Sustainable industrial systems within kernel density analysis of artificial intelligence and industry 4.0

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Abstract. This paper conveys the theoretical perspectives of sustainable industrial systems of On board Unit (OBU) in Electronic Toll and its transportation industry. It proposes kernel density analysis of artificial intelligence approach to industry 4.0. Regulation for technology developments in artificial intelligence and robotics are deemed as one of beneficial yet structurally neglected domain. This domain refers to human perspective on augmenting automation. This regulation was emphasized in 2017 by the European Parliament report level. The mentioned regulation comprises attention in Indonesia transportation industry indicating positive innovation domains in term of safeguards and regulations are needed. Prior, current and posterior trends of the Internet of Things, Industry 4.0, and Physical Internet constitutes the results of the data development and understanding. Therefore, the topical framework of automation and robotics are triggered by these developments. The mention triggers has impacted the most important wide range implementation of industries in the future. Electronic Toll Collection (ETC) system is 40% higher in cost efficiency than Manual Toll Collection (MTC) system. In this situation, Indonesian government has already issued full swing policy implementation on non-contact freeway toll collection system by the end of 2018. Structural Equation Modelling (SEM) is capitalized to proceed to data processing. Result of this research shown the driver's characteristics that significantly affect willingness to pay an on-board unit are education expenses, distance and frequency. The average value of driver willing to pay an on-board unit was 225.781 IDR and factors that affecting values of the willingness to pay an on-board unit are expenses and distance.

Keywords: Kernel density analysis, Artificial intelligence, Industry 4.0, Internet of things, Physical internet
1. Introduction

Car ownership and its growing number in developing-countries, including in Indonesia, are augmented dramatic. According to recent study, Jasa Marga as Indonesian Highway Corporation (2016), indicated that total toll traffic volume in Indonesia is at the level of 1,361.5 million vehicles in 2016. This volume is augmented by 58.44% from total toll traffic volume in 2007. That volume is represented by 859.32 million additional vehicles. The significant and obvious situation occurred on the Cawang-Tomang-Cengkareng toll road section. The mentioned section constitutes the largest proportion of total toll traffic volume during prior ten years. This section contributes an average growth of 1.9% of traffic volume annually and in 2016 the daily average volume is represented by 598.056 vehicles. Given that situation and its growth, Indonesia is deemed indispensable to improve its toll fee collection system. This system has to provide required characteristics of fast and secure one, that are applicable to both toll road user and operators [13]. Electronic Toll Collection (ETC) system is 40% higher than Manual Toll Collection (MTC) system. Jasa Marga as Indonesian Highway Corporation conveys that merely 33.5% of nation-wide toll transaction is capitalizing ETC system. Indonesian Government as a regulator issuing a policy to solve this situation. This government proceed to follow up by ceasing all Manual Toll Collection (MTC) system at all toll gates. Eventually that MTC is shifted to full scale e-money implementation at the end of October 2017. Ultimately, further policy is issued to implement full swing regulation toward non-contact freeway toll collection system by the end of 2018.

Sustainable industrial systems

Sustainable industrial systems constitute the arching theoretical perspectives toward artificial intelligence and industry 4.0. This paper proposes the theoretical perspectives of sustainable industrial systems pertaining one of On board Unit (OBU) in Electronic Toll and its transportation industry.

Regulation for technology developments in artificial intelligence and robotics are deemed as one of beneficial yet structurally neglected domain [28]. Regulation for technology developments in artificial intelligence and robotics are deemed as one of beneficial yet structurally neglected domain. This domain refers to human perspective on augmenting automation. This regulation was emphasized in 2017 by the European Parliament report level. The mentioned regulation comprises attention in Indonesia transportation industry indicating positive innovation domains in term of safeguards and regulations are needed. Prior, current and posterior trends of the Internet of Things, Industry 4.0, and Physical Internet constitute the results of the data development and understanding. Therefore, the topical framework of automation and robotics are triggered by these developments.

Given the important theoretical implication of sustainable industrial systems, several authors have elaborated the sustainable industrial systems toward human perspective on augmenting automation [17]. The sustainability industrial systems are deemed beneficial not merely in theoretical view, but also in in term of safeguards and regulations are needed [5] vis-à-vis world-class and sustainable company [21].

Several scholars have elaborated their scholar works in order to comprehend how sustainable industrial systems can transform transportation industry into group of companies that obtain trends of the Internet of Things, Industry 4.0, and Physical Internet that constitute the results of the data development and understanding [15], [30], [2], [22],[1], [26] and [27]. Ultimately, other scholars have elaborated the resource-based view and Porter generic strategies to comprehend how company deals vis-à-vis artificial intelligence and human
perspectives. However, it is conveyed that the dynamic capability views have scholars work constraints that elaborate framework of automation and robotics in term of sustainable industrial systems [27].

**Artificial Intelligence: Kernel Density Analysis in Computer Science and Engineering**

Artificial Intelligence (AI) is a subject that studies theories, methods, and applications with respect to simulation, extension, and expansion of human intelligence for problem-solving. Application domains of AI include robotics, voice recognition, image recognition, natural language processing, and expert systems [33].

AI, as a branch of computer science, aims to understand the essence of intelligence, and design intelligent machines that can act as human behavior. AI has attracted researchers with respect to its theories and principles since the 1956 Dartmouth conference [24]. The growth of article outputs in artificial intelligence research has exploded since the 1990s, along with increasing collaboration, reference, and citations. Computer science and engineering were the most frequently-used subject categories in artificial intelligence studies [23].

In order to perform the kernel density analysis, this paper at the commencement stage introduced kernel density estimation to visualize the worldwide geographic distribution of authors. Furthermore, this kernel density estimator is intended to represent the worldwide geographic distribution of authors. Let \((x_1, x_2, \ldots, x_n)\) be the spatial coordinates of authors in the field of AI, which is a distribution with unknown density [26].

Its kernel density estimator can be formulated through the following formula:

\[
\hat{f}_h(x) = \frac{1}{n} \sum_{i=1}^{n} K_h \left( \frac{x - x_i}{h} \right)
\]

where \(K(\cdot)\) is the kernel, and \(h\) is a smoothing parameter often referred to as the bandwidth. By means of the kernel density estimator, a continuous surface generated by the quantity of authors all over the world based on the original data. Ultimately, the worldwide geographic distribution of authors can be overlaid with the world map to depict the hotspot area of AI research.

Scholar works on AI were published on 2599 journals and 958 proceedings, as illustrated in table 1 for the 20 most prolific journals. Thus, it is concluded that a high concentration of artificial intelligence scholar works are published in these journals. The mentioned 20 journals (0.6% of 3557 journals) or proceedings have contributed for 1,976 articles, or 9.5% of the total articles.

It is observed that Expert Systems with Applications published the most articles on AI (344). On second place, Engineering Applications of Artificial Intelligence (161), AI Magazine (161), Artificial Intelligence (126), and Knowledge-based Systems (103). AI-related articles published in the mentioned journals have achieved, on average, 13.3 citations, conveying that these scholar works have substantial influences on these artificial intelligence.
Furthermore, several journals published a significance number of highly cited articles, including Artificial Intelligence. Precisely, those are 126 articles with 7341 citations; and IEEE Transactions on Information Theory. Precisely, those are 7 articles with 4524 citations.

**Table 1. Most prolific journals in artificial intelligence research.**

| Year | TA | AU | AU/TAR | NR | NR/TAR | PG | PG/TAR | TC | CPA |
|------|----|----|--------|----|--------|----|--------|----|-----|
| 1990 | 212| 437| 2.1    | 1948| 9.2    | 2017| 9.5    | 706| 3.3 |
| 1991 | 477| 1002| 2.1  | 8166| 17.1   | 5477| 11.5   | 7029| 14.7|
| 1992 | 576| 1357| 2.4  | 8226| 14.3   | 6062| 10.5   | 5403| 9.4 |
| 1993 | 492| 1231| 2.5  | 7985| 16.2   | 5217| 10.6   | 4332| 8.8 |
| 1994 | 576| 1407| 2.4  | 12,576| 21.8 | 12,082| 21.0 | 4667| 8.1 |
| 1995 | 489| 1161| 2.4  | 10,344| 21.2 | 6257| 12.8 | 7015| 14.3|
| 1996 | 534| 1335| 2.5  | 9482| 17.8 | 5691| 10.7 | 3868| 7.2 |
| 1997 | 667| 1676| 2.5  | 10,833| 16.2 | 8683| 13.0 | 7946| 11.9|
| 1998 | 693| 1808| 2.6  | 12,930| 18.7 | 7338| 10.6 | 7688| 11.4|
| 1999 | 541| 1371| 2.5  | 11,742| 21.7 | 6378| 11.8 | 5619| 13.4|
| 2000 | 616| 1713| 2.8  | 12,511| 20.3 | 6722| 10.9 | 6952| 11.3|
| 2001 | 672| 1869| 2.8  | 14,530| 21.6 | 7339| 11.0 | 10,498| 13.6|
| 2002 | 688| 1828| 2.6  | 14,199| 20.3 | 7040| 10.1 | 5991| 8.6 |
| 2003 | 834| 2354| 2.8  | 16,697| 20.0 | 8491| 10.2 | 6830| 8.2 |
| 2004 | 936| 2719| 2.9  | 19,442| 20.8 | 9497| 10.1 | 8267| 8.8 |
| 2005 | 1009| 2826| 2.8 | 18,833| 18.7 | 9573| 9.5 | 5839| 5.8 |
| 2006 | 1102| 3248| 2.9 | 23,748| 21.5 | 10,788| 9.8 | 6276| 5.7 |
| 2007 | 1107| 3163| 2.9 | 23,692| 21.4 | 10,926| 9.9 | 7360| 6.6 |
| 2008 | 1234| 3543| 2.9 | 26,857| 21.8 | 11,344| 9.2 | 6412| 5.2 |
| 2009 | 1388| 4104| 3.0 | 30,768| 22.2 | 12,685| 9.1 | 6906| 5.0 |
| 2010 | 1073| 3338| 3.1 | 26,878| 25.0 | 11,111| 10.4 | 4928| 4.6 |
| 2011 | 1090| 3445| 3.2 | 28,424| 26.1 | 11,498| 10.5 | 4391| 4.0 |
| 2012 | 1222| 3959| 3.2 | 35,036| 28.7 | 12,476| 10.2 | 3376| 2.8 |
| 2013 | 1324| 4437| 3.4 | 38,571| 29.1 | 13,241| 10.0 | 1824| 1.4 |
| 2014 | 1153| 3971| 3.4 | 39,783| 34.5 | 13,623| 11.8 | 767| 0.7 |
| Total | 20,715| 59,302| / | 464,204| / | 221,545| / | 141,050| / |
| Average | / | 2965| 3.4 | 23,210| 26.3 | 11,077| 13.7 | 7053| 9.7 |

TA: Total articles; AU: number of authors; NR: cited references; PG: page count; TC: total citation counts; CPA: citations per article; TU/TAR, NR/TAR and PG/TAR: average of authors, references, and pages per article, respectively.

This paper and table 1 of scholar work of Niu et al., 2018 has elaborated the evaluation of artificial intelligence research from years ranging from 1990–2014 by using bibliometric analysis. Precisely, this paper elaborated spatial analysis and social network analysis as geographic information retrieval methods for spatially-explicit bibliometric analysis. This study and scholar work of Niu et al., 2018 refers to analysis of data originated from database of the Science Citation Index Expanded (SCI-Expanded) and Conference Proceedings Citation Index-Science (CPCI-S) [23 and 42].

**Industry 4.0 within its concept**

Disruptive Innovation Theory of Christensen and Bower (1995) nowadays is applicable and could outperform both entrant and incumbent transportation company. The original theory and its revamped versions [3] and [41] indicate that disruption is applicable within artificial intelligence and industry 4.0.

The mentioned industry 4.0 refers to respectively global setting of industrial revolution 4.0 of Davos, as depicted in table 2 scholar work of Niu et al., 2016 [42]. Ultimately, it refers
to Indonesia local setting and culture in term of Making Indonesia 4.0, as initiated by President of Republic Indonesia, Joko Widodo prior April 2018.

Table 2. Definition of Industry 4.0 and its related concepts to scholar work of Niu et al., 2016

| Term/Concept            | Author                          | Definition                                                                                                                                 |
|-------------------------|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| Industry 4.0            | Platform I4.0                   | Industry 4.0 is a reform and re-organization of value chain to a networked coordination in the era of 4t industrial revolution. More precise, industry 4.0 uses real-time individual customer request and environment balances ('big data") from all participant institutions of the value chain to holistically integrate the production process |
| Industry 4.0            | Schmidt et al. (2015)           | Industry 4.0 is the superposition of several technology development that embrace both product and processes. It is related to the so-called cyber physical system that describe the merger of digital with physical workflow |
| Industry 4.0            | Sendler (2013) p.7              | Industry 4.0 is the linking of product and services with one another and with their respective environment through the internet and other network services that enables the development of new product and services so that many functions of products work autonomously - without human intervention |
| Industry 4.0            | Felser (2015)                   | Industry 4.0 realizes an optimized collaborative value (smarter services and processes) by a smart cooperation of new and enhanced competences and capabilities in a supply network on basis of new technologies, in particular information and communication technologies |
| Industry 4.0            | Schmidt et al. (2015)           | Industry 4.0 shall be defined as the embedding of smart products into digital and physical processes. Digital and Physical processes interact with each other and cross geographical and organizational border |
| Cyber-physical system   | Sendler (2013) p.8              | Cyber-physical system is a network of interacting elements with physical in- and output in contrast to stand alone machine but also in contrast to sole data or communication networks without physical in- and output |
| Cyber-physical system   | Schmidt et al. (2015)           | Cyber-physical system include compute and storage capacity, mechanics and electronics, and are based on internet as a communication medium |
| Internet of Things      | Sendler (2013) p.9              | Internet of Things/ Internet of Things and services is describing a new evolutionary step of the internet, as not only computers (including mobile terminal devices) are embedded in the network but any devices. |
| Internet of Things      | Kovatsch et al. (2012)          | Unlike traditional networked embedded systems, the Internet of Things interconnects heterogeneous devices from various manufacturers with diverse functionalities |
| Smart Factory           | Radwizon et al. (2014)          | A Smart factory is a manufacturing solution that provides such flexible and adaptive production processes that will solve the problems arising on a production facility with dynamic and rapidly changing boundary condition in a world of increasing complexity. This solution could be related to automation, understood as a combination of software, hardware and mechanics. On the other hand, it could be a seen in a perspective of collaboration between different industrial and non-industrial partner, where the smartness comes from forming a dynamic organization |
| Smart Products/Entities | Schmidt et al. (2015)           | Smart products are product that are capable to do computations, store data, communicate and interact with their environment |

2. Methods

Data Collection

This session elaborates information on how to collect data within process of data collection. Total 100 drivers are invited in data collection through survey periods during 3rd week of September 2017. Among those 100 drivers, eventually 85 drivers are deciding to participate.
Total 6 indicators were developed for preliminary research according to the following parameters: First, the indicator constitutes Drivers’ Distance Trips (DT). The mentioned indicator means that they are willing to use toll for distance trips less or equal to 30 km (DT1); and willing to use toll for distance trips more than 30 km (DT2). Second, the indicator constitutes Drivers’ Trip Frequencies (TF). The mentioned indicator means that they are willingness to use the toll for the single destination trip (TF1); and willingness to use the toll for two destination trips (TF2). Third, the indicator constitutes willingness to pay an OBU (WTP). The mentioned indicator means that they are willingness to pay an OBU at current price 450.000 IDR (WTP1); and willingness to pay an OBU at suggested price 500.000 IDR(WTP2).

The survey was performed using the so called Likert-scale-type. This scale is indicated by response 1 (Strongly disagree) until its response of 4 (strongly agree). This preliminary research in this paper is capitalizing software that is known as, SmartPLS software.

Hypotheses of preliminary research are indicated in the following hypotheses of:
- Drivers’ distance trips had positive and significant effect on willingness to pay (H_1)
- Drivers’ trip frequencies had positive and significant effect on willingness to pay (H_2).

Data Processing

The data processing in this paper is using software known as structural equation modelling (PLS-SEM). This PLS-SEM is also known as Partial Least Square Path Modelling (PLS-PM) and its structural measurement [29].

Measurement Model (Outer Model) Test

The convergent validity analysis in this study indicates that all indicators are valid. This validity is indicated by the fact that loading factor is higher than 0.5 as shown in figure 1.

The bases scores of all validity test, first, the instruments had good convergent validity (loading factors > 0.60 and Average > 0.50). Those two numbers of validity means that all indicators are valid according to measurement tool for its latent construct. Second, the instruments had good discriminatory validities (cross loading factors > 0.60). That validity means that indicators of one latent variable are different from others.

Third, the convergent and discriminatory validities and sampling process, those instruments of the research had good internal and external validity. Fourth, the instruments
had good consistency to measure the latent variable (Composite reliability > 0.70, Cronbach’s Alpha >0.70).

**Structural Model (Inner Model) Test**

The structural model was tested by score of coefficient of determination that constitute a goodness-of-fit test. It was used to measure level of change variation of independent variable on dependent variable.

| Coefficient effect | Original sample (O) | Standard Error | T-statistics |
|--------------------|--------------------|----------------|--------------|
| DT → WTP           | 0.711              | 0.227          | 3.131        |
| TF → WTP           | 0.177              | 0.247          | 0.718        |

The result of Construct-DT showed 0.711 (figure-1) that variation change of the drivers’ distance trips (DT) was explained by willingness to pay (WTP) by 71.1%. The result of Construct-TF showed 0.177 (figure-1) that variation change of the drivers’ time frequencies (TF) was explained by willingness to pay (WTP) by 17.7%, although the rest was explained by other variables outside the purposed model.

3. **Discussion**

The results from figure 1 and table 3 of hypothesis test such as Drivers distance trips (DT) had positive and significant effect on willingness to pay (WTP), it means that longer drivers distance trips (DT) the higher the drivers’ willingness to pay an OBU (WTP). This conclusion based on t-statistics (3.131) > t-table (1.96), coefficient value 0.711, and standard error 0.227.

The drivers’ trip frequencies (TF) had no positive and not significant effect on willingness to pay (WTP). This conclusion based on t-statistics (0.718) > t-table (1.96), coefficient value 0.177, standard error 0.247. This conclusion based on mediation coefficient result is 0.125847 from (0.711*0.177), z-statistics-1.05 between the area of z-table -1.96 to 1.96, significance level (α) 0.05.

The questionnaire developed in this research is divided into three sections: the first section is primarily the driver’s characteristic information including travel characteristics; the second section explores the driver’s knowledge and willingness to pay an OBU; and the last section includes driver’s concern and suggestion about on-board unit and non-cash policy. Each section is described as follows.

1. Driver’s characteristic information. This section asks for the driver’s socio-economic background, including gender, age, education level, and monthly income, monthly expenses, average trip distance, and trip frequencies.
2. Driver’s knowledge and willingness to pay an OBU. This section asks for the driver’s willingness to pay an OBU at certain price and maximal price they willing to pay.
3. Driver’s concern and suggestion about on-board unit and non-cash policy.
This paper is using quantitative and qualitative analysis for data analysis. Qualitative analysis is use for data such as respondent characteristics. Meanwhile, quantitative data analysis is capitalized to analyze the relation between drivers’ characteristic.

The mentioned characteristics relate toward willingness to pay with Chi-Square test and estimation value of willingness to pay using contingent valuation method approach. Ultimately, multiple regression analysis is used to determine factors that influence the value of willingness to pay. Calculation formula for average value of willingness to pay is formulated as the following:

$$EWTP = \sum Wi.Pf$$

(2)

Where $Wi$ is value of willingness to pay; $Pf$ is frequency. Subsequently, the equation to estimate value of willingness to pay is in form of multiple linear regression. Ultimately, in this paper, analysis is formulated as the following:

$$WTP=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\beta_7X_7$$

(3)

Where $\beta$ is constant and $X$ is driver’s characteristic factor to measure willingness to pay.

Hypothesis proposed in this research are as follows:

- There is no positive impact between drivers’ characteristics with willingness to pay OBU ($H_0$) and there is a positive impact between drivers’ characteristics with willingness to pay OBU ($H_1$).
- There is no positive impact between policies with willingness to pay OBU ($H_0$) and there is a positive impact between policies with willingness to pay OBU ($H_1$).

4. Conclusion

Full scale of non-contact freeway toll collection system in Indonesia by the end of December 2018 is likely to be feasible. This paper indicates that 46.88% drivers are willing to pay an on-board unit. Driver's characteristics are deemed as important factor that influences the willingness to pay. Those factors are identified as education, expenses, distance and frequency. The average value of driver willing to pay an on-board unit was 225.781 IDR.

Given the fact that this paper proposes sustainability industrial systems; sustainability is deemed beneficial as future research for research in this paper. Precisely, it is beneficial to follow up some scholars works that elaborate sustainability [30]. These scholars elaborate the research scholar works through sustainability lens to proceed further perspectives. Those scholars synthesize their papers through the following scholars works [4], [6], [9], [10], [11], [19], [20], [25], [34], [35] and [38].

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