challenges

Review

Challenges in Governing the Digital Transportation Ecosystem in Jakarta: A Research Direction in Smart City Frameworks

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Abstract: Mobility is one of the most difficult domains of the smart city to face. In fact, most large cities in the world are still facing urban mobility problems, especially traffic congestion. Particularly, in Jakarta, Indonesia, traffic congestion is a major issue that negatively affects productivity and the overall living quality of the citizens. Along with the development of the information communication and technology (ICT), the transportation domain in Jakarta has formed a digital transportation ecosystem, shown by the emergence of innovative digital-based transportation services. In line with this current condition, this paper hopes to contribute to the improvement of urban traffic in Jakarta by proposing research directions to govern the digital transportation ecosystem within a smart city framework. The significance of the research directions is reviewed using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology in a systematic review of previous studies. Ultimately, the research directions proposed in this paper lead to the necessity for an architectural perspective and relevant big data analytical tools to improve the digital transportation ecosystem in Jakarta.

Keywords: mobility; transportation; smart city; digital; ecosystem; governance; prisma

1. Introduction

Nowadays, most people are living in urban areas. According to the United Nations, 54% of world's population was living in urban areas in 2014, and it is projected that 66% of world's population will live in urban areas by 2050 [1]. This urbanization trend creates significant challenges for cities, including scarcity of resources, inadequate infrastructures, energy shortage, human health concerns, and demand for better economic opportunities [2]. Such negative consequences in the city occur because the physical system of the city (natural resources, energy, and infrastructure) hasn't evolved at a speed compatible with the functional aspects of the city, such as economy, health, education, etc. [3]. This situation has brought to into focus the need to manage cities efficiently, while at the same time making the quality of life in cities better [4]. To this end, the smart city concept was introduced [4].

The smart city can be defined as technology-intensive and advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce, and an increased life quality [5]. To successfully manage the smart city [6], proposed a smart city integrative framework as shown in Figure 1.

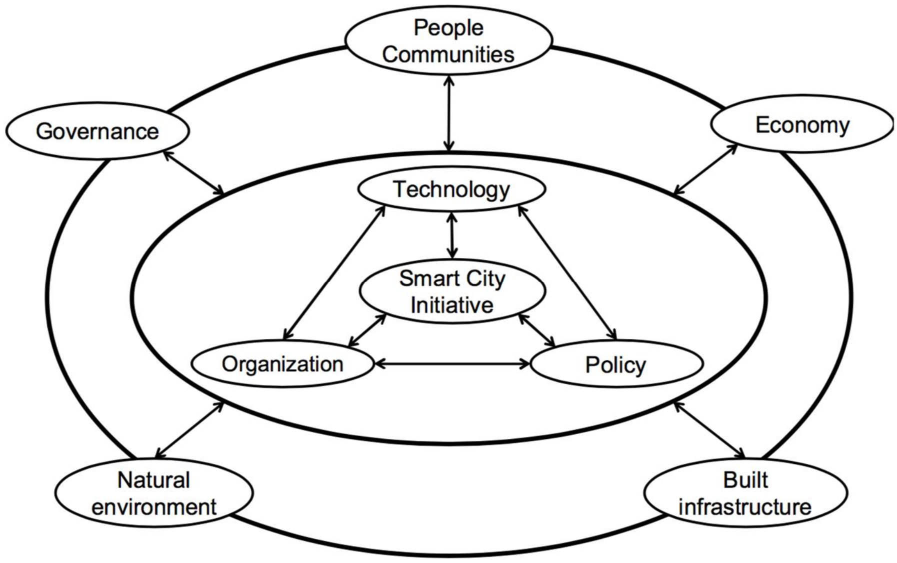

Figure 1. Smart city integrative framework [6].

Within the framework, the outer factors—namely, governance, people and communities, economy, infrastructure, and natural environment—have more influence on the success of smart city initiatives compared to the inner factors (technology, organization, policy) [6]. Particularly, as smart city initiatives involve multiple stakeholders, it is crucial to have effective governance to manage these initiatives [6]. In general, governance refers to the means for achieving direction, control, and coordination of wholly or partially autonomous individuals or organizations on behalf of the interests to which they jointly contribute [7]. Based on the above definition, this paper defines governance in the smart city context as the orchestration practices that includes direction, control, and coordination activities of the involved stakeholders to achieve the success of smart city initiatives.

The smart city concept is applied in at least six domains of the city; namely, transportation, economy, governance, people, environment, and living [8]. In particular, transportation is one of the most difficult domains to face, especially in metropolitan areas [9]. It is complex since it involves multiple aspects of the city, including people, the environment, technology, and the economy [9].

Most large cities in the world are still facing urban transportation problems, especially traffic congestion [10]. Traffic congestion is a crucial city problem to address, since it impacts multiple living aspects in the city, including the economy, citizen productivity, environmental sustainability, and energy consumption. Traffic congestion has cost the global economy billions. Recent statistics show that traffic congestion is responsible for economic losses that cost €200 billion in Europe, and energy losses that waste 1.9 billion gallons of fuel worldwide [10].

Particularly, in Jakarta, Indonesia, traffic congestion is a major issue that negatively affects the productivity and overall living quality of its citizens [11]. From an economic perspective, it is estimated that the total loss caused by the traffic congestion in Jakarta reaches Rp. 12.8 trillion per year [12]. Further, according to TomTom Traffic Index, in 2017, Jakarta placed as the third-most congested city in the world [13].

To tackle traffic congestion in Jakarta, several initiatives have been undertaken; one of these is the Jakarta Smart City (JSC) initiative. JSC was initiated as an integrated public reporting and information platform that provides public information about Jakarta, managed by the Jakarta Smart City Technical Executive Unit, which was established in 2015 [14]. To get city information, there are at least three applications that act as data sources connected to JSC, namely Qlue, Waze, and @petajkt. Qlue is an application that connects individuals with their neighborhood and city officials through which they can report information about their surroundings. Waze is an application that provides a mapping service to enable its users to share real-time traffic and road information. Meanwhile, @petajkt is a Twitter account that manages information specifically about floods in Jakarta. Specifically, in the urban traffic domain, information gathered by JSC is used to provide real-time traffic information, real-time routes, and real-time situational reports for urgent urban infrastructure issues such as traffic congestion or flooding [14].

In addition to JSC, initiatives in Jakarta's urban traffic have formed a digital transportation ecosystem. Based on Nachira (2002) [15], constructed digital ecosystem as the adoption of internet-based technologies on such a level that business services and the software components are supported by a pervasive software environment, which shows an evolutionary and self-organizing behavior. This digital ecosystem in the transportation domain—or, in this paper, referred to as the digital transportation ecosystem—is shown by the emergence of innovative digital-based transportation services, such as vehicle-hailing apps (e.g., Go-Jek, Go-Car, Uber, Grab, etc.), electronic ticketing and payment in public transportation (e.g., TransJakarta e-Ticket, e-Toll, Rail Card, Go-Pay, e-money, etc.).

However, despite the emergence of the digital transportation ecosystem, Jakarta is still placed as the third-most congested city in the world [13]. As learned from the JSC initiatives, there are six main concerns of the ecosystem; namely, poor data management, continuity of the initiative, cooperation between public officials, conservative culture in the government, citizen participation, and social-economy disparity of the citizens [14]. Given these concerns, therefore, a new approach is needed to increase the quality of urban traffic in Jakarta.

As the stakeholders involved in the digital transportation ecosystem have their own roles, interest, and business model, it is necessary to have these stakeholders working together in a coordinated manner to achieve the goal of the ecosystem, while at the same time beneficial for each of the stakeholders [16]. In order to effectively govern the stakeholders, it is important to map their roles, interest, and business models comprehensively [17]. To this end, development of architectural perspective of the ecosystem that represents the interaction of the stakeholders within the ecosystem is needed. This architectural perspective is important since it can capture the structural, behavioral, and informational aspect of the ecosystem in an organized manner, so as to facilitate quantitative analysis of the ecosystem [18]. Further, to provide improvement recommendation for the ecosystem, it is important to develop suitable model-based and data-driven analytical tools to continuously monitor and assess the ecosystem, leveraging the architectural perspective of the ecosystem [19,20]. This paper proposes several research questions that need to be elaborated as research directions in order to positively contribute to the improvement of urban traffic in Jakarta.

2. Methods

As this research sees the transportation domain as part of the smart city initiative, the significance of the proposed research direction can be seen by understanding the current state of research in the area of architectural perspectives on the smart city and smart transportation as a part of the smart city initiative in the transportation domain. This paper follows Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to systematically review relevant publications. The review was conducted on academic publications, searched on Scopus, IEEE Xplore, and Google Scholar using keywords "Smart City Ecosystem" AND ("Architecture" OR "Big Data Analytics") dated from 2011 to 2017. This search returned 24 hits on Scopus, 46 hits on IEEE Xplore, and 164 hits on Google Scholar.

3. Results

Identified search results using PRISMA methodology are then screened using these following inclusion criteria: (1) discussed architectural perspective or smart transportation in smart city context and (2) relevance ranking. Assessment using the inclusion criteria leaves 14 articles to be further elaborated for analysis. Table 1 shows selected articles related to architectural perspectives on the smart city, which were collated in order to gain a more holistic understanding of the ecosystem.

Table 1. Research related to architectural perspectives on the smart city.

Author	Perspective	Description
[21]	Technological	Layers of smart city platform, consists of data sources, IoT platforms, platform agnostic management, monitoring and governance, and smart city application and tools.
[22]	Technological	Layers of smart city ICT architecture, consists of natural environment, hard infrastructure (non-ICT), hard infrastructure (ICT-based), services, and soft infrastructure.
[23]	Technological	Multilevel smart city architecture, consists of sensors, communication service, data collection, data processing, data integration and reasoning, device control and alerts, communication services, and customized services.
[24]	Technological	Layers of smart city ICT architecture, consists of sensing layer, network layer, and control & services layer.
[25]	Governance	Analytical framework to govern smart city's innovation ecosystem, represented on smart city ecosystem layers that consists of city layer, the green city layer, the interconnection layer, the instrumentation layer, the open integration layer, the application layer, and the innovation layer.
[26]	Governance	Smart city architecture that represents relationship between involved stakeholders with central focus on corporative open data services.
[27]	Governance	Value network of Machine Type Communication (MTC) in smart city ecosystems, specifically for stakeholders in telecommunication industry.
[28]	Governance	Conceptualization of smart tourism ecosystem concerning technological aspect, value exchanged between involved stakeholders and business model aspect.

As shown in Table 1, two perspectives are used to categorize the related articles—namely, technological and governance perspectives. Articles that study the hardware or the software architecture of the smart city are categorized as belonging to the technological perspective. On the other hand, articles that emphasize the orchestration of related components involved in the smart city are categorized into the governance perspective. The subjects of studies considered to be categorized in this perspective include the interaction of the stakeholders, the business model, and the value chain. As this paper focuses on the transportation domain of the smart city, Table 2 presents selected articles that specifically study the transportation domain of the smart city ecosystem.

Table 2. Research related to transportation domain in smart city context.

Author	Perspective	Description
[29]	Technological	Development of intelligent transportation system based on internet of things technology to provide real-time traffic controlling and monitoring.
[19]	Technological	Development of real-time intelligent transportation system using graph-oriented approach. The proposed system utilizes big data analytic to process the data from IoT devices.
[30]	Technological	Review intelligent transportation system related research around the world in technological perspective.
[31]	Technological	Big data analytics platform to analyzes the urban transportation data to get the understanding of traffic patterns.
[32]	Governance	This study explores the changes of the governance structure of public transportation system in Seoul to supports the design and implementation of smart card public transportation system (T-Money).
[33]	Governance	Development of a conceptual model of smart transportation management system to analyze the influence of the included factors in distribution activities and identifies the management issues.
[34]	Governance	Development of sustainable transportation scenario in the context of smart city for India, based on the case studies in developed countries.

The same as in Table 1, articles listed in Table 2 are categorized in two perspectives—namely, the technological and governance perspectives. Articles that study the hardware and software aspects of smart transportation are categorized into the technological perspective. Additionally, articles that emphasize the orchestration of involved stakeholders in the smart transportation system are categorized into the governance perspective.

Technology is surely an integral part of the smart transportation system or smart city ecosystem in general. However, despite its importance, from a strategic perspective, the orchestration of involved stakeholders in the ecosystem is the key to achieving the desired outcome and the long-term success of the smart city ecosystem [16,25]. In this regard, this paper considers that it is critical to perform research that can provide directions to develop an architectural perspective on the transportation domain in the context of the smart city that considers the governance aspect.

4. Discussion

In an effort to improve urban traffic in Jakarta, this paper proposes directions for further research in the form of several research questions. The main research question to be further elaborated is the following:

How to improve urban traffic in Jakarta by governing the digital transportation ecosystem in smart city framework?

The objectives of the main research question are:

1. To understand the digital transportation ecosystem in Jakarta from an architectural perspective.
2. To identify measurable critical performance indicators for the digital transportation ecosystem in Jakarta.
3. To design an analytical mechanism employing big data analytics that can provide recommendations for improving urban traffic in Jakarta.

To answer the main research questions, this paper proposes several sub-research questions, as follows:

Sub-Research Question 1: How to describe the value network of the digital transportation ecosystem in Jakarta in consideration of the roles, interest, and business models of the involved stakeholders?

Since digital transportation ecosystem involve the interaction of multiple stakeholders, it is important to map their roles, interest, and business models in a comprehensive manner, such that the governance of the ecosystem can be well managed [17]. To this end, value networks will be used to construct the relationship within the ecosystem. Representation in the form of a value network is suitable to be applied for this ecosystem, because values in the ecosystem are created from interaction between the multiple stakeholders involved [35]. Value networks developed in this sub-research question will be used as the basis to develop an architectural perspective of the ecosystem in the next sub-research question.

With regard to the interaction of involved stakeholders, as shown in Figure 2 [26], suggest the relationship of involved stakeholders and components in smart city services. Based on this illustration, a huge amount of data acquired from smart sensors is a crucial component that feeds information to the open data services. Related industries, developers, and application services will be benefited by the aggregated data collected in this open data service.

However, the research mentioned above does not completely represent the interaction of the stakeholders in terms of their roles, interest, and business models, and does not specifically study the transportation domain. To this end, this question is still relevant to exploring the interaction between involved stakeholders in the transportation domain of smart city, in the form of a value network.

Sub-Research Question 2: What architectural viewpoints should be described in order to comprehensively understand the digital transportation ecosystems in Jakarta? How should such architecture be formally described?

An architectural perspective is needed to represent the interaction between stakeholders within the digital transportation ecosystem, which encompasses the interest of all the involved stakeholders, such that it can balance the stakeholders' concerns. In this research, the Archimate framework can be used to formally describe the architectural perspective of the ecosystem, since it is considered to be a comprehensive framework that can visually represent the ecosystem in three layers—Business, Application and Technology—and considers the structural, behavioral, and informational aspects within each layer [18,36].

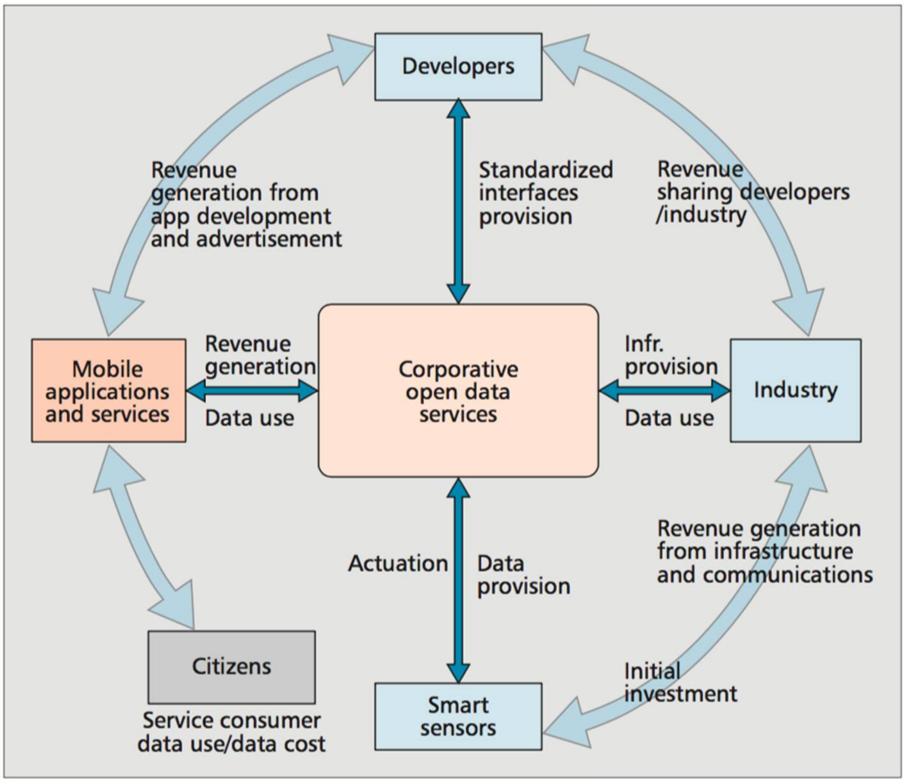

Figure 2. Stakeholder relationships in smart city services [26].

The architectural perspective can be described from different viewpoints based on stakeholder's interest in the ecosystem. Examples of these viewpoints are the goal analysis viewpoint and the resource allocation viewpoint [15]. The goal analysis viewpoint can be defined as a perspective that translates ecosystem objectives into specific and observable performance, while resource allocation viewpoint is a perspective with a focus on optimization of the resources in the ecosystem [15]. This research question will evaluate suitable viewpoints, such that it can help to comprehensively understand the digital transportation ecosystem in Jakarta, encompassing roles, interest, and business model aspect of the stakeholders that are represented in the value network developed in the previous sub-research question.

As shown in Figure 3, to comprehensively capture the interaction between all involved stakeholders in the ecosystem, the Archimate framework represents the ecosystem in three layers; namely, the business layer, the application layer, and the technology layer [18]. Furthermore, the Archimate framework identifies relationship between and within layers by considering the structural, behavioral, and informational aspects of the ecosystem [18].

Archimate also facilitates quantitative measurement associated with the objects and relationships represented in the model [18]. In the context of this research, this feature will support the development of simulation model that will be addressed in sub-research question 4.

Sub-Research Question 3: What are the most suitable performance indicators that can be used to measure and monitor the performance of the digital transportation ecosystem in Jakarta?

This research question proposes to define performance indicators of digital transportation ecosystem in Jakarta, such that quantitative analysis can be used to measure and monitor the ecosystem. It is important to enable quantitative analysis, since it may provide accurate information for decision making, given a complex reality [15]. The quantitative analysis proposed in this paper will leverage big data analytical tools developed in the next sub-research question.

Sub-Research Question 4: What are suitable model-based and data-driven analytical tools for the continuous monitoring and assessment of performance of the digital transportation ecosystem in Jakarta?

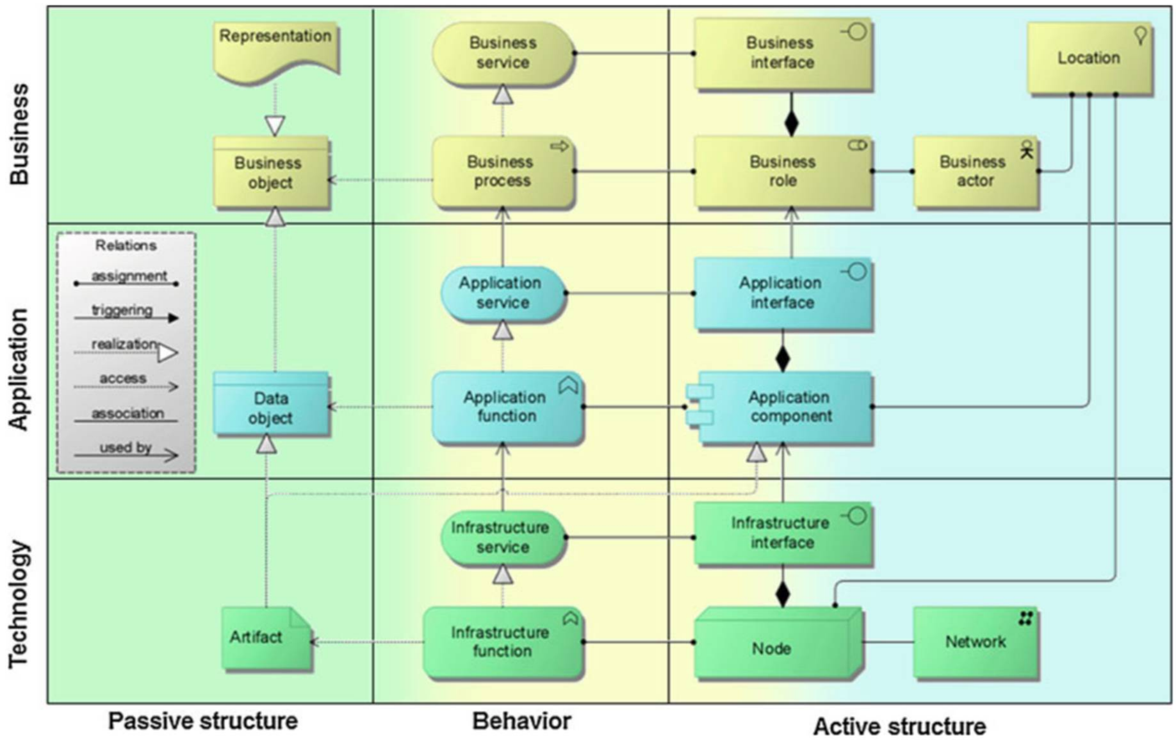

Figure 3. Simplified Archimate model [18].

To be able to quantitatively measure the performance indicators, a quantitative simulation model is required. The simulation model should be able to address complex problems that involve the interrelationship and feedback loops between components in the system. Further, as digital transportation ecosystems generate what we refer to as big data, it is important to be able to analyze the data correctly, such that real-time analysis can be made to aid problems that arise in the ecosystem [19,20]. Further, for big data to achieve its goal and enhance services in the digital ecosystem, it needs the right tools and methods for efficient and effective data analysis [37]. Therefore, it is important to develop suitable model-based and data-driven analytical tools to continuously monitor and assess the ecosystem, leveraging the architectural perspective of the ecosystem developed in previous sub-research questions.

In particular, the big data analytical tools proposed in this study can adopt the big data analytics framework developed by [38], as shown in Figure 4.

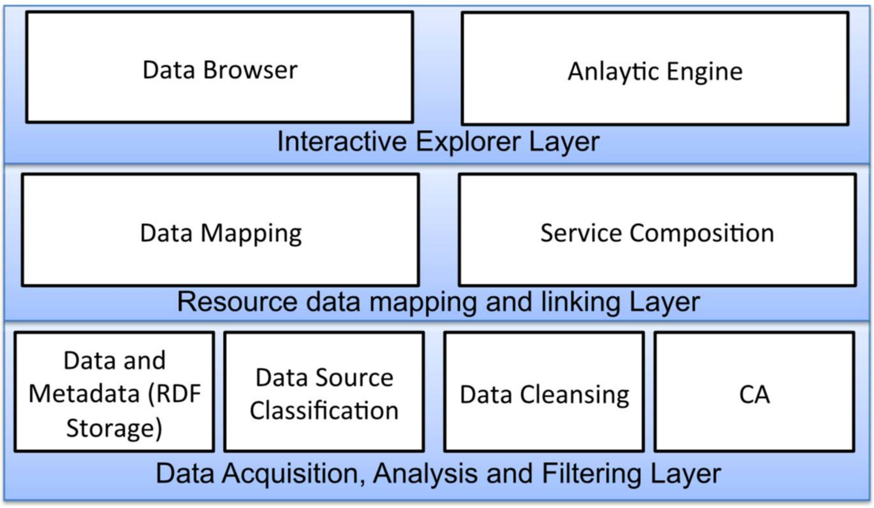

Figure 4. Big data analytics framework [38].

The above big data framework consists of three layers that represent the main components of big data analytics. The first layer basically consists of various data acquisition devices that provide a huge amount of data to be further analyzed. In the second layer, data collected from heterogeneous data sources with different formats will be organized to enable the easier data-mining process. Finally, the top layer processes the data for application-specific purposes. Particularly with regard to this sub-research question, the big data analytical tool will acquire and aggregate the data from various data sources related to the transportation ecosystem in Jakarta. Further, the top layer will provide the specific data needed by the developed simulation model.

Sub-Research Question 5: How can the results of these analytical tools be used in the governance and improvement of such digital transportation ecosystem?

Model-based and data-driven analytical tools developed in previous sub-research questions will be applied with real data from digital transportation ecosystem in Jakarta. The result will used to provide recommendations in operational, planning, policy aspect such that can improve the quality of performance indicator of the ecosystem. From an operational perspective, the results of the analysis can be used, for example, to provide an optimum route for the citizen or to mobilize public transportation vehicles at certain times. From a planning perspective, transportation infrastructure can be better planned; for example, by defining new optimum routes for public transportation vehicles, or by defining the types of public transportation that need to be built. From a policy perspective, more comprehensive policy can be made, for example in defining the maximum number of vehicles or specific areas allowed for certain type of transportation mode, or by defining tariff policy for vehicle hailing apps.

Elaborations on the above research questions can hopefully provide directions that can positively contribute to the improvement of urban traffic in Jakarta.

5. Conclusions

Along with the development of ICT, a digital transportation ecosystem has formed in Jakarta. This phenomenon is shown by the emergence of innovative digital-based transportation services such as vehicle hailing apps, electronic ticketing, and electronic payment for transportation services. However, despite the emergence of the digital transportation ecosystem, traffic congestion is still a major problem in Jakarta's urban traffic. To positively contribute towards improving Jakarta's urban traffic, this paper proposes several research questions as recommended directions for further research. The main research question is followed by five sub-research questions, which are explained in this paper, ultimately leading to the needs of the architectural perspective of the digital transportation ecosystem that represents the interaction of the stakeholders within the ecosystem. Further, it is also important to develop suitable model-based and data-driven analytical tools based on the architectural perspective to provide improvement recommendation for the ecosystem. From an academic perspective, following the PRISMA methodology, research in this direction can be considered significant. It is found that lack of research conducted in the development of architectural perspective and big data analytics that encompasses roles, interest, and business model aspect of the stakeholders within the smart city ecosystem, particularly in the mobility domain of the smart city, which is the main focus of this paper.

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