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Integrated Public Transportation Systems Model for Passengers' Convenience and Safety

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***Abstract*—This paper aims to propose an integrated transportation system model for catering the convenience and safety needs especially in the developing countries context. Following intelligence transportation system principles derived from the literature, it identified four provisions essential for making the current public transport appealing based on the Indonesian context. These include integrated ticketing system, real-time vehicle information position, smart trip assistance and complaint system. Based from these requirements, this paper then proposed the business logic of each provision and how technological components, embedded system, hardware, software could be composed resulting architectural models for fulfilling passenger convenience and safety needs. Considering these results, this paper contributes to the limited but growing research on the intelligence transportation system by providing a reference architecture model for improving public transportation services. The models presented in this paper also offers practical insights to the public transportation operators especially in the developing countries that seek recommendation and approaches to enhancing and ensuring passengers' convenience and safety during the trip. Since this study based on Indonesian context, further research could look at different countries to offer new insights. Finally, it would be interesting for future works to adopt and implement the proposed architectures to solve the real problem in making public transportation more appealing.**

Keywords—architecture model, framework, integrated system, intelligence transportation system, public transportation,

I. INTRODUCTION

Public transportation plays a pivotal role in all around the globe as it is required to connect people, enable the delivery of products, and enhance the way of living and overall the society. Especially in modern world, it has been an integral part of its society and has become a priority, vital to well being and even to national security. Accordingly, in many countries, any ongoing efforts to foster the current or emerging roadmaps to advice the future development of better public transport system are gaining support from government.

Despite its central role, public transportation is not free from problems due to its unique characteristics in nature. For instance the high degree of accessibility in nature, where large number people can use it for various purposes, has made public transportation likely poses a risk of safety and security [1]. In addition as public transport relies on vast amounts of infrastructure such as roads, railways, and other public facilities, it is also subject to face multiple challenges from providing better services, convenience and efficient to travellers.

It is, therefore, necessary to provide a public transportation system which enables the inter-connection of multiple transportation modes along with the schedules, routes, ticketing, fares, and payment methods across local and regional area into a coordinated manner. The implementation of such inter-connected system among different transportation modes, lines and operators is widely known as an Integrated Public Transportation System (IPTS). Generally speaking, the term "integrated" when used in public transport refers to the inter-connection of public transports elements including infrastructure, tariff and information both between inter-modal and within intra-modal resulting in overall better performance. While in this paper, IPTS is considered as an ICT-based system composed of adaptive technology, sensor, intelligence, and autonomous systems to enable, facilitate and guarantee the physical inter-connection of multiple transportation modes seamlessly for passengers' safety and convenience.

For many advanced countries such as UK, Japan, US and Australia, the implementation of IPTS has provided numerous advantages such as increased safety; efficiency in the use of resources; improved accessibility; and environmental protection [2]. With such integrated form, the IPTS significantly offer transportation operators better collaboration rather than competition to gain more benefits related to improving efficiency, reliability, acceptability and profitability [3, 4]. Moreover, IPTS not only could improve the revenue, but also lead to societal benefit such as commuters' convenience and satisfaction [5].

With its vital roles, it is not surprising that IPTS has been a subject of research for both theorists and practitioners. IPTS is also interesting area of study in its own right as it involves providing multifaceted operations including coordinating vehicles, providing quality services to passengers and ensuring the safety during the trip. As a result, IPTS generally employs complex and innovative system which relied on the vast amount of data, adaptive, the interplay or the inter-connection of various advanced technologies such as ICT, sensor networks, IoT, automation, GPS, and GIS. Therefore one of the research topics frequently discussed in the literature is the development of principal architecture, conceptual design, framework, model, enabling technology or system configuration used to guide the development of IPTS better [6-9].

It is also important to note that the implementation of IPTS involves two main integration, lower and higher level [10]. Therefore, the successful operation of IPTS not only relies on the well-designed technological solutions as the lower level. Beyond that, it also is necessary to ensure the integration at higher level including synchronising policies, different payment system, fares, and schedules required to operate and guarantee the operation of IPTS. Accordingly, a substantial work also found in the literature that has examined various institutional and non-technical aspects contributing to the success of IPTS implementation [11, 12]. Other studies reported the experiences and the examples of the best practices on how successful IPTS implementation through the integration of both technical and non-technical aspects [13, 14].

In the Indonesian context, a growing concern from the researchers has also been placed to study IPTS, especially after the development of mass transportation system such as MRT, commuter line and bus-way in major cities. For example some scholars proposed model for developing IPTS in Indonesia derived from other advanced countries' experiences [15, 16]. Other researchers attempted to gain insights of the conditions or problems of the existing public transport services in Indonesia [17-19] and evaluation performance [20, 21] for developing better IPTS. A number of studies conducted by public institutions also found in the literature which attempted to report and provide practical guide for developing IPTS in Indonesia [22-24].

Much of the existing studies, in Indonesia context, generally focused on higher issues associated with the strategic and managerial issues of integrated public transportation. Accordingly, the plethora of works so far has paid little attention to explore the system, technological components, infrastructure and solutions which enable the integration of public transportation services in Indonesia provide better customer services. A great deal of works discussed technological aspects, such as the infrastructure architecture [25], roadmap or planning [26, 27], and design intelligent system [28, 29], yet most studies aimed to solve problems in transportation such as road safety and congestion. Some researchers has attempted to propose technological components as ingredients for enhancing the existing public transportation services including suitable platform [30], trip optimisation [31, 32], and ticketing system [16]. Apparently, the existing works do not discuss and gave special attention as to how such components are warrant and can be embedded within different architecture to facilitate and guarantee the implementation of IPTS for passengers' safety and convenience.

The discussion above highlights, more research on IPTS in the Indonesia context is needed from which this paper could fill the gap. Therefore, this research at hand aims to propose architecture model and enabling technologies for IPTS. A notable aim of this research is how the proposed model captures the need to provide IPTS which is able to cater passengers' convenience and safety needs. The reminder of this paper is structured as follows: Section 2 describes the research approach used in this study. Section 3 presents the architecture models of IPTS and discusses how these could address the security and convenience risks in public transport. Finally, Section 4 concludes this paper by highlighting the contribution and highlight future research agenda.

II. RESEARCH APPROACH

In general this research is a design science research in nature that seeks to produce an innovative IT artifact along with the knowledge about the design principles in creating such instance to solve an identified problem [33, 34]. However, since this research is aimed to present a conceptual model of IPTS, it specifically adopts the approach to develop IT architectures of intelligence transportation system as informed in the previous work [35] as illustrated in Fig. 1.

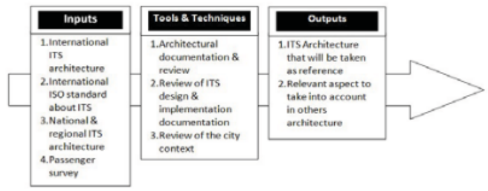

Fig. 1. Research approach based on Salazar-Cabrera and Pachón [35]

As can be seen in Fig 1, the proposed research design consists of three major stages as discussed below.

A. Phase 1: Input

The first stage is input process that aims to identify the main problem and challenge in the public transportation in term of providing better services to passengers. It also attempts to understand the passengers' needs on how the existing services could be improved or what additional features may need to be added to improve convenience and their safety during their trip. For these purposes, in this stage, the relevant reports, case studies, academic papers, technical guidance and documents related to Intelligence Transport System (ITS) frameworks, standardisation, architectural layers for national and regional as well city context were collected. In addition, a series of surveys were run involving public transportation passengers to hear their voice and expectation on how the current public transportation facilities and services should be available to ensure convenience and safety. All the data collected in this stage were organised for further analysis in the next phase.

B. Phase II: Tools and techniques

In this second stage, both primary and secondary data were reviewed and analysed using content and thematic analysis. The technical documents including framework, architecture, and standardisation were examined to find any technological components, algorithms, communication technologies, and embedded software or systems that are suitable for developing IPTS architecture model for passengers' convenience and safety. While the data gathered from the surveys were also analysed to identify the requirements for convenience and secure public transport services from the passengers' point views. The analysis and synthesise processes were done iteratively until all the requirements for developing an IPTS architecture model are gathered.

C. Phase III: Outputs

Once the data collection and analysis were completed, the next process is to design the IPTS architecture model for passengers' convenience and safety. Following T&M

model architecture design principles [36], firstly, this stage mapped the technological instances found previously as well as the requirements to correspond with the business logic domains (convenience and safety). It then selected kind of components used, algorithms, embedded software or system for each domain and define how their logical connections and the rule of relationship. Next, using the classic a three-tier architecture all the components were then composed into presentation, functional and data layer resulting architectural models. The next section discusses the results of this research approach.

III. Results

This section reports the results of this study by applying the overarching approach to develop IPTS architecture model. As mentioned above, this article aims to contribute to the current limited yet growing research on IPTS in the Indonesian context, by presenting architecture models. Of particular interest is how the passengers' convenience and their security concerns during their journey using public transportation are catered in the model. Analysis from the data gathered during survey revealed that four essential instances highlighted by passengers for making the current public transport appealing including (1) integrated ticketing, (2) real-time vehicle information position, (3) smart trip assistance and (4) complaint system. Therefore, in the following sub-sections discussed each of the proposed instances.

A. Integrated E-Ticketing architecture design

One of the fundamental services in the IPTS frequently demanded by passengers is the transfer facility among transportation modes and the interchange between public and private operators. In addition, it is also important to provide an ease of use mechanism by which passengers have flexibility to perform transaction or payment. Accordingly, the proposed architecture model should be developed as integrated ticketing systems that permit the switching between multimodal transport services within a single fare or ticket. The integration also aims to unify the existing fare policies, ensure the security, ensure the inter-organisational data exchange, enable the transportation operators collect information about transportation usage for strategic analysis and decision making. Fig. 2 illustrates how such requirements are captured in the architecture.

As Fig. 2 shows, the e-ticketing architecture relies on several technological components such as E-transport mobile app, database, QR code, digital money, and embedded systems integrated within a restful web services that handle the process in e-ticket transaction such as purchasing, reporting, top up and validation. The architecture also aims to serve four key actors (passengers, transport operators, banking system and drivers) and each of which has different functions in the system as followings:

- The architecture will enable passengers to make transaction using the mobile-based app called E-Transport. They can use the application to search and purchase tickets they wish and then precede the payment using QR code. The payment gateway will automatically deduce the balance available in the passengers' E-cash. The E-cash is a mobile-based app designed as electronic wallet for the users to convert their cash into digital money using bank transfer or other top up payment at partner stores. The app also has authentication mechanism using fingerprint, QR Code, or pin code to protect and secure the transaction activities such as purchase tickets, make payment, retrieve account balance, download transaction history, transfer money to other account, top up credit.

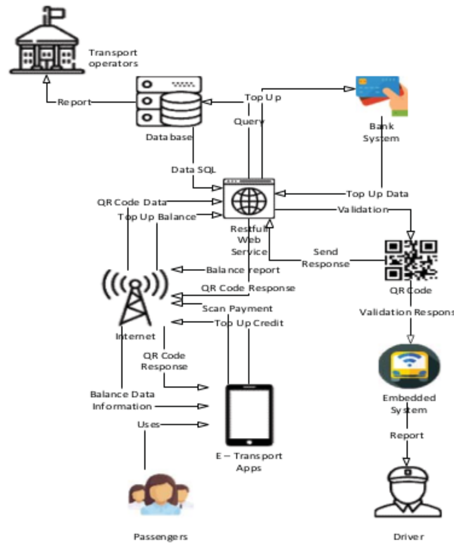

Fig. 2. A. Integrated E-Ticketing architecture design

- For the transportation operators, the architecture will provide dashboard interfaces to access the central database for generating reports. In addition, using the dashboard, they can also gather information about transportation usage, transactions, and other statistics. The dashboard also provides data visualisation to assist the operators with strategic analysis and to make decision making process more accurate and faster.

- The architecture is also designed to enable communication and data exchange with bank system. This feature is designed to enable the passenger to have virtual account as their e-wallet. the application consumes the API (Application Programming Interface) provided by the bank as a mechanism to conduct virtual transactions between passengers and bank including top up credit and transaction history report.

- Finally, the architecture also enables the automatic authentication when the passengers use the transportation services. The validation system embedded in the vehicles will calculate the fares based on the tariff policies for instance distance, zone, passenger categories, time and concession. The system also enables the driver to access and generate report on the usage every time the operation is finished.

B. *real-time vehicle information position architecture*

During the data collection, the respondents highlighted an important issue that must be addressed during the survey was the limited information and uncertainty about the public transportation services especially when unexpected events occur. In addition, the poor quality and availability of the information may also hinder the passengers from using public transportation services. This implies that the availability of clear and real-time information relating to the public transportation operations is one of the provisions for improving the quality of public transportation services. While for operators, this also important to support them provide better services to customer.

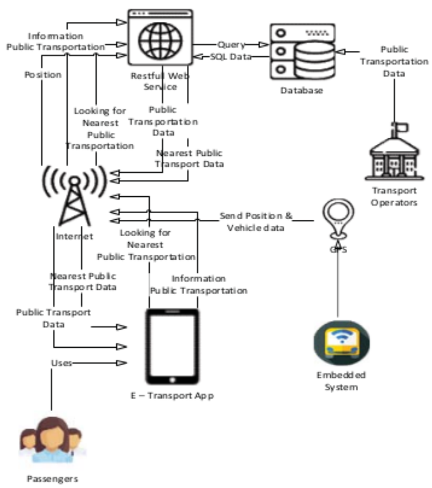

Fig. 3. Real-time vehicle information position architecture design

Fig. 3 shows the architecture design of a real-time vehicle information system and how it addresses the problems above.

- The architecture is designed to send vehicles' data and the live position automatically using the system embedded on board. The system will also update the position; calculate the arrival time to the nearest stop based on the current road traffic condition and then send to the server for real-time monitoring. In case of disruption or emergency, the system will broadcast notification along with the live location to server.
- The architecture will enable passengers request various information regarding the current status of public transportation modes they wish to use through E-transportation app. The information they requested may include vehicle live position, estimated departure time, next transit, seat availability, and type of vehicle. When the passenger on board, they can get notification about estimated arrival time, next or previous stops, trip tracking, transits, interchanges, connecting lines and important announcement. In the case of unexpected situations, the passengers will receive information about emergency or contingency plan, the estimated delay time, planned detours, alternative routes, and location-aware during the disruption.
- For the operators, the architecture will provide them with dashboard interfaces to track and monitor the transportation modes they operate; analyse the usage, get real-time notification regarding accident, delay, disruption or other unexpected situations. The architecture also has query interfaces to enable operators gain particular information they wish. Finally, the operators will be able to post important message or notification and then broadcast to all users who are currently off and on board.

C. *Smart trip assistance architecture design*

The data collection also identified the growing requirements on the need for integrated travel information which could provide passengers trip recommendation to reduce search time, and find the best transportation modes based on their preferences. There also greater need for more information about multi-modal trip planner, interchanges location, facilities (e.g. restaurant, hotel and shop) around the station, fares, and total travel time especially to foreigners of those who are not familiar and rarely use public transportation. Fig. 4 illustrates how such requirements are captured in the following architecture design.

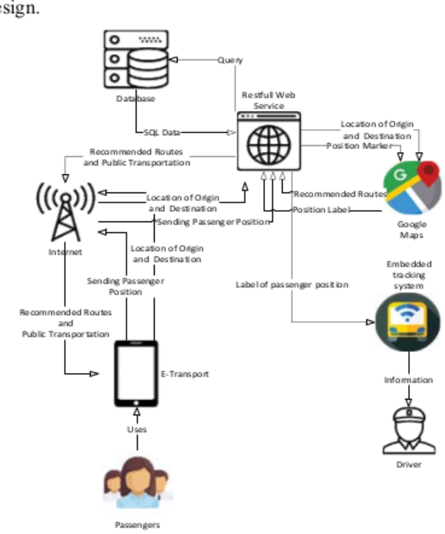

Fig. 4. Smart trip assistance architecture design

As can be seen in Fig. 4, the architecture ties together internal and external systems to provide integrated travel information system for passengers. The external system mainly employs Google Map to record and track the actual vehicle location from which is then used to arrange pre-trip information using shortest path route algorithm, showing schedule, calculate arrival time and generate multimodality trip or interchanges along with the fares. The Google Map services also offers digital map to identify facilities near the passengers' location or vehicles' stops as well as imagery satellite such as street view, direction, shortest path and traffic update. All these information is store in the

framework provided in the earlier works. A key strength of this study is the requirements or provisions were derived based on the feedback and the voices of the passenger making the architecture locally relevant. In the context of developing county, like Indonesia, the findings of this study could be used to help authorities that plan to develop integrated information systems to improve and make their public transportation more convenience and safer. Finally, further design action research needs to be carried out to implement the proposed architectures above into working prototype or fully functioned application.

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