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Air and Land Transportation Development: A Mini Systematic Review of Ergonomics Contributions

Twin Yoshua R. Destyanto[1a◆], Chandra Dewi Kurnianingtyas[1b], Etika Muslimah[2c]

Abstract. *Indonesia's transportation sector has experienced rapid growth. Research conducted in the field of ergonomics has resulted in a transportation mode development, that provides a comfortable and safe experience for passengers according to their basic needs. The research covers interior design, work environment, and workload in the transportation sector. However, there has yet to be a systematic review of the role and contribution of ergonomics in seeking ergonomic and human-centered transportation, as per the author's research. Therefore, this study examines ergonomics research (cognitive, physical, organizational) applied to Indonesia's innovation in air and land transportation over the past decade (2013-2022). A total of 23 articles were reviewed (6, 6, and 10 for air transportation, land and rail sectors, the land transportation sector other than trains, respectively). The results show that ergonomics impacts the development of ergonomic transportation in Indonesia. The potential for various studies is available in physical, cognitive, and organizational ergonomics.*

Keywords: *air transportation; land transportation; railways; ergonomics; transportation..*

I. INTRODUCTION

It has been a decade of rapid development for the Indonesian transportation industry. The government is developing new land transportation modes in Indonesia, such as Mass Rapid Trains, Light-Rail Transits, and high-speed rail trains (Ibrahim & Prakoso, 2016; Pambudi & Hidayati, 2020). The development of air transportation has also yet to escape the government's attention, which has built several new airports throughout the country. Considering that Indonesia is an archipelago, this development is essential to meeting the needs of its people.

As the transportation sector has developed, research has been conducted on creating a comfortable and safe transportation environment (Erlangga & Nurfajriah, 2019; Indahsari & Wulandari, 2016). A mode of transportation that performs well must be equipped with facilities and environmental conditions that provide a good travel experience for passengers. To ensure the safety and comfort of transportation users, interiors in transportation vehicles and passenger waiting rooms must be developed.

The field of ergonomics plays a crucial role in the development of the transportation industry by considering safety and comfort. Ergonomics studies and research in the field of transportation have resulted in innovation (Suhardi & Suryono, 2013; Sulistiya Ramadhan & Suryadi, 2022) and development (Pambudy et al., 2014; Suriadi & Atmika, 2017) to transportation that does not only function according to the basic needs of passengers, but also can provide a comfortable and safe experience for its users. The design and analysis process in ergonomics is iterative (Shorrock & Williams, 2016; Sun et al., 2018), focuses on humans (Caputo et al., 2018; Nelles et al., 2016), and takes human cognitive aspects into account (Kistan et al., 2018; Plant & Stanton, 2013), producing various outcomes that have made fundamental contributions in multiple fields including transportation. For example, the design of seats in different modes of transportation has been initiated to be based on anthropometric data of passengers, ensuring long-term and

[1] Department of Industrial Engineering, Universitas Atma Jaya Yogyakarta, No. 43 Babarsari St., Sleman 55281, Indonesia.
[2] Department of Industrial Engineering, Universitas Muhammadiyah Surakarta, Pabelan, Kartasura, Sukoharjo, Central Java 57169 Indonesia.

[a] email: twin.destyanto@uajy.ac.id
[b] email: chandra.dewi@uajy.ac.id
[c] email: etika.muslimah@ums.ac.id
◆ corresponding author

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short-term comfort and safety (Djunaidi & Arnur, 2015; Suhardi & Suryono, 2013; Yudiantyo & Hartadinata, 2018). An assessment of the mental workload of transportation drivers (Finahari & Soebiyakto, 2022; Saputra et al., 2015a, 2016; Sugiharto, 2019) has also been carried out to propose improvements to driver performance, and this may have an impact on the safety of passengers in this mode of transportation.

These various studies and outcomes can be used as guidelines in designing interior designs, work environments, and workloads in the transportation sector in Indonesia in the future. Nevertheless, according to our best knowledge, there is no systematic review of ergonomics' role and contribution in human-centered transportation. Therefore, this study aims to extensively review ergonomics research (cognitive, physical, and organizational) applied to Indonesia's innovation and development of air and land transportation over the past decade (2013-2022).

II. RESEARCH METHOD

This study used qualitative research methods with a systematic literature review approach to achieve its objectives. The process was divided into three main steps comprising review planning, conducting the review, and dissemination reporting (Cahyo, 2021; Tranfield et al., 2003). The

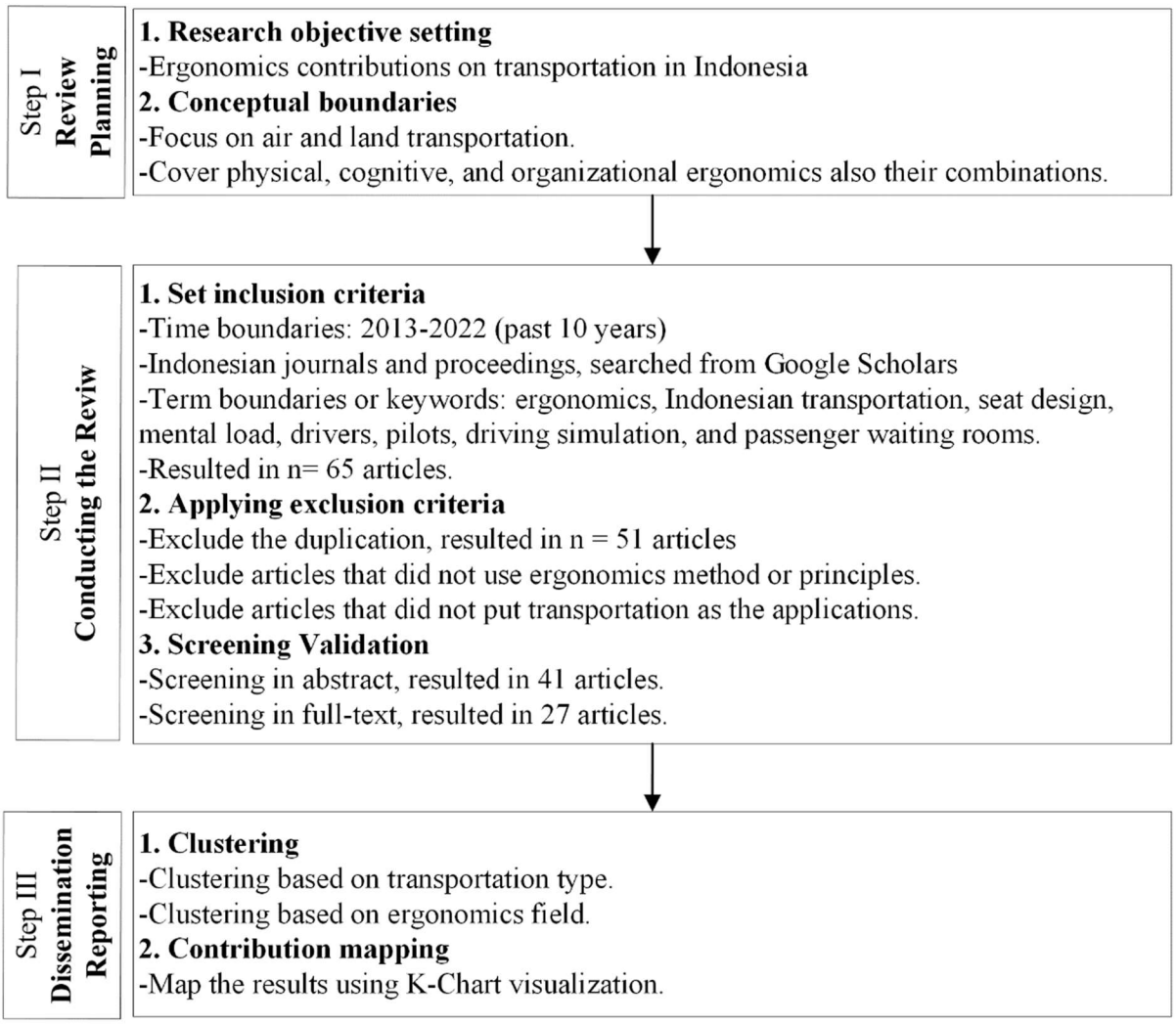

Figure 1. Summary of steps in systematic review process

planning step was done by setting the review goal which was finding how ergonomics contributed to the field of transportation, both air, and land in Indonesia. The application is not only to the means of transport used but also to other facilities and stakeholders related to these means of transportation, such as Air Traffic Controller (ATC), passenger waiting rooms, and the performance of transportation drivers. Moreover, in the planning stage, the conceptual boundaries were defined to focus the review search. Therefore, the search was carried out, focusing on research that involving physical, cognitive, and organizational ergonomics, or a combination of several types of ergonomics applied in transportation sector.

The second step was done by setting the inclusion criteria comprising publishing period and term boundaries, applying exclusion criteria, and search results validation. Related to publishing period, article searches were conducted on articles published from 2013 to the end of 2022 or past decade from Indonesian journals and proceedings. The term boundaries were set to the keywords: ergonomics, Indonesian transportation, seat design, mental load, drivers, pilots, driving simulation, and passenger waiting rooms. The investigation by using these keywords resulted in 61 article titles. The exclusion criteria was duplication, and discussion did not focus on air or land transportation, the study did not applied any ergonomics principles or methods. Using these exclusion criteria, the 61 articles were then filtered to eliminate duplication of papers and produce 47 article titles. A total of 37 articles passed the abstract filtering stage, and the full-text filtering resulted in 23 articles as the final stage after validation.

Finally, the dissemination reporting was done by clustering the ergonomics contribution to each transportation type. The contributions found in review than were mapped using K-Chart (Abdullah et al., 2006; Cahyo, 2021; Zaheer et al., 2020) to visualize the ergonomics contributions to air and land transportation in Indonesia. The visualization might help to find novelty of research in this area for future studies (Cahyo, 2021). The steps in this systematic review process are summarized using Figure 1.

III. Result and Discussion

Ergonomics Contribution to Air Transportation

Ergonomics research and development conducted in the air transportation sector is dominated by studies on employee mental workload which is included in cognitive ergonomics. Analysis of how the level of mental workload on pilots (Saputra et al., 2015a, 2015b, 2016) has been conducted to measure how pilots respond to the workload they receive in the flight process. Measurement of the mental load is also applied to ATC officers (Senjaya et al., 2020; Sugiharto, 2019). ATC officers are responsible for guiding and controlling the traffic of many aircraft in the air. The displays and controls used by ATC officers are complex and pose a high risk of human error (Aricò et al., 2017; Niessen & Lang, 2021).

Ergonomics makes a real contribution to measuring the mental workload of pilots and ATC officers. This mental workload analysis is carried out by investigating the factors that predominantly influence the workload of pilots and ATC officers. The results obtained can be used to design a system engineering proposal and work environment to reduce the workload of pilots and ATC officers. The results will also impact the safety of the aircraft and passengers.

Another research that also contributes to the air transportation sector in Indonesia is the application of physical ergonomics. The design is based on the anthropometric data of the cabin crew to design an ergonomic cockpit (Finahari & Soebiyakto, 2022; Sasongko et al., 2017). The analysis conducted on existing cockpit sizes on various aircraft tends to ignore cabin crew with above-average body size (Sasongko et al., 2017). Therefore, in the future, it is necessary to consider widening the scope range that is applied in the cockpit interior design process, thereby increasing the flexibility of its use, oriented to the size of the user.

The research that has been reviewed proves that ergonomics can contribute to developing

Table 1. Literature summary showing the contribution of ergonomics to air transportation in Indonesia

No.	Authors	Year	Application	Ergonomics Scope	Contribution
1	Saputra, Abadi Dwi Priyanto, Sigit Bhinnety, Magda	2015	Pilot workload mental analysis.	Cognitive ergonomics	Identify the dominant factors that contribute to the pilot's mental workload.
2	Saputra, Abadi Dwi Priyanto, Sigit Bhinnety, Magda	2015	Pilot workload mental analysis.	Cognitive ergonomics	Determination of the task that causes the highest workload (landing).
3	Saputra, Abadi Dwi Priyanto, Sigit Muthohar, Imam	2016	Pilot workload mental analysis.	Cognitive ergonomics	Identify the dominant factors that contribute to the pilot's mental workload.
4	Sasongko, Triyono Widi Kartika, Nina Septyan, Tegar Bahtera E, Dimas Sampurno, Budi	2017	Ergonomic aircraft cockpit design.	Cognitive ergonomics.	Shows the relationship between mental workload and job stress on ATC officers
5	Sugiharto, Fauziah Mukti	2019	ATC officer stress analysis.	Cognitive ergonomics	Shows the relationship between mental workload and job stress on ATC officers.
6	Senjaya, Mahdia Noer Adiba wahyuni, Ida Widjasena, Baju	2020	Analysis of human error ATC officers.	Cognitive ergonomics	Shows the relationship between demographic factors, mental workload, and work duration with the level of human error for ATC officers.
7	Finahari, Nurida Soebiyakto, Gatot	2022	Ergonomics cockpit designing.	Physical ergonomics.	Seats and cockpit layouts, and cockpit control systems dominate the study of cockpit ergonomics research.

and improving air transportation in Indonesia. The human-centered design principle in designing air transportation (mode and crew) helps create a comfortable and safe work system and environment for passengers and aircraft drivers. The summary of the studies that have been reviewed can be seen in Table 1.

Ergonomics Contribution to Railway as Land Transportation

The role of ergonomics in developing railways in Indonesia is dominated by the results of physical ergonomics research (Erlangga & Nurfajriah, 2019; Indahsari & Wulandari, 2016; Sitio & Purwaningsih, 2016; Supriadi, 2019; Theresia et al., 2013). In particular, much research has been done on the design of train passenger waiting rooms (Indahsari & Wulandari, 2016; Supriadi, 2019; Theresia et al., 2013). What is often found at various stations in Indonesia is the mixed arrival and departure areas (Indahsari & Wulandari, 2016) which resulted in the accumulation of passengers arriving and departing in the same place. This phenomenon motivates researchers to view the provision of an ergonomic waiting room as necessary for passenger comfort. The contributions made are pretty diverse in terms of lighting (Indahsari & Wulandari, 2016), visitor circulation (Indahsari & Wulandari, 2016), noise intensity (Supriadi, 2019), temperature (Supriadi, 2019), and service resources working at the station (Supriadi, 2019; Theresia et al., 2013). Applying physical ergonomics in the waiting room can increase the level of satisfaction of train station users.

Physical ergonomics also improves the driver's cabin (Erlangga & Nurfajriah, 2019), as is also applied to aircraft. Erlangga and Nurfajriah (2019) designed a cabin adapted to the drivers' work posture. The results obtained from the Quick Exposure Check (QEC) method and based on the assessment using the Rapid Upper Limb Assessment (RULA) contribute to the dimensions of the seat and cabin. In addition, the layout of the controllers and screens to monitor flight conditions was also proposed, taking into account the working posture of the driver. This redesign can reduce the risk of musculoskeletal disorders (MSD) in drivers and crew working in train cabins. Other research that was also applied to the driver's cabin was carried out to improve the display design of malfunction indicators in the

cabin and control design, namely control diameter and control labelling (Sitio & Purwaningsih, 2016).

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Research that has also been carried out on rail transportation is also applied not only in trains or waiting rooms but also on railroad tracks. Pambudy et al. (2014) conducted a cognitive ergonomics analysis on the signalling display design and the slogan on the fire. The results of this study contribute by proposing improvements to the distance of the signal entering the station and the distance of the slogan so that the receiver more clearly receives it. Moreover, cognitive ergonomics was also utilized for analysing the cabin environment (Wahyuning et al., 2017) and sleepiness detection for train drivers (Theresia, 2019). Physical and cognitive ergonomics over the past decade have helped improve the quality of rail services in Indonesia. Holistic improvements in terms of passenger waiting room facilities, the interior of the driver's cabin, and the train control system have been touched on by ergonomics to create safer and more comfortable rail transportation. A summary of the literature that focuses on ergonomics research on rail transportation can be

Table 2. Literature summary showing the contribution of ergonomics to railway transportation in Indonesia

No.	Authors	Year	Application	Ergonomics Scope	Contribution
1	Theresia, Clara Tambunan, Mangara M Nazlina, M T	2013	Railway station waiting room facilities.	Physical ergonomics	Recommendations for the design of train station waiting room facilities, including the physical environment, and improving the human resources of train station employees.
2	Pambudy, Anggo Hapsoro Yadi, Yayan Harry Susihono, Wahyu	2014	Analysis of signaling displays and slogans at train stations.	Cognitive ergonomics	Proposed improvement on the distance of incoming signal to the station and the length of the symbol.
3	Indahsari, Safi Nur Wulandari, Ratri	2016	Railway station waiting room facilities.	Physical ergonomics	Environmental analysis of train station waiting room facilities, lighting, and visitor circulation recommendations.
4	Sitio, Yusfran Purwaningsih, Ratna	2016	Display and control of the train machinist's cabin.	Physical ergonomics	Proposed improvements to the malfunction indicator display design in the cabin and control design, namely control diameter and control labeling.
5	Wahyuning, Caecilia Sri, Indah Rachmatiah SS, Iftikar Z. Sutalaksana	2017	Cabin work environment design to mental workload	Cognitive ergonomics	There was not enough data to prove the impact of work environment design on training drivers' mental workload.
7	Erlangga, Djodi Nurfajriah, Nurfajriah	2019	Design of commuter drivers' cabin facilities.	Physical ergonomics	Recommended dimensions of facilities in the driver's cabin on an ergonomic commuter.
8	Theresia, Clara	2019	Sleepiness detection for train driver.	Cognitive ergonomics	There is significant positive correlation between blink frequency to sleepiness level.

seen in Table 2.

Ergonomics Contribution to Non-Rail Land Transportation

As with trains, the contribution of ergonomics in the land vehicle sector, such as cars, bicycles, buses, and motorcycles, is dominated by physical ergonomics. The design of passenger or driver seats (Djunaidi & Arnur, 2015; Rahman et al., 2018; Suhardi & Suryono, 2013; Suriadi & Atmika, 2017; Susanti & Agustion, 2015; Yudiantyo & Hartadinata, 2018) has been done in the application of physical ergonomics. The safety aspect was raised by Suryono (2013) to propose seat dimensions on buses for pregnant women. This site will increase the comfort of pregnant women, their safety, and the baby being conceived. Using anthropometric data on pregnant women with various gestational age ranges is required in designing these seats. The design of bus seats needs to be considered holistically using anthropometric data, which includes the size of the footwear, seat backs, lumbar basins, and the angle of inclination of the bus seats (Suriadi & Atmika, 2017).

In addition to the size of the seats, the physical facilities of the bus were also improved, especially the armrests, which are sometimes too high or low, as well as magazines or drink holders placed in front of the passenger seats (Yudiantyo & Hartadinata, 2018). The chairs in the waiting room at the bus terminal have also been improved by applying physical ergonomics to obtain proposed seat dimensions according to the anthropometric data of existing facility users at the bus station (Uqrama & Andrianto, 2020).

The contribution of physical ergonomics was also found to play a role in the design of manual bicycles (Susanti & Agustion, 2015) and motorcycles (Djunaidi & Arnur, 2015). Bicycle parts such as saddles, handlebars, and pedals must be designed with anthropometric data appropriate for the bicycle user's age (Susanti & Agustion, 2015). The design of electric bicycles and motorbikes to be physically ergonomic must also be carried out to prevent accidents caused by inadequate design processes in both types of transportation. The speed used on motorcycles and electric bicycles is higher than that of manual bikes, so ergonomics also needs to be applied in designing its components for a preventive measure against traffic accidents.

In addition to vehicles generally used for transportation, physical ergonomics also contributes to the design of feed carriers and mini cars with three wheels. The tools applied to all-terrain vehicles, or ATVs, were ergonomically designed by Achmad (2019) to make it easier for staff to feed animals at zoos. A three-wheeled car, which has a limited capacity, is recommended by Rahman et al. (2018) to refer to the anthropometric data of the passengers and drivers of the car to obtain an ergonomic seat design for both passengers and the driver of the mini car. These results are the contribution of physical ergonomics to land transportation on bicycles, electric bicycles, motorbikes, buses, and other vehicles.

Even if they do not dominate, organizational ergonomics also contribute to ergonomics in the non-railroad land transportation sector. The satisfaction level of visitors is used as a tool to improve the interior design and physical environment of a bus (Utami & Utomo, 2020). Bus users' participation in designing the bus's interior and layout makes the resulting design closer to consumer needs in bus services. Moreover the cognitive ergonomics were initiated to be utilized for road type selection (Halim & Haryono, 2022) and situation awareness analysis in driving simulation fields (Utami et al., 2022).

The results of ergonomics research on the development of the land transportation sector other than trains add to its contribution to the world of transportation. Land trips are generally carried out for a long time, making user comfort a critical requirement that needs to be prioritized. The incidence of motion sickness experienced by public transportation passengers such as buses can be prevented by ergonomically designing seats and accompanying facilities. These existing contributions can be briefly summarized in **Error! Reference source not found.**.

Table 3. Literature summary showing the contribution of ergonomics to land transportation other than trains in Indonesia

No.	Authors	Year	Application	Ergonomics Scope	Contribution
1	Suhardi, Bambang Suryono, Fitri Yulianti	2013	Designing unique bus seat designs for pregnant women.	Physical ergonomics	The proposed size of the bus seat, which includes the size of the seat base, armrest backrest, and footrest base, is based on anthropometric data of pregnant women.
2	Susanti, Lusi Agustion, Yogi Hendra	2015	Bike designing	Physical ergonomics	Recommended height dimensions for bicycle handlebars, saddles, and pedals that cover the body size of the Indonesian population (small, medium, and large).
3	Djunaidi, Zulkifli Arnur, Rahmadani	2015	Ergonomic risk analysis of motorcycle seats on student body size.	Physical ergonomics	Findings of potential traffic accidents due to incompatibility of the design and size of motorcycle seats with student anthropometric measurements.
4	Suriadi, Igak Atmika, I Ketut Adi	2017	Minibus seat design.	Physical ergonomics	The proposed minibus seat dimensions include the size of the footrest, seat back, lumbar concavity, and seat inclination angle.
5	Yudiantyo, Wawan Hartadinata, Dwi	2018	Seat design and physical facilities (armrests, belts, footrests, etc.) on the bus.	Physical ergonomics	Seat design, physical facilities supporting seats, and ergonomic bus layout.
6	Rahman, M Faiz Fazlur Juniani, Anda Iviana Setiawan, Tri Andi	2018	Three-wheeled car seat design.	Physical ergonomics	Seat design, physical facilities supporting seats, and ergonomic bus layout.
7	Achmad, Hafidh Salviandy Muttaqien, Teuku Zulkarnain Pujiraharjo, Yoga	2019	Additional interior design for the ATV (all-terrain vehicle) for distributing animal feed at zoos.	Physical ergonomics	The design of a feeding aid for the ATV body, according to the anthropometry of the ATV rider.
8	Utami, Nevia Rizkyning Utomo, Nugroho	2020	Analysis of the satisfaction level of bus passengers from an ergonomic standpoint.	Organizational ergonomics	Assessment of the bus interior design and the physical environment of the bus.
9	Uqrama, Amirul Andrianto, Andrianto	2020	Seat design at bus terminal facilities.	Physical ergonomics	Proposed seat dimensions according to the user's anthropometric data.
10	Sulistiya Ramadhan, Air Suryadi, Akmal	2022	Electrical bike designing.	Physical ergonomics	Vital ergonomic electric bicycle innovation has an attractive product design, product form, and function to suit consumer needs.
11	Halim, Winda Haryono, Anggie Ervany	2022	Sleepiness and heartbeat analysis on different road conditions.	Cognitive ergonomics	High density road condition as recommended road type.
12	Utami, Mia Tri Lin, Chiu-Hsiang Hartono, Budi Azzahra, Faradhina	2022	Situation awareness analysis to driving simulator interface.	Physical and cognitive ergonomics	There is significant impact of interface design to mental workload but no significant impact to situation awareness.

Ergonomics Research Development Potential in the Field of Air and Land Transportation in Indonesia

The results and discussion in each transportation sector above illustrate the different polarization of ergonomics. On trains and non-railways, land transportation is dominated by physical ergonomics, while cognitive ergonomics dominates air transportation. This phenomenon shows the potential for each sector to be different. Research that applies physical ergonomics can be carried out in the air

transportation sector. An analysis of physical and ergonomic aspects must be conducted continuously to ensure aircraft user satisfaction and safety. On the other hand, cognitive ergonomics also needs to be developed to empirically measure the driver's workload. Many studies have been conducted using driving simulation tools (Arya et al., 2014; Suhardi & Suryono, 2013). However, research on drivers in the field can also contribute to the discipline of cognitive ergonomics in the future.

Besides these two dominant disciplines, macro-organizational ergonomics is also a potential area for ergonomics research in transportation. Transportation equipment and work environments can be ergonomically designed when all stakeholders are involved in the interior design process and facilities related to transportation. Improving the quality of human resources, especially drivers, can reduce human error (Soleh et al., 2017) in carrying out their duties to deliver passengers to their destinations.

In order to find the research novelty, generated modified K-Chart (Cahyo, 2021), shown in

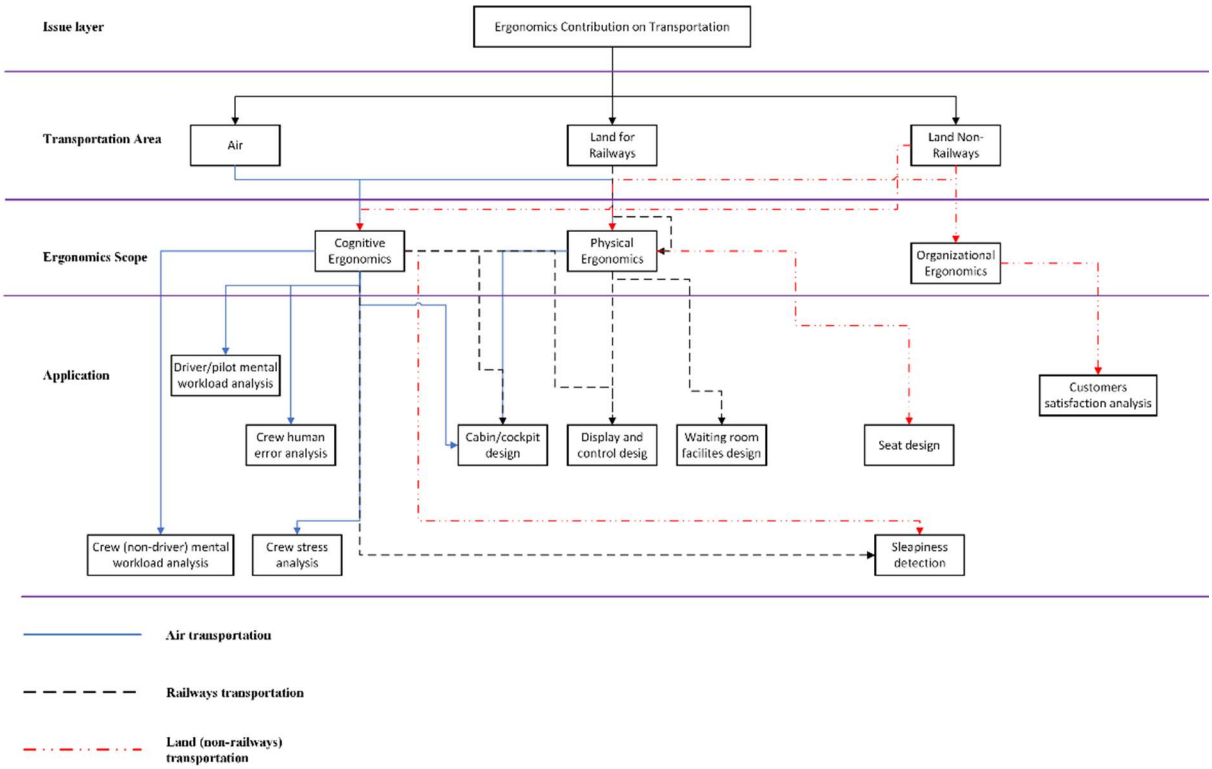

Figure 2. Modified K-Chart for mapping the ergonomics contributions to Indonesian transportation in past decades

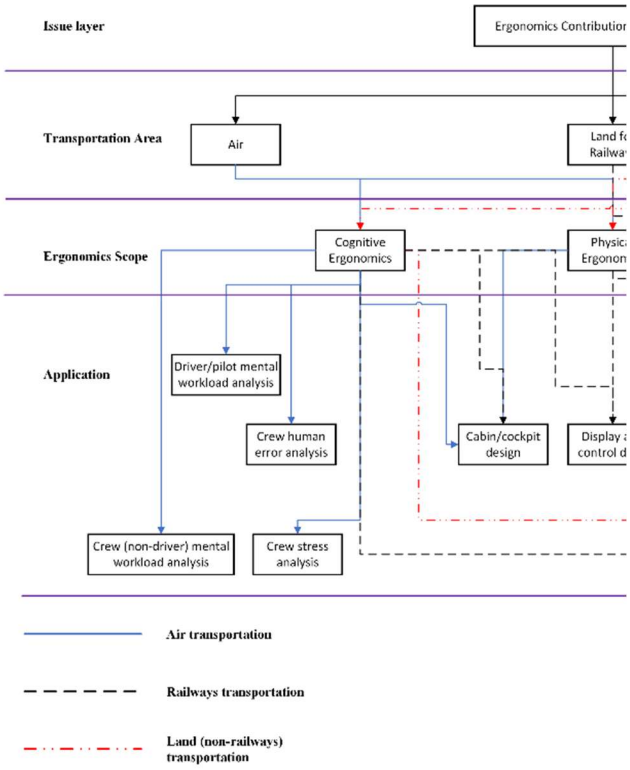

Figure 2 helps to map the specific applications of ergonomics methods usage in each transportation area and ergonomics field. The corresponding line from each transportation area (e.g., blue line for air transportation, black dash line for land-railways transportation, and red dash line for land non-railways transportation) shows the contribution of ergonomics in specific application.

Applications that are not traversed by specific lines are potential novelties of research in the transportation area concerned. For example, seat design and waiting room evaluation can be promising contributions for air transportation area. Organizational ergonomics also has the potential to be a new research area for air and railways transportation. The generated K-Chart can be used for showing the future research direction about ergonomics transportation in Indonesia.

IV. Conclusion

The results and findings in this literature review have provided an overview of the role of ergonomics in the innovation, improvement, and development of the air and land transportation sector in Indonesia. These improvements and innovations increase the comfort and safety of users and other stakeholders related to air and land transportation. Existing studies can also be used as a reference for future research, namely an overview of research potential in each transportation sector and the application of ergonomics disciplines that have yet to be widely implemented. Namely, organizational ergonomics and physical ergonomics developed in air transportation and cognitive and organizational ergonomics in land transportation (rail and non-rail).

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