Sustainability and Industrial Engineering Perspectives on Industry 4.0 and Electronic Device in Toll Gate

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Abstract

This discourse elaborates the theoretical aspect on sustainability and industrial engineering (SIE) on applied technology within Industry 4.0 and E Device in Toll Gate. This aforementioned SIE refer to empirical perspectives on PT Jasa Marga (Persero) Tbk,. This company constitutes the regulator of toll gates. Subsequently, this company envisages to implement 100% touchless payment system, known as using On Board Unit (OBU). This paper conveys research purpose of obtaining the insight and public expectations vis-à-vis OBU. Ultimately it explores further research on related device, promotions and collaborations. Within the industrial engineering method and Industry 4.0, furthermore, this paper meticulously evaluates the measurement of resulted efficiency versus transaction time as it is intertwined with House of Quality (HoQ). Posterior to research methodology sequences, this paper generates summarized result of selecting Single Piece Microwave OBU. This selection is combined with a promotional program within collaboration of gas stations and its discounted purchasing an OBU tool. Ultimately, the resulted ratio and further results are the following. First, V/C Ratio and simulation modelling methods indicate that the utilization of OBU tool has effect and implies the reduction of transaction time by 47,48% and 56,23%.

Keywords
Sustainability, Industry 4.0, Industrial Engineering, Electronic Device, House of Quality

1. Introduction

PT Jasa Marga (Persero) Tbk, is one of regulator companies on toll roads in Indonesia. It has implemented payment transactions to be 100% non-cash vis-à-vis an e-toll card, as one of the Electronic Toll Collection (ETC) tools. The implementation of non-cash transactions is one of supporting policies toward Bank Indonesia's program, namely the National Non-Cash Movement, known as Gerakan Nasional Non Tunai (GNNT). This policy has the objectives encouraging people to increase the use of non-cash payments as a transaction tool. To some extent, the policy to implement 100% non-cash transaction is to increase the effectiveness and efficiency of transaction time, as stated in the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 16/PRT/M/2017. This regulation provides services to toll road users effective, efficient, safe and convenient. Precisely, it is necessary to develop technology for cashless payment systems that can facilitate toll road accessibility and reduce transaction service time at toll gates. As an effort to overcome congestion at toll gates due to the high volume of vehicles, in which non-cash toll transaction is implemented. The application of ETC in Indonesia is not only limited vis-à-vis e-toll cards,. That technology development continues so that there is a technology called contactless for toll road payments. Contactless transactions are transactions carried out by road users without having physical contact with toll transaction equipment.

The stages of implementing ETC in Indonesia commence from implementing the use of e-toll cards as a means of overall transactions on toll roads. Subsequently, preparations for the application of the next technology called Multi Lane Free Flow (MLFF) are carried out. MLFF is a toll payment transaction process without having to stop the vehicle at the toll booth, in which case the toll booth is removed, in this case MLFF is included in contactless technology. Current available technology that has been used by toll road users can support contactless transactions. It refers to the tool, known as On Board Unit (OBU). OBU is a payment instrument with a sensor system so that users do not need to open the windshield to stick the card in the reader. The specifications for the existing OBU tools are in accordance with Governor Regulation Number 149 of 2016 Article 8 paragraph 1 point c regarding Electronic Paid Toll Road System Technology, namely 'using short-range Dedicated Short Range Communication (DSRC) with a frequency of 5.8 GHz (five point eight gigahertz)', however, due to several pros and cons, the regulation was revised by the Governor of DKI Jakarta by eliminating the provisions regarding Dedicated Short Range Communication (DSRC) with a frequency of 5.8 GHz (five point eight gigahertz), With this revision, the OBU tool does not have to be driven by DSRC technology, so that other technologies can participate in selecting the appropriate technology to use. One of the technologies being considered is Radio Frequency Identification (RFID).
In the implementation of 100% non-cash electrification with an e-toll card that has been carried out, there are pros and cons from toll road users, as well as if MLFF is implemented where the OBU tool is used 100%. Therefore, it is necessary to explore user expectations regarding this OBU tool, the goal is that the OBU tool can be well received and in accordance with the wishes of the user. This exploration is carried out by distributing online questionnaires, then the results obtained can be made a House of Quality (HoQ) regarding the wishes of toll road users and how these wishes can be fulfilled by the company. The results obtained are expected to be considered as a consideration for the selection of OBU technology that will be determined for future use.

As an effort to attract the attention of toll road users to switch to using e-toll cards into OBU tools, various promo programs and collaborations with other companies can be carried out, for example, providing discounts, awarding points, and so on. In general, differences in residence can affect toll road users' different interest in promotions and collaborations. Therefore, the k-means clustering method is used as a reference for decision making to determine what kind of promo and cooperation programs can be carried out in each region, especially the Jabodetabek area.
One of the purposes of using the OBU tool as a transaction tool is to reduce or even eliminate queuing time at toll gates, so that users do not have to experience congestion due to bottlenecks at toll booths, in this case it is about transaction time efficiency. In the exploration of the questionnaire, one of which contained the time efficiency of transactions with the OBU tool. As a tool to prove time efficiency with the OBU tool, V/C Ratio calculations and simulation modeling are carried out. In this study, the calculation of the V/C Ratio on the CTC Branch (Cawang-Tomang-Cengkareng) toll road section, totaling 27 toll gates, was carried out. They are intended to evaluate the capacity or performance of each toll gate to conduct transactions. The calculation of the V/C Ratio produces an analysis of density or congestion at toll booths when toll road users make transactions, this can be related to the simulation modeling method whose output is the average transaction time and congestion queue. In the V/C Ratio method and simulation modeling, a comparison of the output between the transaction process using e-toll cards and OBU tools is carried out with the same number of transaction data, so that it can be determined

2. Literature Review

2.1. Sustainability

Sustainability is the key trending topics in every aspects of human kind. This paper elaborates both theoretical and empirical aspects of sustainability. Through Bibliometric approach, then, Sustainability has been gaining its intensities in term of its theoretical aspects in journal publication and its empirical perspective in specific continents and in global scope. The aforementioned publications are ranging from 2002 until 2019, throughout Europe, United States of America and Asia, as they are illustrated in Figure 1, comprising several scholar works (Karjalainen and Juhola 2021).

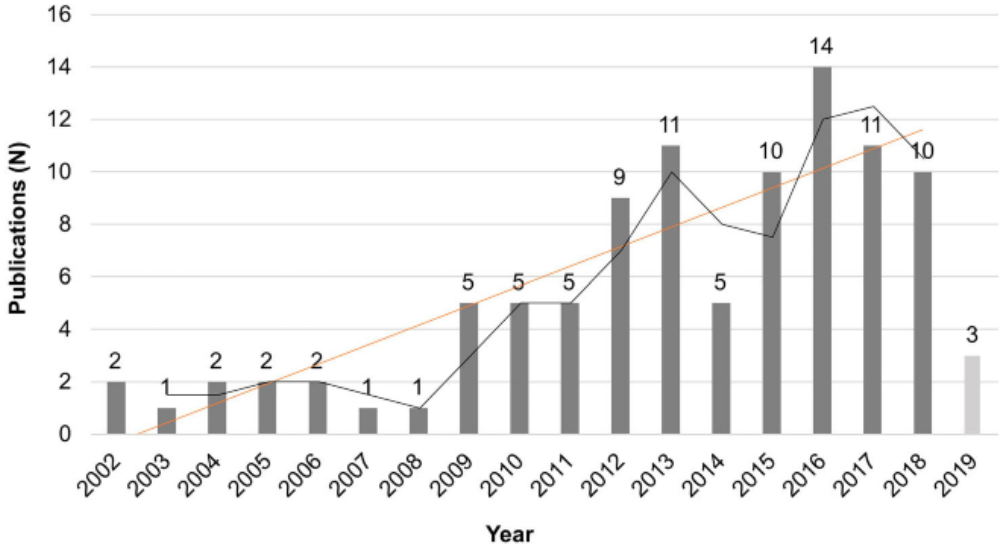

Figure 1. Sustainability Journal Publications from 2002 until 2019

Traffic congestion and relevant problems constitute ubiquitous problems in every city, including smart city. These problems are escalating with the growth of number of vehicles and the traffic congestion in vicinity of toll gate. As city becomes sophisticated from years to years, the involvement of technology is getting intense. Ubiquitous technologies are capitalized vis-à-vis urban infrastructure development for both planning and maintenance to ensure the reduction of traffic congestion, including in toll gate. To begin with the technologies refer to intelligent traffic control, intelligent vehicle or infrastructure related technologies in addition to RFID on OBU and, or MLFF Perspectives.

In addition to the need to include technologies in the equations, it is important to consider the policies in the effort of achieving sustainability. Common policies on this sustainability refer to sustainability planning and policies (Olofsson et al. 2016; Sdoukopoulos et al. 2019). Those policies have significant challenges vis-à-vis the conceptual on sustainability policies versus the common empirical and its implementation. (Marsden et al. 2010). Subsequently, the adequacy of utilized assessment methods require wide array of coverage on sustainability that intertwines with its policies throughout its relevant stakeholders (Jeon & Amekudzi 2005; Marsden et al. 2010), (Banister 2008; Olofsson et al. 2016).

2.2. Industry 4.0

The RFID including the implementation on OBU, E-OBU, and MLFF, requires the involvement of technologies. Specifically, these technologies involvement comprise wider perspectives through the lens of Industry 4.0 in which technologies, known as specifically: big data, cloud computing and 3D within its implementation (Makris et al. 2019). The key factors for those technologies involvement refer to the digitalization in term of digital transformation of Industry 4.0 on Toll Gate, through OBU, E-OBU, and MLFF (Bienhaus & Haddud 2017).

The industry 4.0 discussion can't be separated with its relevancies within logistics, in term of logistics 4.0 and or supply chain 4.0, within the perspective urban transportation. These relevancies, begin with the discourse on readiness factors, as any new technologies require further adaptation and transition to be implemented in the full swing (Sony and Naik, 2019; (Akyus and Reyhan 2009).

To some extent, the logistics 4.0 and or supply chain 4.0 refers to the digitalization within digital transformation, in which it is implementable within toll gate, as discussed in this paper as part of research methods' guidelines (Burgers et al. 2019), (Gupta et al 2018), (Fortin et al 2012), (Bearman et al 2012), (Seuring and Gold 2012) and (Ganann et al. 2010).

2.3 Radio Frequency Identification (RFID)

Prior to elaborate RFID in detail manner, this session intertwine both sustainability and Industry 4.0. To begin with, the sustainability refers to the transportation in toll gate that relate to OBU, E-OBU, and MLFF in which sustainability and policies constitute the important aspect in urban transportation along with its traffic congestion problems (Pajak and Cyplik 2020) and eventually driver behavior in ensuring smooth and discipline driving manners g (Thisaiveerasingam and Jayaweer Bandara 2019). By comparison, barcode scanner, and versus RFID, in this case RFID is identified through its enhancement, vis-à-vis distance and utilization. Precisely RFID is more flexible for different types of usage, through its trilogy components of operations, as transponder, integrator, and software (Noonpakdee et al. 2018).

3. Methods

3.1 Sustainability Approach and Tools

Sustainability is deemed important in transportation, including in discussion in this paper. The approaches and tools of related sustainability topics refer to trilogy of social, environmental and economics. The papers that comprise all those trilogies are ranging from topic of mobility projects, into freight courier operations, sustainability level, sustainable selection level, alternative fuel vehicles, and eco efficiency (Awasthi et al. 2018); (Bandeira et Al. 2018), (Bojkovi´c et al. 2010),

3.2 House of Quality (HoQ)

House of Quality (HoQ) in this paper has a common relevancy with the sustainability and related discussions. HoQ is defined as device for designing product processes to interpret customer need into engineering perspectives for production purpose. House of quality is resulted from customer needs as it is interpreted into technology and calculated vis-à-vis market launching (Sheng and Wang 2014).

HoQ is deemed important in determining Customer Needs dan Customer Importance. The process prior a product or service is designed; the manufacturer is required to comply with good understanding customers' potential need vis-à-vis the augmented quality of product or service designed will be successful in the market. Ways to find out input (needs) from customers can be done by Focus Group Discussions (FGD), user groups, surveys, questionnaires, and so on (Goetsch and Davis 2014).

4. Data Collection

The questionnaires constitute major part of collecting the data needed for the methods that will be used in solving existing problems. The data collected pertains a. Questionnaire for assessing the use of OBU tools, b. Questionnaires for assessing the important factors of OBU tools, hourly traffic volume on the Jasa Marga CTC branch toll roads when transacting using e-toll cards and OBU tools.

Questionnaire data for assessing the use and important assessment factors of the OBU tool were distributed through an online platform with 311 respondents and 112 respondents respectively. The hourly traffic volume data on the Jasa Marga CTC branch toll road uses volume recapitulation which is for a period of 24 hours. Meanwhile, Time data collection for transactions with e-toll cards is carried out at GT Cililitan Gardu 9 at 14:00 to 15:30 which produces data on 288 vehicles. Transaction time data collection using the OBU tool is carried out at GT Cililitan Gardu 10 at 14:00 to 15:30, at 10:00 to 16:00, at 09:00 to 13:30 which in total produces data on 225 vehicles.

The distribution of the questionnaire in this study aims to explore the wishes or expectations of toll road users for the OBU tool which in the future will be used as a means of paying for toll roads. This questionnaire was distributed through an online platform and resulted in 311 respondents. Furthermore, the stage of processing data from data that has been collected using predetermined methods. The method used in this research is the House of Quality (HoQ), technical drawing using Inventor software, data mining, V/C Ratio and simulation modeling.

Subsequently, the next stage comprises of analyzing each result of existing data processing based on relevant methods in accordance with the existing problems. Ultimately, in term of conclusions, the results of research that have been carried out based on the formulation of existing problems and provide suggestions that can be useful for companies to optimize the performance of electronic toll collection in the application of non-cash transaction systems on toll roads. Table 1 constitute tabulation of the results of collecting questionnaire data obtained, through several parameters that are included in the considerations.

Table 1. Respondents Profile According to its Variables

Variables	Choices	Frequencies	Percentages
Age	17 – 25 Years Old	228	73,31%
	26 – 35 Years Old	24	7,72%
	36 – 50 Years Old	17	5,47%
	> 50 Years Old	42	13,50%
Gender	Male	212	68,17%
	Female	99	31,83%
Residences	Bandung	7	2,25%
	Bekasi	21	6,75%
	Bogor	13	4,18%
	Depok	4	1,29%
	DKI Jakarta	192	61,74%
	Tangerang	38	12,22%
	Others	36	11,58%
Profession	Private	74	23,79%
	SOE	6	1,93%
	Housewives	6	1,93%
	Students	189	60,77%
	Government Employee	3	0,96%
	Employees	5	1,61%
	Entrepreneurs	23	7,40%
	Others	5	1,61%
Incomes	< IDR 1.000.000	83	26,69%
	IDR 1.000.000 –3.000.000	97	31,19%
	IDR 3.000.000 – 8.000.000	57	18,33%
	IDR 8.000.000 – 15.000.000	31	9,97%
	Rp 15.000.000 – 25.000.000	12	3,86%
	> IDR 25.000.000	27	8,68%
	Others	4	1,29%

5. Results

5.1 Visualization of Table 1 in Figure 2

The results in this 5.1 session focuses on the visualization of prior table 1, as depicted in the Figure 1.

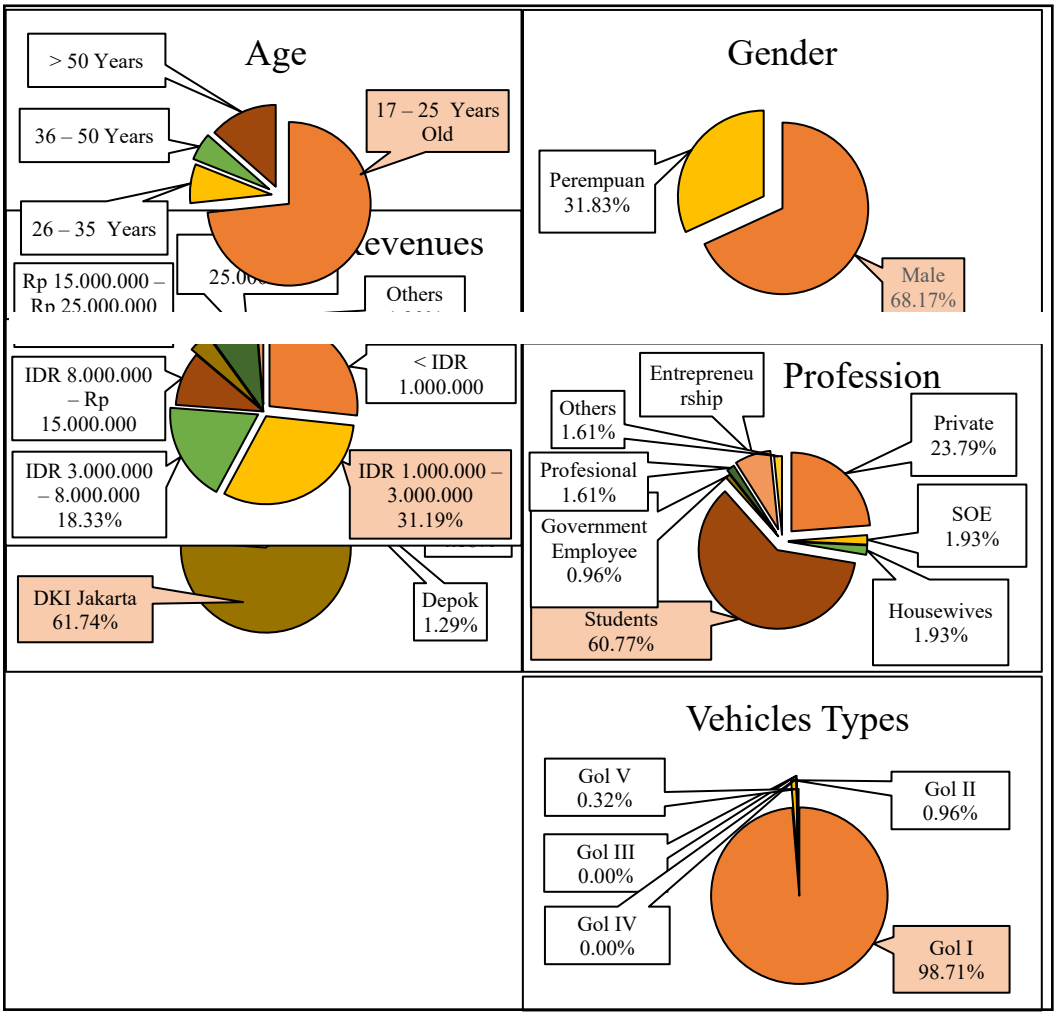

Figure 2 Visualization of Respondents Profile According to its Variables

5.2 Questionnaires on OBU Usage

Table 2 below is a tabulation of the results of the questionnaire where respondents have used the OBU tool as a transaction tool at toll booths, this questionnaire contains the convenience, constraints, size suitability and time efficiency of using the OBU tool:

Table 2. OBU Parameters and Considerations

Variables	Choices	Frequencies	Percentages
Ease of OBU Usage	Very easy	44	53,01%
	Easy	37	44,58%
	Difficult	1	1,20%
	Very difficult	1	1,20%
OBU Dimension	Appropriate	54	65,06%
	Too thick	19	22,89%
	Too wide	5	6,02%
	Too heavy	3	3,61%
	Others	2	2,41%
OBU Accelerated Transaction	Yes	78	93,98%
	No	5	6,02%
OBU Barriers on Usage	Easily damage	6	5,26%
	Lack of gates	34	29,82%
	Lack of banking collaborations other than Mandiri	34	29,82%
	Sensor not sensitive	33	28,95%
	OBU is too big	3	2,63%
	Others	4	3,51%

6. Conclusion

Sustainability and industrial engineering (SIE) on applied technology within Industry 4.0 and E Device in Toll Gate constitutes indispensable materials for both theoretical and empirical. This paper conveys research purpose of obtaining the insight and public expectations vis-à-vis OBU. It explores subsequent research on related device, promotions and collaborations. Within the industrial engineering method and Industry 4.0, furthermore, this paper meticulously evaluates the measurement of resulted efficiency versus transaction time as it is intertwined with House of Quality (HoQ).

From theoretical perspectives, this paper elaborates the literature review on mainly, but not limited to sustainability, industry 4.0 and RFID. As it is indispensable to expand beyond those three theoretical perspectives, in addition to empirical application in PT. Jasa Marga (Persero) Tbk. Posterior to research methodology sequences, this paper generates summarized result of selecting Single Piece Microwave OBU. This selection is combined with a promotional program within collaboration of gas stations and its discounted purchasing an OBU tool. Ultimately, the resulted ratio and further results are the following. First, V/C Ratio and simulation modelling methods indicate that the utilization of OBU tool has effect and implies the reduction of transaction time by 47,48% and 56,23%.

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Biography

Khristian Edi Nugroho Soebandrija is a practitioner in the field of engineering, with study and working exposures in Europe, Asia and United States of America. Currently, he is one of lecturer specialist PhD level, in BINUS ASO School of Engineering. He has been awarded as distinguished honor membership in Sigma Gamma Tau, known as Aerospace Engineering Honor Society; and Tau Beta Pi, known as National Honor Society in USA. He is one of Institute of Industrial Engineers (IIE), in which IIE is now becoming Institute of Industrial and Systems Engineers (IISE).

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#716 as the faculty advisor, resulting in the continual achievement of the Chapter's Gold Award ever since its establishment (2012-2020). She received an outstanding faculty advisor award from the IISE for Southeast Asia Regional Winner in 2016, 2018, 2019 and Asian Regional Winner in 2017 and 2020. She is also a fellow in Industrial Engineering and Operations Management (IEOM) society and is actively involved in numerous IEOM conferences. Concurrently, her previous working experience as a notable CEO in the automotive industry (Audi & Volkswagen Indonesia: awarded as one of 40 best executives in Indonesia in 2002, SWA Magazine) has led her to the frequent invitation as a special guest lecturer in various leading industries.