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INTERDEPENDENT PUBLIC INFRASTRUCTURES OPERATION AND MAINTENANCE COORDINATION: A SOFT SYSTEM BASED CONCEPTUAL MODEL

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Abstract

The existing road network in Indonesia is a public infrastructure system containing utility facilities, such as electricity, telecommunication, and water supply infrastructures in and adjacent to the public right of way. These public infrastructures are integrated and interdependent, meaning that these roads and facilities' operation and maintenance activities affect one another. These activities, when uncoordinated, can have a negative impact on or cause damage of the road and the facilities. However, the interaction is still unstructured and poorly defined because each stakeholder has a different assessment, business, schedule, technique, organization structure, and regulation. A qualitative approach has been conducted to collect information about problem situations in the public right of way in five cities and two districts in Indonesia. This paper aims to develop an interdependent public infrastructures operation and maintenance coordination conceptual model in the existing road system using the Soft System Methodology (SSM). SSM is currently the effective way to understand the problem situation of an unstructured system. This method provides a conceptual coordination model in a constructive manner that can help the authority to improve the problem situation.

Keywords: Conceptual model; Coordination; Interdependent Public Infrastructure; Soft System Methodology.

1. Introduction

The advancement of human civilization, the quality of life of the nation, and the economic strength of a country are reflected in its ownership of public infrastructures (Uddin et al., 2013). Therefore, the government provides and will ensure the sustainability and availability of public infrastructure for its community. However, public infrastructure damage threats potentially appear from various sources, among others, from the presence of other infrastructure and their interactions that occur at the operation and maintenance stage. Several infrastructures in one area are interconnected and interact with each other in several combinations of interactions such as physical, geographic, information systems, and logical interdependencies (Saidi et al., 2018). The operation and maintenance activities of existing roads in most of the cities in Indonesia interact with those of utility facilities such as clean water, electricity, and communication situated underground along the public right of way. All of these infrastructures will be interrelated and connected to each other in an integrated manner, and that is why they

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are called interdependent infrastructures. According to Rinaldi et al. (2001), as Saidi et al. (2018) referred, interdependency of infrastructures is the interaction between two infrastructures that each status will affect and correlate with one another.

Utility facilities located in and adjacent to the public right of way of existing road in Indonesia's cities include clean water distribution pipes of various sizes, underground power cables, underground fibre optic, gas pipe, and electricity, lights, box culvert, electric and phone poles as can be seen in Figure 1. The utility placement in the public right of way facilitates utility operators in determining control points, dividing service distribution areas, and avoiding the obligation to landowners. On the other hand, uncoordinated roads and utilities operation and maintenance activities can cause damage to each other.

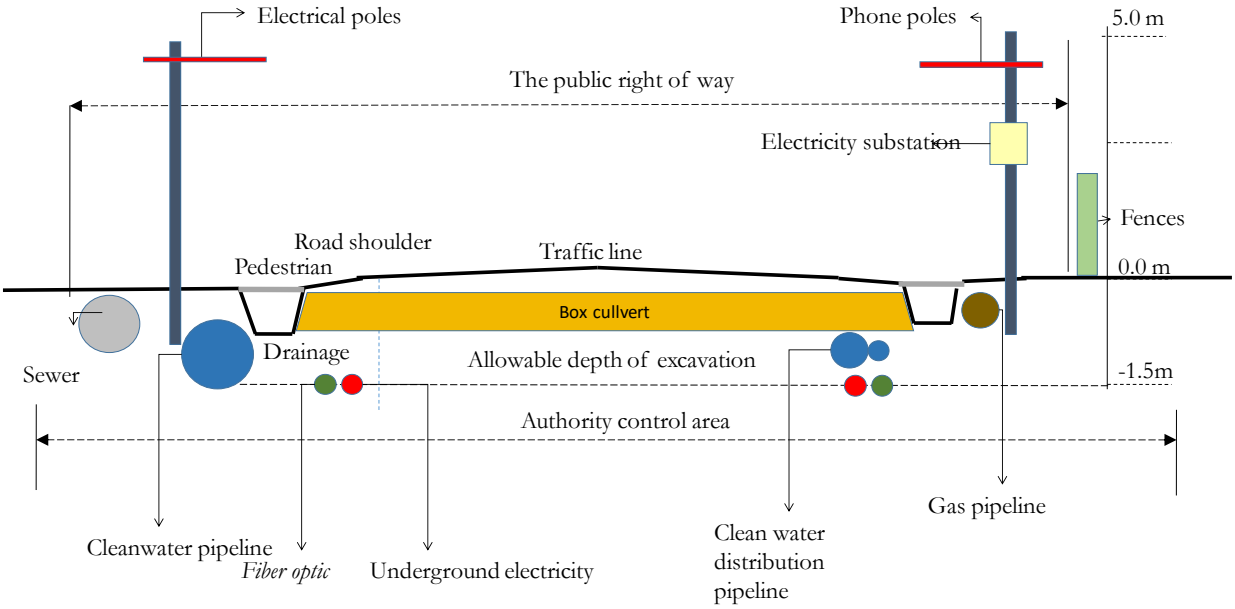

Figure 1. Typical Cross Section of Public Right of Way in Indonesia

During the operational stage of the road, the road authority and utility companies will carry out infrastructure maintenance activities, both routine and incidental. Infrastructure maintenance work can occur at any time at this stage. Maintenance of the infrastructure is important for the continuity of infrastructure services to the community; otherwise, it can lead to asset degradation with negative effects on the economy and cause maintenance costs to increase over time. A good infrastructure maintenance plan is necessary to maintain its performance (Tafazzoli, 2019), without jeopardizing other infrastructure nearby.

New utility installation work can also occur throughout the road operation stage. Currently, cities in Indonesia do not have shared facilities for utilities, so infrastructure damage often occurs. The utility company carries out excavation work for electric cables, installing clean

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water pipes, or repairing fiber optic cables in the public right of way that causes service disruptions. Every infrastructure work will result in road repair work and vice versa.

Damages disrupt traffic flow and cause congestions, repair costs need, and disruption to the implementation of other development programs. When repair works continue throughout the year, road and utility services are also continuously disrupted. The road authority must be able to coordinate the stakeholders' communication, and share the responsibility of activities which is interrelated in order to reach an improved decision making and avoid infrastructure damages (Department for Transport, 2012; Malone, 1987; Shokri et al., 2012; TAC, 2008; Tuomikangas and Kaipia, 2014; Wen and Qiang, 2016). The most important factor in coordination is interdependency (Tellioğlu, 2010). In Indonesia's infrastructure development activities, stakeholders work partially in each sector, therefore coordination is not an easy task. This is due to the fact that stakeholders have different orientations in work assessment, business, schedule, technique, organization structure, and regulation. They have no obligation to obey one another, yet they are interrelated in the public right of way. Thus the relationship between stakeholders in a road system is considered complex and unstructured. Complex system can mean chaotic, unstructured, poorly defined, and involving many different organizations on a system that has never been created before (Daellenbach and McNickle, 2005).

This paper aims to develop a stakeholders' operation and maintenance coordination conceptual model for the complex and unstructured system in Indonesia's public right of way based on Soft Systems Methodology (SSM). This method creates a conceptual model between organizations in an infrastructure system that involves very complex situations. The model can contribute to local governments in coordinating the development of the existing road system under city administration.

SOFT SYSTEM METHODOLOGY (SSM)

Soft System Methodology (SSM) is a part of systems thinking that considers events in the system as a whole. This way of thinking is not breaking the system into components and then trying to understand them (Aldianto et al., 2020). On the other hand, it emphasises how the components of the system work in a network of interactions (Bashan and Kordova, 2021). System thinking help us to understand how to function a system by considering its relation and changes within the system (Kutty et al., 2020). We will analyse how stakeholders interact in a system by making a network of interaction based on information flow. Soft system thinking is the most effective way to understand the current unstructured problem situation of a system (Bjerke, 2008), such as the interdependent public infrastructures system.

SSM is developed by Peter Checkland of University Lancaster, UK in 70's (Mehregan et al., 2012; Mingers and Taylor, 1992; Rodriguez-Ulloa and Paucar-Caceres, 2005). SSM develops models, however the models are not always representing "the real world", though it can help researchers to structure their thinking about the real world. Moreover, SSM can be used in various disciplines, including organization, business managers, OR practitioner, construction projects, health management, information system, logistic system, supply chain management etc. (Maqsood et al., n.d.; Mingers and Taylor, 1992; Sari et al., 2020). Mingers and Taylor

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(1992) attested that the system ideas developed by Peter Checkland can help to decipher confusing management problems. SSM describes a learning process in the form of an inquiry process in problematic situations for concerned people (Rodriguez-Ulloa and Paucar-Caceres, 2005). SSM basic form is a comparison between real world with a relevant system of activities in order to achieve the mutual goals of the system (Checkland, 2000; Nugroho, 2012). SSM identifies as many as involving aspects and their interaction in the system by doing seven stages as shown in Figure 2.

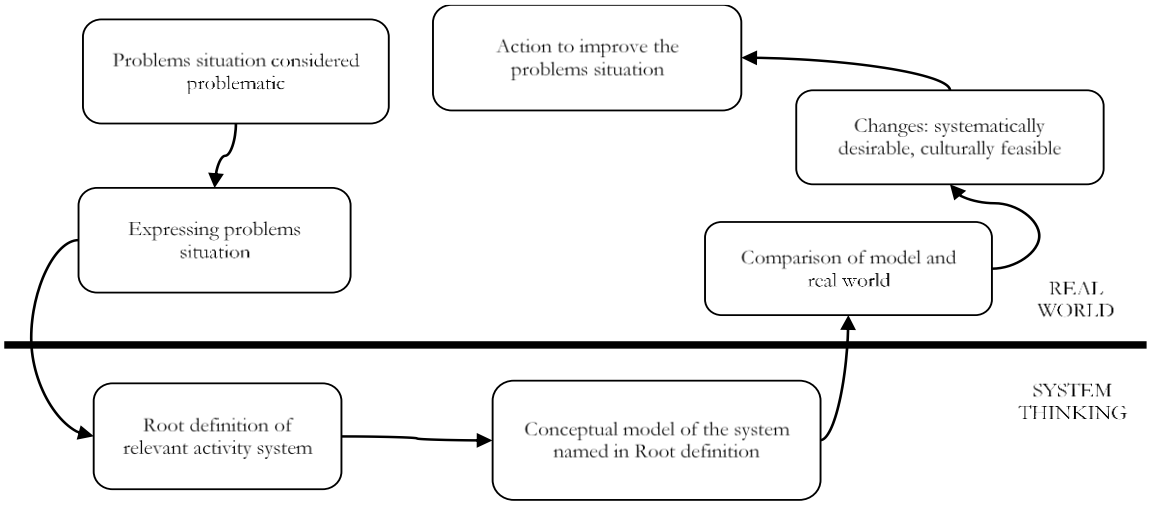

Figure 2. Seven Stages of Soft System Methodology

The SSM process is divided into two parts, the real world and the system thinking activities, however not all of these steps have to be followed. The SSM process is an interactive learning cycle that leads to taking action, and once an action is taken, a new situation and characteristic will arise, and the process repeated (Rodriguez-Ulloa and Paucar-Caceres, 2005). It is very beneficial to use SSM for systems analysis and problems situation. SSM analyses the situation as a system, not parts; SSM tries to solve real-world problems; SSM makes it possible for the analyst to understand different situations through the learning process, rather than immediately replacing them with other ideal situations (Mehregan et al., 2012); SSM provides an effective and efficient way to analyse the processes of a system in which activities are interdependent (Chan and Mills, 2008). Various uses of SSM have been proven effective (Maqsood et al., 2006, n.d.; Mehregan et al., 2012; Mingers and Taylor, 1992; Sari et al., 2020).

2. Methods

A qualitative approach has been adopted to answer the questions based on soft systems methodology (SSM) which begins with the questions: What events or issues will arise in the system? Who is involved in the system and how do they interact with each other? What is the exact definition of the problem at hand? And how can the problem situation be solved to get a

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better situation? The research is limited to the operational and maintenance stage of the road infrastructure system.

Primary and secondary data were collected by conducting in-depth interviews in six cities and two districts spread across Indonesia. Participants are selected by purposive sampling, consisting of those who are involved in infrastructure development with five years' experience in minimum. In-depth interviews provided information on interdependent-public-infrastructure relationship aspects in the road during the operational and maintenance stage.

3. Results and Discussion

3.1 SSM Step 1: Description of Problems Situation

Problems situation in the system is complex, therefore, events and issues of interaction between stakeholder that is considered problematic to be improved are collected (Checkland, 2000). The interdependent-public infrastructure interaction aspects of events or issues are identified through interviews with stakeholders, and these are namely: communication, schedule/project life cycle, regulation/policy, infrastructure data, and risks. Each aspect contains problems situation of interaction among stakeholders. Based on these interaction aspects, it can be understood that infrastructure damages leading to service disturbances on roads are induced by the fact that:

1. Utility companies are not involved in regional development planning deliberations; therefore, the road authority is not cognizant of the utility companies' schedule of work;
2. There is no regulation as a guide on how to communicate, how responsibility is assumed, and how coordination should be carried out. Communication is done only when damage occurs;
3. Infrastructure data is not yet integrated, and it is hard to be accessed by each stakeholder;
4. There are no regular meetings that serve as a form of coordination forum between stakeholders;
5. Infrastructure damages frequently occur;
6. There is no compensation for repair costs;
7. There is no dispute resolution mechanism.

The problem situation is then illustrated in a rich picture in the next SSM step.

3.2 SSM Step 2: Rich Picture

A rich picture describes the problem's situation with a picture that captures many views within the public right of way (Nugroho, 2012). A rich picture is proved effective to explain problems situations in its system. Based on the in-depth interview, we analysed six stakeholders who have interest and assets in the public right of way, their interaction pattern, and interface problems. It is revealed that the communication and the coordination among stakeholders are

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done under particular circumstances and at a very minimum. For some basic reasons, some stakeholders consider every information as confidential. To get a good understanding regarding the problem situation, we then depict parties, interactions, and problems in a rich picture as shown in Figure 2. A rich picture should be designed to reflect the root definition, which eventually led to the CATWOE elements (Valek, 2017) shown in Table 1.

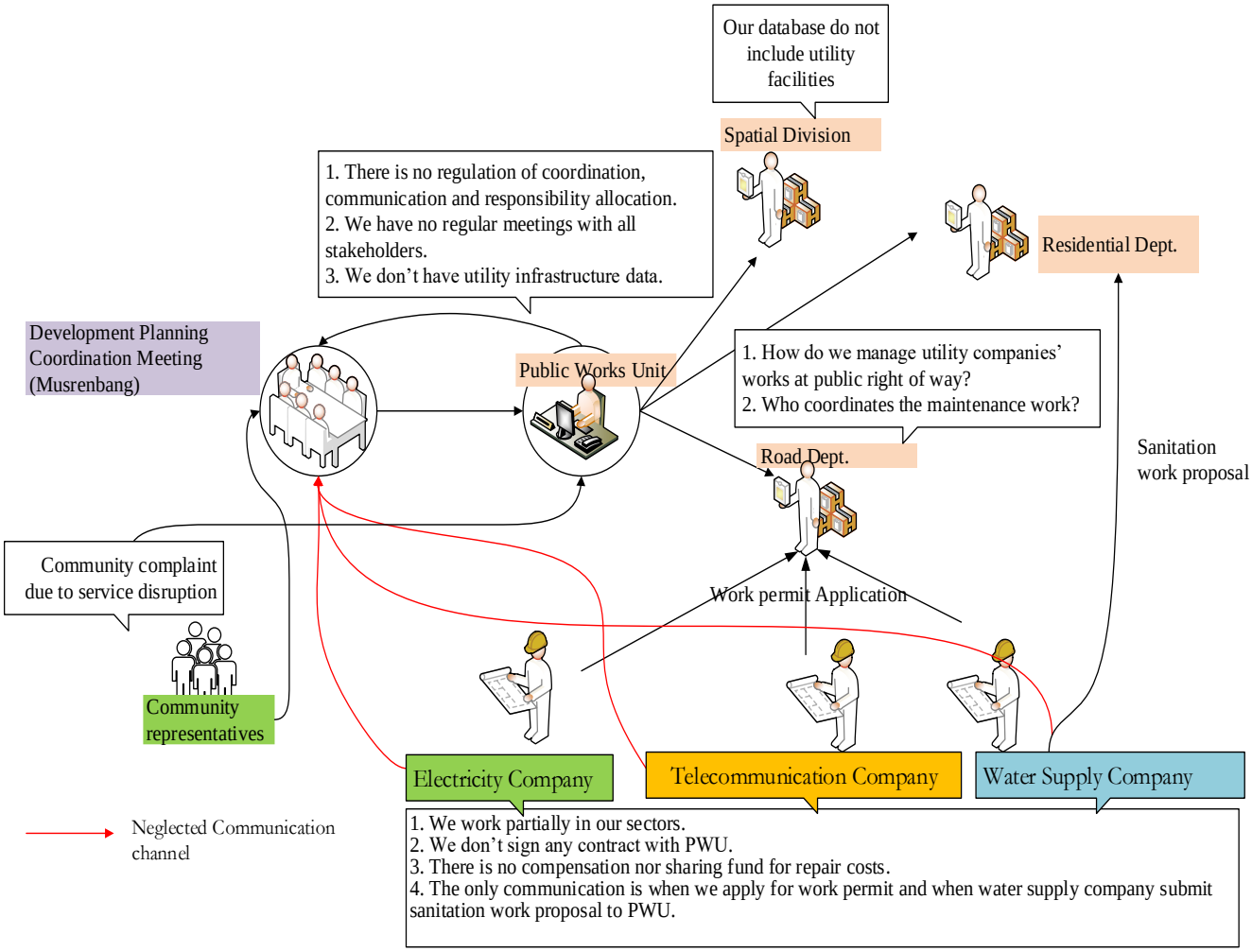

Figure 3. Rich Picture of Problems Situation in the Public Right of Way

3.3 SSM Step 3: Root Definition

The basic form of root definition is "a system does X, using Y, to do Z", where X = what does the system do? Y = how is it done? Z = why is it done? Based on the problem situation and rich picture, the root definition is:

X = The road authority establishes a coordination system between stakeholders that regulates communication, responsibility, and coordination among stakeholders throughout the existing road's operational and maintenance stage;

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Y = The coordination system contains regulations, activity processes, coordination components, interfaces, dependencies, communication, and problem-solving that must be considered throughout the operational life of the road;

Z = The coordination system aims to avoid overlapping work, minimize infrastructure damage, avoid repair costs, avoid public complaints, and ensure a sustainable infrastructure system.

To test the quality of the root definition, we map the definition with the CATWOE (Customers, Actors, Transformation, World view, Owners, and Environmental constraints) elements in Table 1.

Table 1: CATWOE Element

CATWOE Element	Description
Customers	Community/Users
Actors	Road Department, Spatial Planning Division, Residential Department, electricity company, communication company, water supply company.
Transformation	Build a coordination system by prioritizing communication, information sharing, and responsibilities during the operation and maintenance stage to ensure a sustainable interdependent public infrastructure system.
Weltanschauung/ World view	Coordination, communication, and sharing of information and responsibilities will avoid conflicts between stakeholders due to damage to infrastructure during road operation and maintenance.
Owners	Public Works Unit.
Environmental constraint	Stakeholders have different business orientations, technical, goals, and regulations.

3.4 SSM Step 4: Coordination Conceptual Model

A conceptual model is a model that conceptualizes reality and can compare to the real world to identify what changes can be in the system. This model consists of CATWOE elements, and we added a wider system as the external stakeholder. The model forms a cycle, starting from the development deliberations and discussion. The annual deliberations results are implemented by the Public Works Unit as the system owner, who delegates the institution strategic plan to the actors/department/division. The Road Department coordinates two other divisions and the utility companies during the operational and maintenance stage. Each stakeholder transforms their respective activities to support communication, coordination, and sharing of information and responsibilities within the system. The conceptual model removes the neglected communication lines between the utility company and the development planning coordination meeting and shifts them to the road department. Furthermore, the transformation carried out is supported by the weltanschauung/world view. The goal is to achieve customers' satisfaction with infrastructure services, which will affect the future deliberations process, then the coordination process is repeating itself. The important thing to be considered is environmental constraints. We stated internal and external constraints which act as input and

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output for stakeholders during the coordination process to be improved. The coordination conceptual model is shown in Figure 4.

3.5 SSM Step 5: Comparison Between Model and the Real World

The conceptual model provides an impression of how a system should develop by being attentive to the current system. Therefore, we need to compare the conceptual model with real conditions in the region. In the real world, synchronizing government programs with the utility company's program is almost impossible; sharing infrastructure data is considered problematic; authority of the road department regarding supervising the utility works are very limited; holding a regular meeting needs a complex arrangement, and communication between stakeholders is very minimum. This gap occurs due to environmental constraints and impassable boundaries at the interface that every stakeholder has to face. Therefore, it is necessary to make changes to the system.

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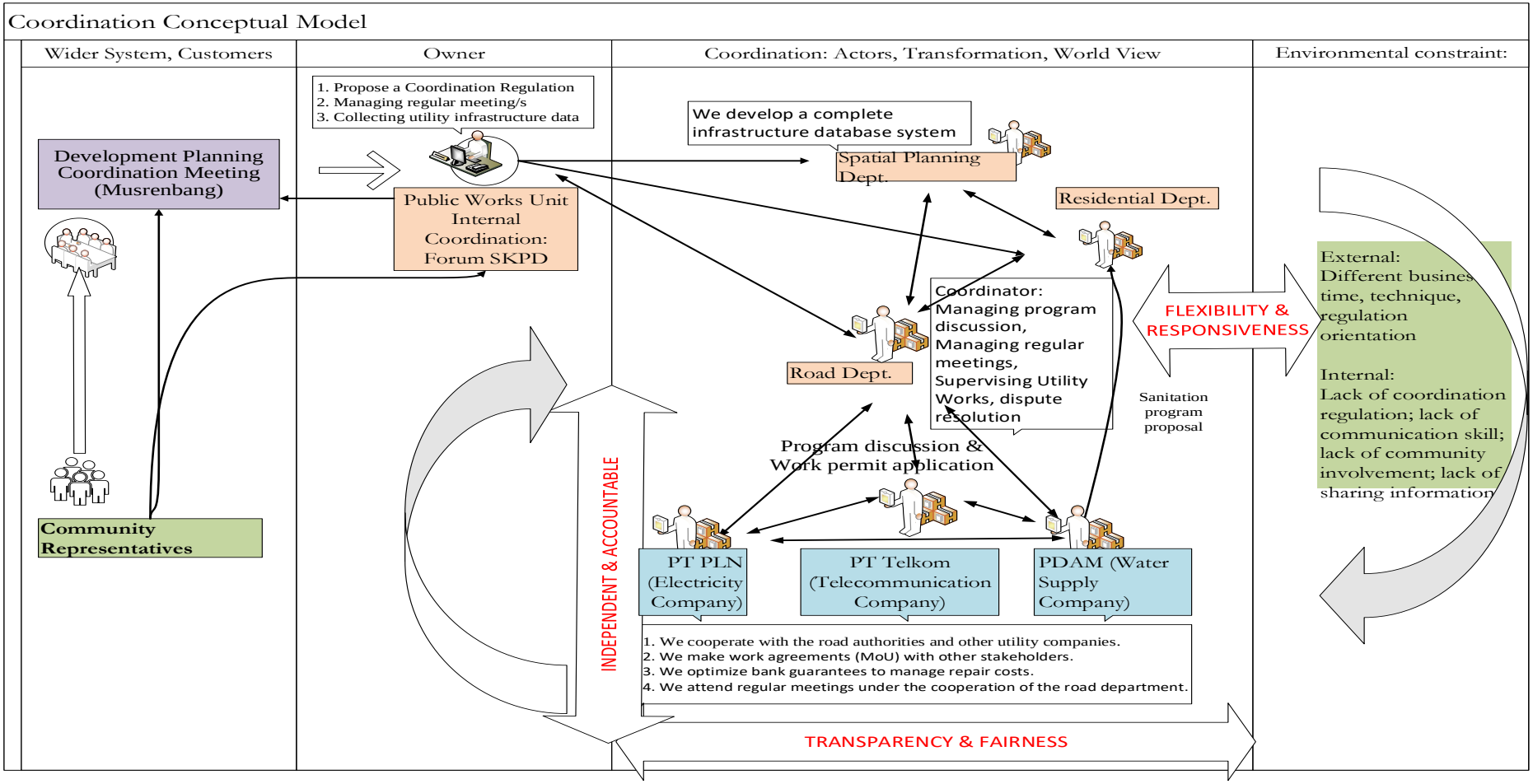

Figure 4: Interdependent Public Infrastructure Coordination Conceptual Mode

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3.6 SSM Step 6: Changes; Systematically Desirable, Culturally Feasible

The changes needed are not only in physical form, but more so for social, cultural, and mindset aspects. These are the changes that may be made to the real world to realize approximately the ideal situation in the conceptual model. Ideally, improvements to the problem situation will be implemented, but organizations are living things that do not immediately accept changes even though the changes are very logical in the model. The world view of the root definition must be considered and thought thoroughly at this step.

Based on the comparison of the model and real-world, we can draw a common thread of what changes should be made in the road's public right of way. Firstly, we need to build trust among stakeholders. Trust is an important thing in coordination. Within the trust, the Road Authority can gather all stakeholders to communicate, share information, share each infrastructure data, and share each annual program to be managed by the authority. All of those impacts can be determined in a regular meeting. Secondly, there is a guarantee to keep the confidentiality of infrastructure data. The government must assure the utility companies that their assets are safely saved in the database system. Thirdly, the Road Authority must have full access to supervise utility works in the public right of way. Fourthly, a database system is a must. The government should have a database system consisting of all kinds of infrastructures that exist in the region. Finally, we need to build a dispute resolution mechanism to solve all disputes regarding infrastructure damage without involving the judiciary system.

3.7 SSM Step 7: Action to Improve the Situation

Actions to improve the situation are carried out after “desirable” and “feasible” changes are obtained. Corrective action will result in a new system that will affect the larger system and continue to new opportunities and problems, thus the process repeats itself.

4. Conclusions

The conceptual model helps us to identify what needs to be done in a complex system of the public right of way. According to the coordination conceptual model, the road authority needs a few changes in managing maintenance works in the public right of way. However, the organization is a living thing where culture will be more accepted than an abstract model even though the model is very logical. It's hard to change habits that have been there for a lifetime. Therefore, to build a coordination system that will result in desirable and feasible changes to improve the situation, a suitable approach is needed. These changes should pay attention to some elements, i.e. trusts, guarantee of safe infrastructure data that are considered confidential, regular meetings among stakeholders, regulation regarding supervision of utility works by the road department of the Public Works Unit, database system of infrastructure in the region, and dispute resolution mechanism. These elements must also consider the environmental constraints faced by each stakeholder, and the system coordinator must be able to overcome all these obstacles. In future research, we require to develop a stakeholder coordination model based on the project life cycle by taking into account the dynamics of the system.

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