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UNDERSTANDING COGNITIVE LOAD IN HUMAN-MACHINE INTERACTIONS AT MRT TICKET VENDING MACHINES: A NASA TLX EVALUATION

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Abstract The provision of Mass Rapid Transit (MRT) and its supporting facilities in Jakarta necessitates an analysis of their user-friendliness for passengers. These facilities include information on various locations such as toilets, mosques, MRT card counters, ticket vending machines (TVMs), and signage directing passengers to the MRT. TVMs are machines that enable passengers to purchase MRT tickets and top up their card balances. A crucial aspect of evaluating TVM performance is assessing their user-friendliness, which is determined by the ease with which passengers can understand and operate them. This study aims to analyze the user-friendliness of TVMs at MRT stations using the NASA TLX approach. NASA TLX evaluates the impact of using TVMs based on mental, physical, and temporal demands, as well as performance, effort, and frustration. Data were collected through accidental sampling of respondents aged 18–28 years. The NASA TLX questionnaire explored users' cognitive perceptions of the TVMs' displays and procedures. The results will reveal how the factors measured by NASA TLX influence the interaction between passengers and TVMs at MRT stations. The findings will provide recommendations for MRT managers to enhance TVM designs and modify display procedures to improve user satisfaction.

Keywords: Accidental Sampling, Mass Rapid Transportation, User-Friendliness, NASA TLX, Human Machine Interaction

1. Introduction

The development of mass transportation systems in Indonesia has improved over the past decades, as evidenced by the initiation of the MRT (Mass Rapid Transit) as a pilot project. The MRT is expected to be effective in addressing congestion problems in major Indonesian cities, such as Jakarta. [1]. This is supported by the successful use of trains as a mode of mass transportation in developed countries, such as those in Europe and North America, where usage increases by 3% each year [2]. To further complement the use of MRT, the concept of transit-oriented development (TOD) was introduced. TOD, in practice, can reduce the reliance on private vehicles, alleviate congestion, and lower transportation costs [3], [4] and improve air quality [5], increase social cohesion [6], and promote an active lifestyle that is conducive to improving health and well-being [7]. This and non-technical factors. For instance, some MRT users require assistance to better understand the MRT system [8].

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During the development of the MRT system, access to essential facilities was often neglected in favor of focusing on mass transportation[9]. Essential facilities include information boards, transportation accessibility, waiting rooms, and other relevant infrastructure at train stations. This neglect is concerning, as irregularities at train stations, particularly MRT stations[10], [11], are common and create inconvenience[12]. Addressing these issues is crucial, especially given a societal culture that often overlooks safety [13].

TVMs are facilities that support the MRT system (see Fig. 1 for an image of a TVM at an MRT station). A TVM is an automatic machine that passengers can use to purchase tickets and top up their balances [14]. One of the reasons for implementing this machine is to reduce the queue at counters for purchasing or refilling MRT tickets [15]. However, the use of TVMs is far from optimal, as passengers often prefer to queue at counters rather than use the machines. Observations indicate that this preference is due to a lack of knowledge and the time required to learn how to use the machine. Only a few curious

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young passengers are willing to try using the TVM. Additionally, case studies have shown that passengers frequently need assistance from staff to operate the machine. This situation presents an opportunity to analyze and optimize the use of TVMs further.

Fig. 1TVM in The MRT Station

To encourage more frequent use of TVMs by the community, design improvements are necessary. It is crucial for the public to better understand and be informed about the systems available at train stations [16]. An evaluation of the current conditions related to TVMs at train stations is needed. The insights gained from this evaluation should inform design improvements for TVMs at MRT stations. This evaluation can be based on the Human-Machine Interface concept and measured using NASA TLX. This method offers a more objective and precise assessment of workload, helping designers enhance the system's effectiveness [17]. Using NASA TLX, this study will assess the impact of TVMs on mental, physical, and temporal demands, as well as performance, effort, and frustration. The NASA TLX questionnaire will gather users' perceptions of the TVMs at MRT stations. The findings will reveal how these factors affect user interaction with TVMs and will provide recommendations for MRT managers to improve TVM design, thereby making the system more user-friendly based on human-system interaction principles.

2. Method

2.1 Participants

This study included twenty-three respondents, both male and female, aged between 18 and 28 years, who had used the MRT facility on multiple occasions. Participants needed to be able to read and should not have color blindness. They were residents of Jakarta or its neighboring areas. The analysis of MRT users used an accidental sampling method, which is a non-probability sampling technique where participants are selected based on specific criteria, including accessibility, location, availability, and their willingness to participate[18].

2.2 NASA-TLX

NASA-TLX is an approach to measure subjective workloads. NASA TLX was developed in 1970 with pilots as the object of observation[19]. NASA TLX is tools that can be used to analyze any interface experience that requires certain degree of workload. NASA TLX analyzes mental load based on 6 aspects, namely Mental Demand, Physical Demand, Temporal Demand, Effort, Performance, Frustration (Table 1) [19]. Steps taken in weighting are to compare the aspects in pairs before determining the level of workload on each aspect. The participants will determine an aspect that is more dominant than other aspects, then they are asked to estimate the burden they feel to analyze information on MRT supporting facilities on a scale from 0–100 [20]. The disadvantages of subjective workloads are that they cannot be collected in real time, and allow for changes in perceptions of participants between one time and another, and the background on which the filling is based is biased [21].

Table 1 Aspects of Load Measurement

No	Aspect	Information
1	Mental Demand	Measurement related to the mental load in performing an activity. Mental activity refers to, in this case, thinking, determining, counting, remembering, searching.
2	Physical Demand	Determine how much physical activity is needed by nature to do a specific work
3	Temporal Demand	Determine how much time pressure is felt to complete a work

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Table 1 Aspects of Load Measurement (continue)

No	Aspect	Information
4	Effort	The difficulty of completing an activity with both physical and mental aspects together
5	Performance	The confidence in being able to complete this process
6	Frustration	The level of insecurity, stress, and dissatisfaction in doing the work

3. Results

3.1 Questionnaire Scoring for NASA TLX

In this section, MRT users are asked to evaluate their understanding of the TVM system using the NASA TLX comparison questionnaire. They are required to select and rate various aspects based on their experiences. The results of the weighting provided by MRT users are displayed in Table 2.

Table 2 Scoring Workload for Each Aspect

No	Resulting Weights					
	Mental	Physical	Temporal	Performance	Effort	Frustration
1	5	4	3	0	2	1
2	4	3	5	0	2	1
3	4	4	3	2	0	2
4	5	2	2	3	3	0
.	5	4	3	2	0	1
.	3	5	2	2	3	0
.	5	4	3	1	1	1
23	4	1	1	4	3	2
Total	91	70	65	58	29	32

3.2. Value Estimation for Each Aspect from Participants

After completing the NASA TLX questionnaire, the participants—MRT users in this case—were asked to score each aspect. The assessment for each aspect is on a scale from 0 to 100. The values provided by these participants reflect their perceptions of the process of understanding the information that supports the MRT. The results of this assessment are shown in Table 3. Rating or ranking is the stage that follows the initial weighting. At this stage, passengers are asked to give a score between 1 and 100 for each factor based on the workload they experience when accessing the TVM. The results are presented in Table 3.

Table 3. Results of Participants' Assessment of 6 Aspects of NASA TLX

User #	Mental	Physical	Temporal	Performance	Effort	Frustration	Mean *
1	80	60	40	60	80	30	58.333
2	60	50	80	80	50	20	56.667
3	80	80	80	80	90	10	70
4	80	80	90	70	30	20	61.667
5	40	40	50	70	80	50	55
.	80	90	90	20	50	30	60
.	70	60	80	80	70	30	65
.	70	60	70	80	80	50	68.333
23	60	30	90	10	30	20	40

In Table 3, it is noted that participants estimate the burden of understanding the TVM at MRT stations to be 62.03. The range of assessments varies from a minimum of 10 for the frustration aspect to a maximum of 100 for the temporal aspect..

3.3. Weighted Workload Calculation (WWL)

The WWL value represents the mental burden experienced by MRT passengers in understanding the information that supports the use of the MRT. The variability in the perceived burden—whether high or low—depends on the users' perceptions while using the MRT. The results of the WWL calculations are shown in Table 4. Table 4 demonstrates that the evaluation of the MRT information system is categorized into five distinct groups [22].

1. The value interval between 0–9 belongs to the low category;
2. The value interval between 10–29 belongs to the medium category;
3. The value interval between 30–49 belongs to

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the rather high category;
4. The value interval between 50–79 belongs to the high category;
5. The value interval between 80–100 belongs to the very high category.

Table 4. Load Weight Calculation by MRT Users

Aspect	Weight	Category
Overall	62.03	High
Mental	69.13	High
Physical	63.48	High
Temporal	74.13	High
Performance	68.70	High
Effort	64.35	High
Frustration	26.96	Average

The analysis of the TVM in the MRT, which involves six aspects (mental, physical, temporal, performance, effort, and frustration), indicates an overall value of 62.03, placing it in the high-value category. A further analysis of each aspect's value is detailed below:

a. Mental
The mental aspect has a value of 69.13, which falls into the high category. This indicates that passengers frequently engage in activities requiring mental effort, such as remembering, reading, and understanding information at the TVM. Passengers often struggle with comprehending the information flow and system procedures, including handling machine errors and knowing which types of money to insert. First-time users, in particular, may find it challenging to navigate the information system.

b. Physical
The physical aspect shows a weighted value of 63.48, also in the high category. This suggests that passengers find the physical demands of using the TVM—such as standing and pressing buttons—significant.

c. Temporal
The temporal aspect has a weighted value of 74.13, the highest score among the six aspects. This reflects that the TVM's information system is unclear, requiring passengers to spend considerable time understanding it. In a bustling city like Jakarta, time is a valuable asset, and delays in understanding the system further exacerbate this issue.

d. Performance
The performance aspect has a weighted value of 68.70, placing it in the high category. Passengers feel that they struggle to keep up with the TVM's process flow, affecting their ability to use the machine effectively. This aspect is heavily influenced by each passenger's cognitive abilities.

e. Effort
The effort aspect shows a weighted value of 64.35, indicating a high category. This suggests that passengers exert significant effort to use the TVM and navigate the MRT station. Many passengers often need assistance to locate the TVM, which adds to their effort.

f. Frustration
The frustration aspect shows a weighted value of 26.96, which is in the medium category. This lower score reflects that passengers do not experience significant stress or frustration with the TVM, as they have the alternative option of using the counter to purchase or refill tickets.

Based on the analysis of factors contributing to the high scores in NASA TLX, the following recommendations are made for improving MRT supporting facilities:

a. Place Standard Operating Procedures (SOP) near the machine to make it easier for passengers to read and refer to while using the TVM.
b. Include a simulation feature within the machine to demonstrate the SOP, assisting passengers in understanding how to use the TVM.
c. Position the machine in accessible locations, with its height adjusted to match the anthropometric dimensions of Indonesian people.
d. Provide additional supporting facilities, such as an escalator at the station entrance leading to the TVM, to help reduce physical exertion for passengers.
e. Install additional machines that passengers can use before reaching the ticket counter.

4. Discussion

This paper aims to evaluate the TVM based on NASA-TLX aspects such as mental, physical, temporal, performance, effort, and frustration. The evaluation focuses on how humans interact with the design. The TVM is a physical attribute of the MRT that can enhance the service level at Indonesian MRT stations. MRT providers are required to improve technical attributes to ensure service quality at

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the station[23]. Based on the results, nearly all aspects showed a high workload experienced by participants. The temporal load received the highest score, indicating that participants felt time pressure while using the TVM. Participants expressed dissatisfaction with the time required to complete tasks using the TVM. The evaluation revealed a lack of experience among users when operating the TVM. Participant interaction with the TVM is highly dependent on the information they receive from the environment. Recommendations include placing the Standard Operating Procedure (SOP) near the TVM to provide easy access to usage guidance. This will help reduce human error and improve customer satisfaction by minimizing the time needed to interact with the TVM. Decreasing errors will also enhance the overall efficiency of the MRT system [24]. It is important because time in the MRT station is one of indicator of customer satisfaction in the MRT station[25]. The high workload from NASA-TLX evaluation similar with the result from usability evaluation from Suzianty and Belahakki (2020) which have low value with 4.60 from a scale of 1-7[26]**.**The operation instruction may be improved by enhancing the color contrast and graphics complementing of caption and voice guidance; (2) the transaction interface should be simplified, avoiding using button symbol to show information, and the visual instruction should be supplemented with voice instructions; (3) operation feedback should be strengthened and in line with previous use experience[27]**.** Easy step-by-step visual instructions on screens designed without unnecessary clutter must be praised; the diode lights that indicate the area of the next step (ticket selection–payment–ticket collection) appeared to be a good guidance feature, even if this was not possible to quantify within this experiment[28]

5. Conclusion

The NASA TLX scores for understanding the information provided by the TVM reveal that, out of the six evaluated aspects, only one shows a moderate value of 26.96%, while the remaining aspects exceed 60%, indicating a high cognitive load. This high workload is largely due to the confusing information flow and the challenge of adapting to a mass transportation system that diverges from societal norms. To address these issues and reduce the cognitive burden on users, several solutions are recommended. First, placing Standard Operating Procedures (SOP) near the TVM will provide clear guidance, helping users navigate the machine more easily. Additionally, modifying the TVM's system interface can improve usability by enhancing information clarity and simplifying navigation. Furthermore, relocating the TVM to a more accessible position and adjusting its height to align with Indonesian anthropometric dimensions will ensure greater comfort and ease of use for all passengers. These measures aim to enhance the overall user experience by addressing the specific usability challenges identified in the NASA TLX assessment.

REFERENCES

[1] F. A. Pinagara and S. Khamtanet, "Will Jakarta Still Have Traffic Congestion after MRT?," vol. 36, no. Icbmr, pp. 311–321, 2017, doi: 10.2991/icbmr-17.2017.29.

[2] R. Puentes, A. Tomer, and J. Kane, "A New Alignment: Strengthening America's Commitment to Passenger Rail," 2013.

[3] J. L. Renne and C. Curtis, "Measuring the success of transit oriented development," in *Transit Oriented Development*, Routledge, 2016, pp. 261–276.

[4] A. Stutzer and B. S. Frey, "Stress that doesn't pay: The commuting paradox," *Scandinavian Journal of Economics*, vol. 110, no. 2, pp. 339–366, 2008.

[5] J. Woodcock *et al.*, "Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport," *The Lancet*, vol. 374, no. 9705, pp. 1930–1943, 2009.

[6] B. Giles-Corti *et al.*, "City planning and population health: a global challenge," *The lancet*, vol. 388, no. 10062, pp. 2912–2924, 2016.

[7] C. D. Higgins and P. S. Kanaroglou, "A latent class method for classifying and evaluating the performance of station area transit-oriented development in the Toronto region,"

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2024.012.01.3

J Transp Geogr, vol. 52, pp. 61–72, 2016.

[8] S. Chew and A. Aksan, "Users ' Satisfaction with Mass Rapid Transit and the Effect of Different Genders and Trip Purposes," *International Journal of Academic Research in Business and Social Sciences*, vol. 8, no. 15, pp. 131–145, 2018, doi: 10.6007/IJARBSS/v8-i15/5097.

[9] J. Schneider, "Network condition report 2012," *Annual report, Swiss Federal Railways (SBB-CFF-FFS), Bern, Switzerland*, 2012.

[10] F. Ganansia, C. Carincotte, A. Descamps, and C. Chaudy, "A promising approach to people flow assessment in railway stations using standard CCTV networks," in *Transport Research Arena (TRA) 5th Conference: Transport Solutions from Research to DeploymentEuropean CommissionConference of European Directors of Roads (CEDR) European Road Transport Research Advisory Council (ERTRAC) WATERBORNE^TP European Rail Research Advisory Council (ERRAC) Institut Francais des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux (IFSTTAR) Ministère de l'Écologie, du Développement Durable et de l'Énergie*, 2014.

[11] L. F. L. Hermant, "Video data collection method for pedestrian movement variables & development of a pedestrian spatial parameters simulation model for railway station environments," 2012, *Stellenbosch: Stellenbosch University*.

[12] I. Nio, "Het station als publieke ruimte," *Retrieved July*, vol. 2, p. 2013, 2012.

[13] S. Buchmüller and U. Weidmann, "Handbuch zur Anordnung und Dimensionierung von Fussgängeranlagen in Bahnhöfen," *ETH Zürich, Institut für Verkehrsplanung und Transportsysteme, Studie für Schweizerische Bundesbahnen, Zürich*, 2008.

[14] NAS, "mesin-tiket-otomatis-dan-mesin-isi-ulang-untuk-kemudahan-mobilitas-penumpang."

[15] V. Mantalean, "Mesin Tiket Otomatis MRT Mulai Difungsikan," 2019.

[16] T. Parkinson and I. Fisher, *Rail transit capacity*, vol. 13. Transportation Research Board, 1996.

[17] T. Q. Tran, R. L. Boring, D. D. Dudenhoeffer, B. P. Hallbert, M. D. Keller, and T. M. Anderson, "Advantages and disadvantages of physiological assessment for next generation control room design," *IEEE Conference on Human Factors and Power Plants*, pp. 259–263, 2007, doi: 10.1109/HFPP.2007.4413216.

[18] Z. Dörnyei, "Research methods in applied linguistics," 2007.

[19] Sandra G. Hart, "Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research," *Power Technology and Engineering*, 1988, doi: 10.1007/s10749-010-0111-6.

[20] S. Rubio, E. Díaz, J. Martín, and J. M. Puente, "Evaluation of subjective mental workload: A comparison of SWAT, NASA-TLX, and workload profile methods," *Applied psychology*, vol. 53, no. 1, pp. 61–86, 2004.

[21] B. F. Gore, "Workload and fatigue," in *Space Safety and Human Performance*, Elsevier, 2018, pp. 53–85.

[22] D. D. Diniaty, "Analisis Beban Kerja Fisik dan Mental Karyawan di Lantai Produksi pada PT Pesona Laut Kuning," *SITEKIN: Jurnal Sains, Teknologi dan Industri*, vol. 13, no. 2, pp. 203–210, 2016.

[23] A. Hasanah, N. Ahlina, and D. P. Ishak, "Design of Mass Rapid Transit (MRT) Service Quality Through

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2024.012.01.3

Analysis of Factor Affecting Passenger Behavior Intention Using PLS-SEM and QFD," no. 55, 2022.

[24] T. Canicosa, J. Medina, B. Guzman II, B. Custodio, and A. J. Portus, "Usability Evaluation of Ticketing System of Metro Manila Train Network in Advances in Usability and User Experience AHFE 2017," in *AHFE Advances in Human Factors and Ergonomics*, vol. 607, 2017, pp. 591–602.

[25] R. A. N. Adrielly, S. A. I. Francisca, F. M. Idalia, and L. M. Jéssica, "Designing human mistake-free machine: A Mexico city public transport commuters' approach," *Procedia Manuf*, vol. 42, no. 2019, pp. 399–405, 2020, doi: 10.1016/j.promfg.2020.02.056.

[26] A. Suzianti and A. Belahakki, "Redesigning User Interface of MRT Jakarta's Mobile Application using Usability Testing Approach," *ACM International Conference Proceeding Series*, pp. 73–78, 2020, doi: 10.1145/3429551.3429587.

[27] M. Lu and H. Yueh, "中高齡者使用公共運輸系統自動售票機之可使用性 評估研究 ： 以大**眾捷運系統為例** A Usability Study of the Automatic Ticket Vending Machines for the Middle-aged and Elderly Patrons : The Case of the Taipei Mass Rapid Transit System," vol. 13, no. 2, 2015, doi: 10.6182/jlis.2015.13(2).067.

[28] A. Pashkevich, A. Szarata, T. E. Burghardt, R. Jaremski, and M. Šucha, "Operation of public transportation ticket vending machine in kraków, poland: An eye tracking study," *Sustainability (Switzerland)*, vol. 13, no. 14, pp. 1–15, 2021, doi: 10.3390/su13147921.