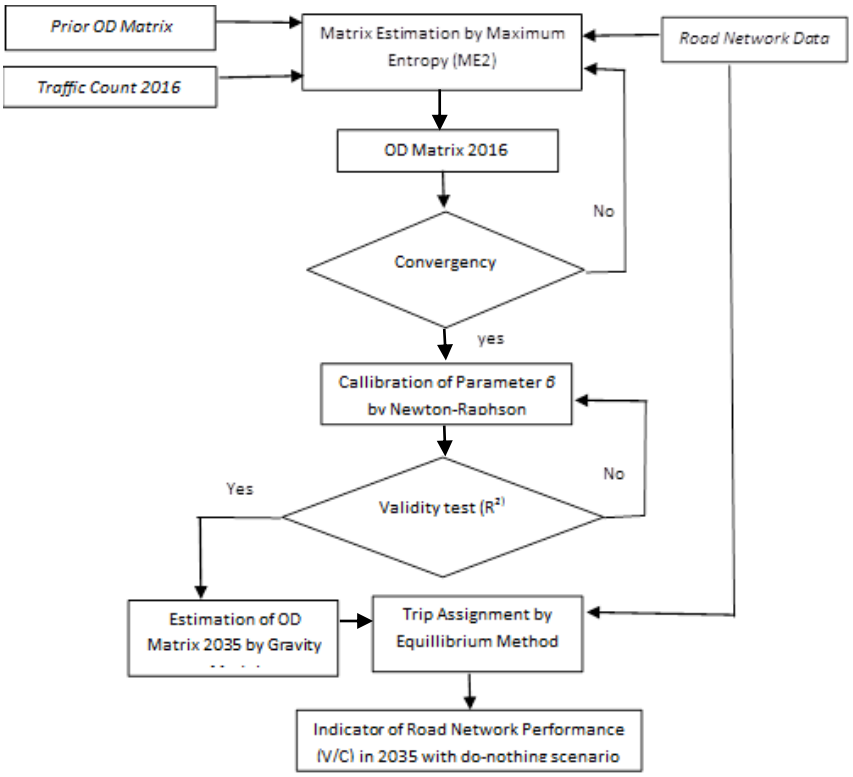

Fig. 2. Steps of the study.

4. Result and Discussion

4.1. OD Matrix Estimation of Surakarta City in 2035

The first step before estimating OD matrix Surakarta city in 2035 is estimation of OD matrix 2016 by traffic count data using the approach of Matrix Estimation by Maximum-Entropy (ME2). At this stage the data entered on softwrare EMME / 3 is the road network database, the traffic count data from observations, and prior matrix. From the calculations, the total OD matrix in 2016 is 41832 pcu/hour. The next step is the estimation of the value of the parameter β which is a deterence function parameter on gravity models using the Newton-Raphson calibration methods with the help of Matlab software. The parameter β obtained is 0.00084. Validity test of parameter β is done using coefficient of determination (R2) which represent the comparison of traffic flow from observation (traffic count) and flow from model (using software EMME/3). The results show the coefficient of determination (R2) of 0.8753 as shown in Figure 3. The value of the validity is classified in the category very high.

OD matrix in 2035 is obtained using gravity models with the parameter β. Results show total travel in the morning peak hour in 2035 is 77520 pcu/hour, almost double that of 2016. The trip distribution in 2035 can be represented in the form of desire line as shown in Figure 4. In this figure, the internal zone divided into four zones that represent the districts (aggregation of 51 villages). While the external zone is divided based on where the zones adjacent to each other, which is 4 points outside the city of Surakarta (aggregation of external zone 14). Thick lines in the figure indicate the large amount of travel movement between the zones.

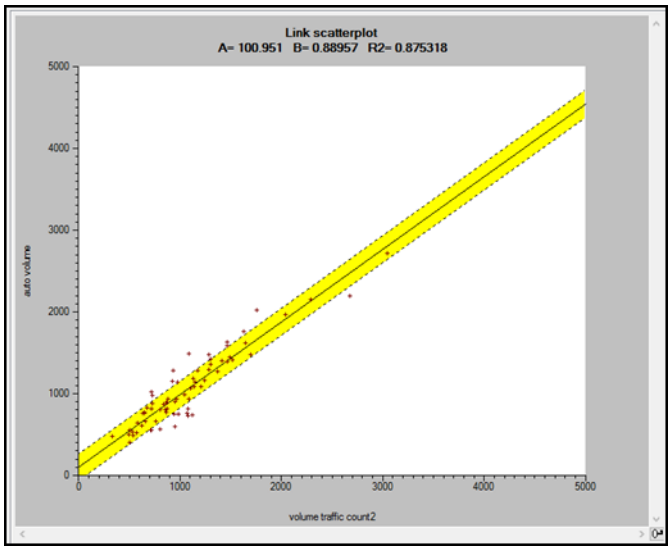

Fig. 3 Comparison between Traffic flow from Traffic Count and Model.

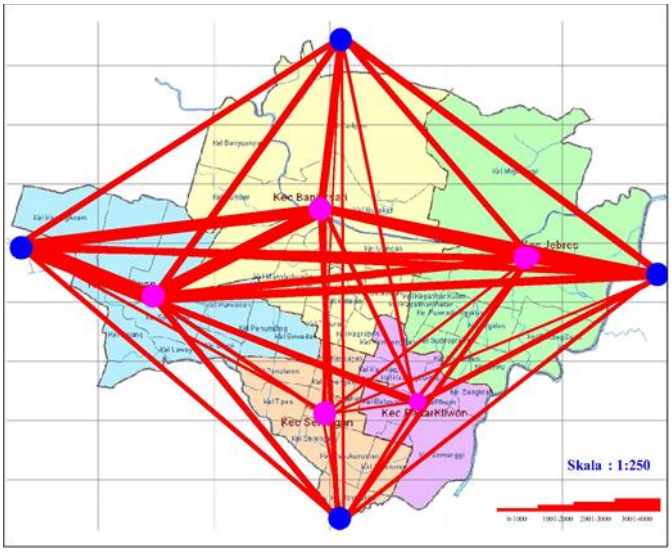

Fig. 4 Desire Line of Trip Distribution of Surakarta City in 2035.

Trip pattern of Surakarta City is dominated by external-internal trip of 36% (27966 pcu/hour) as shown in figure 5. This condition is match with current reality that most of trip movement from external of Surakarta City as commuter trip. Whereas internal-internal trip is 22.56% (17488 pcu/hour). External-external trips representing trips from outside Surakarta city that does not make Solo as the destination journey is relatively large i.e., 13% (10081 pcu/hour). Most of external-external trip mostly is dominated by freight vehicle (Truck, trailer, etc). This movement will give significant contribution on congestion. Building ring road on the north and south side of Surakarta City is needed to reduce the impact of external-external trip.

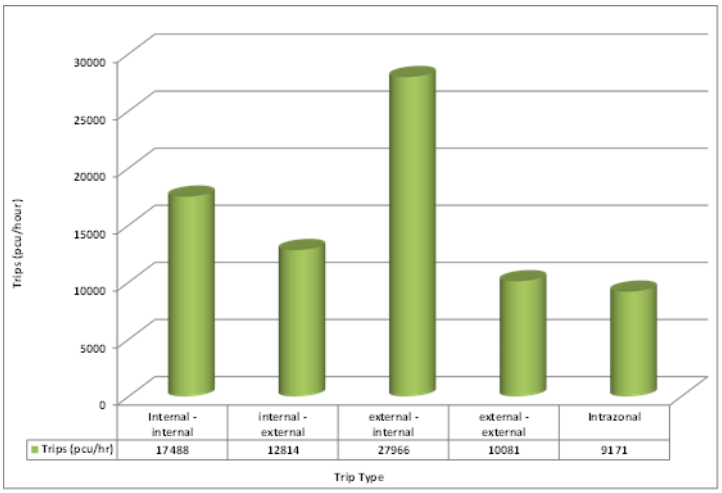

Fig. 5 Trips Type of Surakarta City in 2035

4.2. Road Network Performance of Surakarta City in 2035

Estimation of road network performance is done by assigning OD matrix in 2035 into the road network, known as trip assignment process with the help of software EMME / 3. The scenario used is do-nothing i.e., assuming no changes in the road network. The end result of this process is that we can know the traffic flow in the future year (V). Assuming no change in capacity (C) on each link of the road network, we can obtain the value of V/C which is an indicator of the road network performance in 2035 as shown in Figure 6. The figure shows that in 2035 roads that are still in the stable condition (V/C < 0.8) is 80.2%, an unstable condition (0.8 < V/C <1.0) of 11.5%, and the critical condition (V/C > 1) of 8.3%. The high percentage of the road network in an unstable and critical condition (19.6%) in 2035 can be used as guidelines for government of Surakarta City to anticipate in order to reduce the level of congestion. Some efforts to address the transport system can be done either with traffic management or constructing/enhancement of existing infrastructure. Efforts to address this congestion can be used as the government's work program each year, so that congestion predicted to occur in 2035 can be reduced.

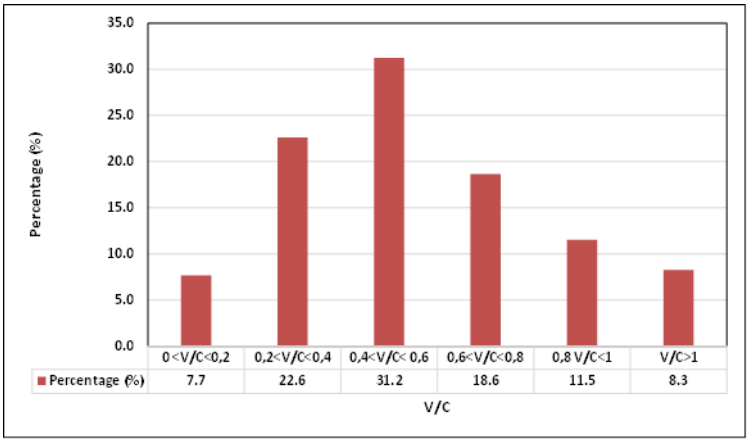

Fig. 6 Road Network Performance (V/C) of Surakarta City in 2035.

5. Conclusion

In 2035, total trip of OD Matrix in the morning peak hour in 2035 is estimated 77520 pcu/hour, almost double that of 2016. Trip pattern of Surakarta City is dominated by external-internal trip of 36% (27966 pcu/hour). Whereas internal-internal trip is 22.56% (17488 pcu/hour). External-external trips representing trips from outside Surakarta city that does not make Solo as the destination journey is relatively large i.e., 13% (10081 pcu/hour).

The value of V/C which is an indicator of the road network performance in 2035 show that the road/link with stable condition (V/C < 0.8) is 80.2%, an unstable condition (0.8 < V/C <1.0) of 11.5%, and the critical condition (V/C > 1) of 8.3%. The high percentage of the road network in an unstable and critical condition (19.6%) in 2035 can be used as guidelines for government of Surakarta City to anticipate in order to reduce the level of congestion. Some efforts to address the transport system can be done either with traffic management or constructing/enhancement of existing infrastructure. Building ring road on the north and south side of Surakarta City is needed to reduce the impact of external-external trip. Efforts to address this congestion can be used as the government's work program each year, so that congestion predicted to occur in 2035 can be reduced.

References

Bell, M.G.H. 1983. The Estimation of an origin-destination matrix from traffic counts. *Transportation Science* 17 (2), 198-217.

Brenninger-Gothe, M., Jornsten, K.O., Lundrgen, J.T. 1989. Estimation of origin-destination matrices from traffic counts using multi objectives programming formulation. *Transportation Research* 23B (4), 257-269

Maher, M.J., Zhang, X. Van Vliet, D. 2001. A bi-level programming approach for trip matrix estimation and traffic control problem with stochastic user equilibrium link flows. *Transportation Research* 35B (1), 23-40.

Nie, Y., Zhang, H.M., Recker, W.W 2005. Inferring origin–destination trip matrices with decoupled GLS path flow estimator. Transportation Research Part B 39. pp. 497–518.

Nie, Y., Zhang, H.M., Recker, W.W 2005. Inferring origin–destination trip matrices with decoupled GLS path flow estimator. Transportation Research Part B 39. pp. 497–518.

Pursula, M., Pastinen, V. 1993. A Bayesian approach to update traffic flow from traffic counts. In: Daganzo, C.F. (Ed). *Transportation and Traffic Theory* Elsevier Science Publication B. V., pp. 507-522.

Robillard, P. 1975. Estimating the OD Matrix From Observed Link Volumes, *Transportation Research*, 9(2/3), 123-128.

Stathopoulus, A., Tsekeris, T. 2003. Framework for analysing reliability and information degradation of demand matrices in extended transport networks. Transport Review 23. No. 1, 89-103.

Van Zuylen, H., and Willumsen, L. 1980. The most likely trip matrix estimated from traffic counts, *Transportation Research* 14B, 281-283.

Willumsen, L.G. 1978. Estimation of O-D matrix from traffic count: a review. Working paper 99, Institute for Transport Studies, University of Leeds.

Wilson, A.G. 1970. Entropy in Urban and Regional Modelling. Poin, Ltd. London, England.

Yang, H., Meng, Q., Bell, M.G.H. 2001. Simultaneous estimation of the origin-destination matrices and travel cost coefficeint for congested networks in a stochastic user equilibrium. Transportation Science 35 (2), 107-123.

3rd International Conference on Sustainable Civil Engineering Structures and Construction Materials

The 3rd SCESCM

Special Topics in Public Works Research and Technology

Sustainability of human society based upon materials and energy cycle via water cycle

Masahiro Yoshimura (吉村昌弘)

Distinguished Chair Professor & Director,Promotion Center for Global Materials Research, Dept of Mater.,Sci. and Eng., National Cheng Kung University, Tainan,Taiwan: "http://pcgmr.mse.ncku.edu.tw/ :yoshimur@mail.ncku.edu.tw
Prof. Emeritus. Tokyo Institute of Technology, Japan :yoshimura@msl.titech.ac.jp

Abstract

As well as organic and/or bio- materials, advanced inorganic materials, most of metallurgical materials, semiconductors and ceramic materials have been used in wide area of applications like structural, mechanical, chemical, electrical, electronic, optical, photonic, biological, medical, etc. They have never been produced in natural processes via biological systems. Biological systems have been based upon water cycle and Solar energy, thus it is most adequet for Sustainability. However most of advanced materials have generally been fabricated artificially and/or industrially by so-called high-technology, where high temperature, high pressure, vacuum, molecule, atom, ion, plasma, etc. have been used for their fabrications. In particular semiconductor and ceramic materials are difficult in shape forming and fixing due to their intrinsic rigidity and brittleness. Even though nano-sized particles of such materials could be synthesized by low-energetic route, i.e. "soft chemistry" or "green chemistry", their shape forming and fixing cost energetically and environmentally. High-technology for the production/fabrication of such artificial advanced inorganic materials favors fast and large production where large amounts of resources and energies based upon fossil fuels. Fossil fuels have been produced from biological resources during millions-billions years on the Earth, thus they cannot recycle in our life time. We cannot allow to continue for even 50-100 years for such high-technology consuming large amount of energies based upon fossil fuels. Real environmental problems are based upon waste heats rather than CO2 itself. The most essential factor in environmental problems should be "How we can eliminate total energy consumption for the production of advanced materials?"

Considering the lowering of total energy consumption, we have challenged to fabricate those advanced inorganic materials with desired shape/size/location, etc. directly in low energetic routes using aqueous solutions since 1989 when we found a method to fabricate BaTiO3 film on Ti substrate in a Ba(OH)2 solution by Hydrothermal Electrochemical[HEC] method at low temperatures of 60-200 C. We proposed in 1995 an innovative concept and technology, "Soft Processing" or "Soft Solution Processing," which aims low energetic (=environmentally friendly) fabrication of shaped, sized, located, and oriented inorganic materials in/from solutions. It can be regarded as one of bio-inspired processing, green processing, or eco-processing.1,2)

When we have activated/stimulated interfacial reactions locally and/or moved the reaction point dynamically, we can get patterned ceramic films directly in solution without any firing, masking nor etching. They can be called Direct Patterning methods which differ from previous patterning methods consisting of multi-step processes. The notable feature of Direct Patterning is that each reactant reacts directly on site, at the interface with the substrate. Therefore, the chemical driving force of the reaction, A+B=AB, can be utilized not only for synthesis but also for crystallization and/or consolidation of the compound AB. It is rather contrasting to general patterning methods where thermal driving force of firing is mostly used for the consolidation of the particles.3)

We have developed the Direct Patterning of CdS, PbS and CaWO4 on papers by Ink-Jet Reaction method and LiCoO2 by electrochemically activated interfacial reactions. 3) Furthermore, we have succeeded to fabricate BaTiO3 patterns on Ti by a laser beam scanning and carbon patterns on Si by a needle electrode scanning directly in solutions. 4) Recent success in TiO2 and CeO2 patterns by Ink-Jet Deposition, where nano-particles are nucleated and grown successively on the surface of substrate thus become dense even below 300 C 3) will be presented. Nano-structured films will be also talked 4-6).A recent novel subject, Soft Processing for various nano-carbons including Graphene and functionalized Graphene, 7-9) will be introduced. Where we have succeeded to prepare functionalized Graphene Ink via successive processes under ambient temperature pressure conditions.

If I have a time, I will talk about [A] "How we can learn from literature then exceed it to create true originality in our research?" and [B] "Importance of writing in own notebook(s) to improve one's understanding for efficient study/research."

References

MRS Bulletin,25[9],Sept. issue 2000, special issue for Soft Processing of Advanced Inorganic Materials ,Guest Editor:M. Yoshimura and J. Livage.
Yoshimura, M., J. Mater. Sci.,41 [5],1299-1306 (2006), 43[7]2085-2103(2008).
Yoshimura, M. and Gallage R., Solid State Electrochem., 12[7/8]775-782(2008).
Watanabe,T., Yoshimura, M. ,Thin Solid Film, 515, 2696-2699 (2006), Carbon, 44, 799-802 (2006).

Wu, J-J., Liao, W-P., Yoshimura,M. Nano Energy,On-line July 11, 2013 .
M.Yoshimura,N.Sugiyama et al.,Mater. Sci. Eng. B,148 (2008)2-6, & Acta Biomaterialia,5(2009),1367-1373,Mater. Sci. Eng. B,161(2009),31-35.
J. Senthilnathan, M.Yoshimura et al., J. Mater Chem A, 2014, 2, 3332-3337 a Hot Paper 2014.
J. Senthilnathan, K. SanjeevaRao, M. Yoshimura, et al ., 2014, Scientific Reports 4, 0427 & 04395.
K. SanjeevaRao, J. Senthilnathan, M.Yoshimura,et al., 2015, Adv. Funct. Mater.,25, 298-305.