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Human Centred Design Considerations for the Development of Sustainable Public Transportation in Malaysia

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Featured Application: We demonstrate the importance of Human Centred Design considerations for future mobility projects which can apply to other developing countries facing similar challenges.

Abstract: The growing trend of private car ownership in Malaysia is increasing traffic congestion. As part of a solution, the Malaysian Automotive Association (MAA) chose to develop technologies for an electric bus system in Kuala Lumpur and initiated a project to design and engineer an electric bus system with a focus on Human Centred Design (HCD) principles. In order to fulfil this a total of 28-hours of user observation was conducted in Kuala Lumpur (KL), Malaysia. Alongside this field research an online questionnaire study of future users (n = 102, Age 21–35) was conducted to further substantiate findings. As a result, we address the need for HCD considerations to be included in sustainable public transport systems in Malaysia. User observation revealed six key issues associated with the daily routine of a commuter which were then used to inform the questionnaire survey. Alarmingly, the survey revealed that over 60 per cent of respondents had never used the bus system in Kuala Lumpur stating problems such as frequency, comfort, driver attitude and bus shelter access. This provided a necessary platform for improvement resulting in eight key recommendations ranked by importance with the aim to increase bus usage in Malaysia.

Keywords: human centred design; HCD; public transportation; user research; system design; Malaysia

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1. Introduction

Many studies show that replacing private vehicles with public transport can reduce the pollutant emissions respectively proclaiming that the modal shift from private vehicles to public transport is the key solution to improve the quality of urban lifestyle [1–5]. With road transport becoming serious threats to urban air quality and global warming there needs to be a clear policy around these issues encouraging the reduction of emissions in Malaysia [3]. It was with sustainability in mind that a modular electric bus system was proposed to the Malaysian government to respond to both the National Automotive Plan (NAP) and the global energy constraints of future transportation demand (Malaysian Automotive Association 2014). Despite other modes of transport that could be deemed more sustainable, an electric bus system was the focus, as this was identified as having an immediate to medium-term impact for Malaysian public transport. Research also showed that the Light Rail Transit (LRT) and monorail services were adequately represented in the Central Business District (Klang Valley) of KL, Malaysia and the issue was more around the surrounding network and node connectivity. This led to an electric bus system being an ideal development that was considered a viable financial commitment reviewed by MAA. As a result, the Malaysian government contracted Swinburne University of Technology in Melbourne, Australia to develop this project leveraging the university's combined strengths in engineering and design (Swinburne University of Technology 2022). As a design researcher with an industrial design background and professional experience in

the Korean automotive industry, the first author developed a core research theme to create greater awareness and acceptance of sustainable multimodal public transportation systems.

This paper contributes to current approaches to mobility and HCD with a strong focus on user interaction, policy and principal response, design scenarios and the importance of integrated systems. Recent studies employing HCD in the mobility sector have focused on service systems [6] and human-machine interfaces. This study takes a broader human centred mobility approach to design as described by Mitchell, Claris & Edge [7]:

"The transport system needs to be user-centric with all elements from ticketing to wayfinding highly intuitive. It needs to be efficient, cost-effective, and accessible to the widest population, so it can support a growing and vibrant city. The system should be mode agnostic, so a passenger can switch between walking or cycling, or taking a bus, tram, or car as this provides flexibility, but is also inherently resilient if there is failure in one mode or maintenance is required. The ticketing system and real-time information should enable seamless end-to-end journeys across all modes [7]".

Currently there are no studies on human centred sustainable transportation for Malaysia. The literature shows that most projects of this nature are driven by a technological push [8–10]. However, we demonstrate the need to consider HCD elements within the new system to ensure a greater uptake of patronage when implemented. In this paper, we discuss how to identify issues and set design considerations by using a HCD approach for public transportation development. The need for a HCD approach highlighted is specific to KL, Malaysia; however, other developing countries facing such challenges should relate to this approach. Key contributions drawn from our questionnaire survey provide a clear list of priorities for design intervention using HCD principles to increase patronage.

2. Background

Urban cities in developing countries have many social, economic and environmental problems from apparent factors such as population growth, increasing incomes and rapid urbanisation; all resulting in increased travel demand [11]. Malaysia has similar issues with increases to income relating to more private car ownership that has a direct effect on the public infrastructure and air pollution [12]. For public transportation, the integration between modes of public transport is lacking, resulting in poor accessibility for the passengers [13]. There is traffic congestion due to a growing number of private vehicles, and ongoing roadworks add to the traffic blockage. A current lack of distinction between pedestrian footpaths and roads needs improvement, as this is having a direct effect on pedestrian safety [14]. Pedestrians are possible future patrons, making the elements surrounding the electric bus system in Malaysia vitally important in encouraging pedestrians to use the surrounding public transport systems. Prioritising pedestrians and understanding the user needs concerning transportation formed the HCD approach outlined in this paper. Most outer suburban public transport users use the LRT as their main means of transport, with a large number using the 'park and ride' system. The LRT system in Malaysia is the most popular means of transport because of its reliability, which current bus systems fail to deliver [15]. Public transportation should have good integration with all other transport modes to promote patronage [15,16]. This is not currently occurring, with integration shortcomings in current public transportation networks, which includes a lack of continuity in routes and a lack of real-time information to help passengers plan their journey [17].

According to the Malaysia Automotive Association (MAA) *Malaysia Automotive Roadmap 2014*, improving urban public transport is one of the key initiatives (Malaysian Automotive Association 2014). The Malaysian economy, and particularly the economic middle-class are developing so fast that it enables most people to have private vehicles, resulting in significant traffic congestion [18]. Almselati, Rahmat & Jaafar [18] note that congested roads with a lack of public transport facilities significantly worsen the quality of urban living. Contextual studies with a particular focus on Malaysian public transportation show that current systems are inadequate in terms of dealing with urban growth, environmental pollution and transport needs [18]. According

to the Comprehensive Development Plan (CDP) of South Johor Economic Region [19]—a policy package relating to low carbon living in Iskandar, Malaysia—investing in sustainable public transport systems is one of the key agenda items to reduce CO_2 emission [20]. Over 80 per cent of total air pollution is produced by mobile sources such as motor vehicles [1]. Enforcing a modal shift from private vehicles to an electric public bus system would significantly reduce CO_2 emissions; however, a forced change approach is not possible if the system that exists is inadequate to meet the needs and demands of the users. The current environmental issues require policies highlighting sustainability-focused public transport systems to influence the modal shift in Malaysia [21], showing that such sustainable transport systems are important for sustainable economic growth [22].

Vehicle ownership and automobile-dependent development (planned or unplanned) are creating lock-in scenarios that challenge the viability of efficient bus systems [13]. In a recent study conducted in Putrajaya, Malaysia, a current modal split of 15:85 between public: private transport was achieved, with service quality—and, to a lesser extent, attitude—the most significant determinant of behaviour change, while environmental quality had no effect [23]. This suggests that technological efficiency alone will not achieve the desired public behaviour change in urban Malaysia.

The systematic HCD approach to an integrated bus system can promote change by developing appealing future scenarios. Current Malaysian public transport systems demonstrate a lack of consideration for pedestrians [22] and the reason behind the failure of most new public transportation development is due to a lack of correct planning and design [24]. Among the major issues is the lack of consideration to the users of such systems, which is one of the most serious aspects of the successful design process [24]. Improving urban transport requires an emphasis on the end-to-end journey experience, from the moment commuters step out of their homes to when they arrive at their destination [17,25]. In considering such end-to-end experiences, HCD must be integrated from the very beginning to generate viable outcomes for the public.

2.1. Transportation Status: Kuala Lumpur, Malaysia

Public transportation in Kuala Lumpur, Malaysia consists of bus services, mainly operated by a government owned company (Rapid KL); railway services; light rail transit (LRT) and Monorail. Both privately owned and government owned public transport have poor integration and coordination [15]. In a study done by Kamaruddin, Osman and Pei [15], the most preferred mode of public transport in Malaysia is LRT (35.8%) and Monorail (28.1%). This result was predominantly influenced by safety followed by accessibility [15]. The integration between modes of public transport is lacking, which results in poor accessibility for the passengers [13]. This was a key factor in developing an improved public bus system to improve node connectivity that would have an immediate to medium-term impact for Malaysian public transport.

There are four different types of buses operating in Kuala Lumpur, Malaysia. This can often cause confusion together with a lack of real-time bus tracking display [17]. Bus tracking systems help track the destination and saves on travel time, which will help promote the advantages of public transport usage. Visual and auditory displays on bus stops improve the quality of the bus travel experience [17]. Such information puts confidence in the passengers with the reliability of the service, which is one of the major issues with the current Malaysian system [16].

2.2. Human Centred Design

The context of any designed artefact needs to be understood and telling designers that products should be intuitive is not enough; some design principles are needed to guide the design. Norman [26] suggests that the following seven principles of design are essential for facilitating the designer's task:

(a) Use both knowledges in the world (procedural memory) and knowledge in the head (memory that requires learning). By building conceptual models, write manuals that are easily understood and that are written before the design is implemented.
(b) Simplify the structure of tasks. Make sure not to overload the short-term memory, or the long-term memory of the user. On average the user is able to remember five things at a time. Make sure the user has control over the task and make sure the task is consistent and provide mental aids for easy retrieval of information from long-term memory. Examples of mental aids are acronyms, acrostics, rhymes and/or common associations.
(c) Make things visible: bridge the gulfs of execution and evaluation. The user should be able to figure out the use of an object by seeing the right buttons or devices for executing an operation.
(d) Get the mappings right. One way to make things understandable is to use graphics.
(e) Exploit the power of constraints, both natural and artificial, in order to give the user the feel that there is one thing to do.
(f) Design for error. Plan for any possible error that can be made, this way the user will be allowed the option of recovery from any possible error made.
(g) When all else fails, standardise. Create an international standard if something cannot be designed without arbitrary mappings [26].

These principles helped direct the design methods used to ensure the created bus system meets the needs and desires of the public transport users. The elucidation of these intents and how they influence the direction of this study were used to construct an argument to validate a HCD approach for public transportation design. By understanding these factors and identifying methods within a human centred design methodology, a thorough concentration of criteria can be determined to develop an optimum system to satisfy the intentions of this project—that is, to develop an electric bus system in Kuala Lumpur that far exceeds the current systems in place.

Human (user) and behavioural factors are critical to achieving the successful implementation of sustainable public transport systems [27]. A HCD approach is critical for this project to understand all levels of transport design; from the setting of transport policy, to its implementation, through to infrastructure, vehicle and interface design [28]. To improve urban transport, there should be an emphasis on the end-to-end journey experience on public transport from the moment commuters step out of their homes to the moment they arrive at their destination [25]. When considering such end-to-end journey experience, human centred design must be integrated at the very beginning to generate viable outcomes for the public. By doing this, an innovative outcome can be achieved if done correctly, while acknowledging all factors that need to be understood along the journey [28]. It's not just about the physical manifestation of a particular outcome, as the surrounding context and human behaviours need to be considered throughout the entire design process.

Specific to human centred design principles used for an electric bus system we referenced work by Evans and Azmin-Fouladi [14]. In 'Value co-creation as a determinant of success in public transport services', Gebauer, Johnson and Enquist [29] emphasise the importance of understanding the value of co-creation during the development of a new system. This includes activities such as, customer engagement, self-service, customer experience, problem-solving and lastly co-designing. As discussed by Gebauer, Johnson and Enquist [29], customer engagement is a form of marketing, which involves co-creation with customers such as customer feedback on the service. For public transport system development where it involves a wide variety of users, it is important to consider all possible scenarios [28]. Gebauer, Johnson and Enquist [29] go on to state that customer experience leads to positive emotional bonds between the system and the customer. Problem solving within such a system gives self-controllable opportunities for the customer. The customer should be able to navigate and solve the problem with the given system which will result in easy interactions between the system and the customer making a user-friendly environment [29]. This point refers back to Norman [26] who aims to 'humanise technology' and

ensure it is easy to learn, easy to use and easy to understand. To do this the system must understand the user—validating the use of HCD as an appropriate design methodology in this research.

3. Methods

User-focused methods, such as user observation are more likely to reveal genuine problems and novel solutions. This type of method is required to find out whether people can use products and services successfully [30], which will ultimately reveal key design considerations when developing public infrastructure and systems. Furthermore, an online questionnaire conducted in Malaysia, Swinburne University of Technology, Sarawak Campus followed the user observation study to rationalise the HCD approach in this project. Survey methods are commonly used in understanding the views of target users. For instance, a study conducted by Bouhouras et al. [31] used a questionnaire to university students to understand their satisfaction with public transport. Our approach also follows more recent work from Adenaw & Bachmeier [32] in generating activity-based mobility plans which microscopically reproduce real-world mobility demand but circumvent the complexity of activity-based approaches [32]. The methods were chosen as they were deemed the most appropriate to better understand user perspective and to identify issues with the current Malaysian public transport system. They were used to ascertain key findings to promote greater acceptance for a Malaysian public transportation system that will ultimately result in cleaner infrastructure in Malaysia. Sections 3.1 and 3.2 describe these methods in relation to this research.

3.1. Field Research: User Observation

A one-week field research study on user observations was conducted to gain a deeper understanding of the current issues of the public transportation in Kuala Lumpur, Malaysia. The first author spent twenty-eight hours in total during the study. To understand the travelling pain points beyond the KL city centre, the observation took place starting from Putrajaya to Gombak through KL City Centre. The "fly on the wall" technique was used as a method of collecting valid user data in an unobtrusive and cost effecting way [33]. The first author observed and participated in waiting and riding four different bus companies during this study. This user observation was documented between 7 AM to 10 AM and 6 PM to 9 PM. Reflection notes and photos were taken as a means of data collection during the observation. The collected data was then categorised into issues of system and physical design issues. In the field of behavioural studies, both problem-focused and solution-focused approaches can be explored in relation to goal-oriented activities [34]. Problem-focused approaches were taken during this study to identify the current issues. These were then used to help construct the online questionnaire to provide a greater understanding of user needs. The main factors that were recorded in the field notes (Figure 1) and photos were the waiting time and how users enter and exit the current bus network, as well as focusing on touch points along the journey such as paying and collecting fares, user comfort levels (both at bus shelter and on bus) and general wayfinding.

3.2. Online Questionnaire

An online questionnaire was developed based on the user observation findings during the field research to gain a greater understanding of the current problems in need of addressing and to support the importance of a HCD approach outlined in this paper. User observation revealed common pain points and issues when using the current bus system in Kuala Lumpur. The key findings are shown in Table 1.

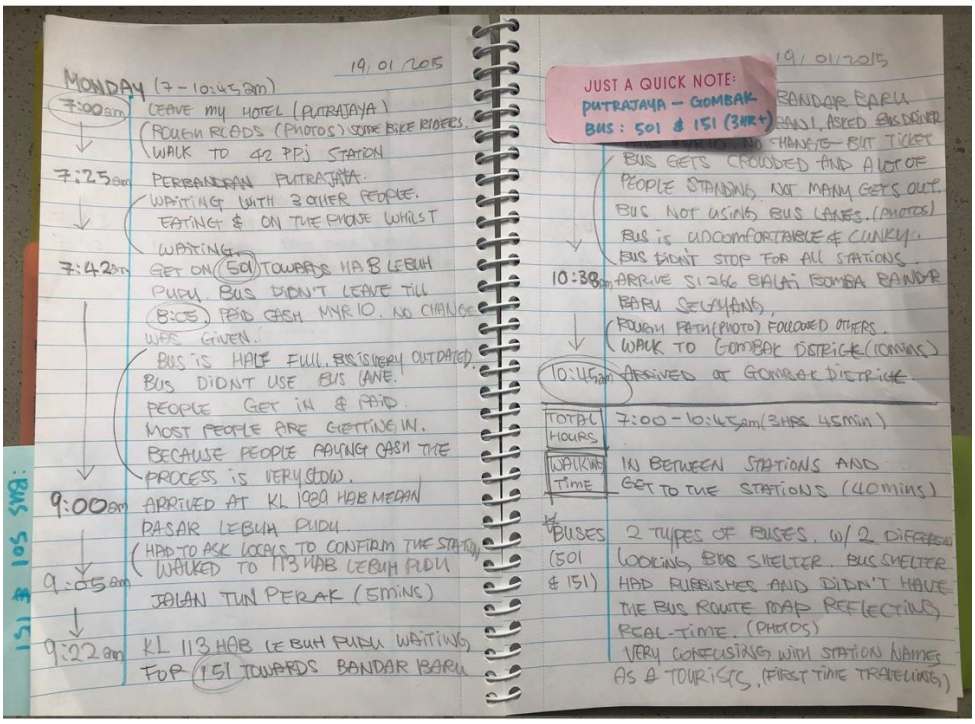

Figure 1. Field notes for user observation.

Table 1. Key findings of the user observation in KL, Malaysia.

Key Finding of the User Observation	
1	Getting on and off the public transport (ingress and egress)
2	Access to remote bus stops and train stations (safety)
3	Smart ticketing system (better integration)
4	The road condition (physical constraints)
5	Real-time display (wayfinding and timetables)
6	Stricter rules around other road users (dedicated bus lane)

These findings helped focus the questionnaire which was effective for quantitative research designed to collect information from a much larger number of users. The questionnaire survey was conducted in Malaysia, Swinburne University of Technology Sarawak campus. The online link to the questionnaire was distributed by the Swinburne University of Technology online platform. In total, 102 Malaysians participated in the structured online questionnaire, which took approximately 10-minutes to complete. These particular Malaysian participants were chosen as a representation of current and future public transport users. Ten questions on participants' public transportation experience were asked. By analysing the data, participants' travel values were revealed. The result of the questionnaire highlighted the important factors required for a public transport system effective enough to promote modal shift.

4. Results

4.1. Field Research: User Observation

User observation revealed six key issues associated with the daily routine of a commuter as documented in Table 1. These key issues were identified through the recording and examining of how users interacted when using the bus system. The first author collected this information and a qualitative analysis grouped key themes which were tabulated. Data compiled followed an approach from Fox, Bowden & Smith [35], which explains that results should be used as a signpost to further research rather than being accepted as absolute

truth. This is why a questionnaire was developed to strengthen the research outcomes and provide a more accurate set of recommendations for the development of a sustainable bus system for Malaysia.

As noted in Table 1, the issues identified for ingress and egress as documented in Figure 2, show dedicated bus lanes not being used resulting in users having to walk onto the road to get on the bus. With no indication of when the bus will arrive due to no real-time display, in this instance, the user waited over twenty-five minutes for the bus, which, when it finally arrived, stopped on the road instead of using the bus lane provided. This was due to the inconvenience to the bus driver of having to navigate back onto the road in traffic with a lack of bus priority.

Figure 2. User observation conducted in KL, Malaysia.

There were also many occasions where lanes designated for buses and taxis only, were completely ignored by both car drivers as well as bus drivers. Even designated bus shelter/lanes were ignored because it was inconvenient for the bus driver to 'pull-in' to the bus shelter and then having to negotiate their way back into traffic. During the observational research, the first author came across four different types of bus services with four different ways of bus fare collection (Table 2).

Table 2. Bus companies and fare collection methods in KL, Malaysia.

Bus Company	Fare Collection Methods
Rapid KL	Require exact change for the fare
Metro Bus	Fare to the ticket collector in the bus
SJ Bus	Exact change to the bus driver
Go KL	Free inner-city bus service

This creates confusion amongst new bus users, as well as a disconnection between modes of transport as documented in the key findings. During the observation problems around disconnections between different modes of transportation were highlighted with an assessment of the negative effect on accessibility. Currently, different Malaysian bus services have different methods of purchasing a ticket. Metro Bus has a person onboard collecting the fare, while on Rapid KL, one must have the exact change which the bus driver collects themselves. This causes inconvenience for the users and time delays.

The way the fare is collected can also be the reason for delayed boarding. During inclement weather in Kuala Lumpur, the cash ticketing system onboard creates delays in bus boarding time, sometimes exceeding ten minutes (Figure 3). Having different methods to pay the fare, including some requiring the exact fare with the one-person operation, can be confusing for both locals and tourists who are unfamiliar with these different systems.

Figure 3. Delayed ingress during inclement weather in KL, Malaysia.

During the field research, safety was also noted as one of the key issues. Some of the poor road conditions jeopardising pedestrian safety were witnessed (Figure 4), as this often involves larger-scale damages forcing pedestrians to negotiate the trajectory in inadequate environments.

Figure 4. Damaged pedestrian paths in KL, Malaysia.

When designing for an urban environment, the inclusion of pedestrian needs should be embedded to promote safer journey experiences [14]. User observation during field research revealed closely related issues which indicated a need for broader systematic solutions rather than partial solutions. Observational research as such is not the only factor to determine the design rationale; however, it helped gain a deeper understanding of the users' behaviour and emphasised a need of developing a system with a strong focus on HCD. The observational analysis also found inadequate pedestrian and road conditions in Kuala Lumpur, as well as a lack of priority given to the bus network.

The research did not want any preconceived biases so the approach for the user observation was intentionally unstructured. Data collection was qualitative with the knowledge that the questionnaire would provide a quantitative response. Sample size was not an issue for the user observation research as it was conducted in the public domain specific to those using the public bus system. This can be categorised as 'Naturalistic Observation' which involved spending time with users and observing their behaviour with the bus system in day-to-day life. The research team determined this approach as more reliable as when people use a system in 'real-life', they are much more likely to encounter the frustrations and benefits of real-life use than they are in a lab following a set of instructions [21].

4.2. Online Questionnaire

The purpose of the questionnaire is to ensure that all problematic actions, positive and negative experiences, and the overarching opinion of those completing the survey is to be revealed. The questionnaire further validated findings from the key observations outlined in the observational research. In total, 10 questions were asked related to demographic profiling, use of public transportation in general, and a series of questions specific to the Malaysian bus system. For the purpose of this paper, we focus specifically on questions related to design considerations (Figure 5).

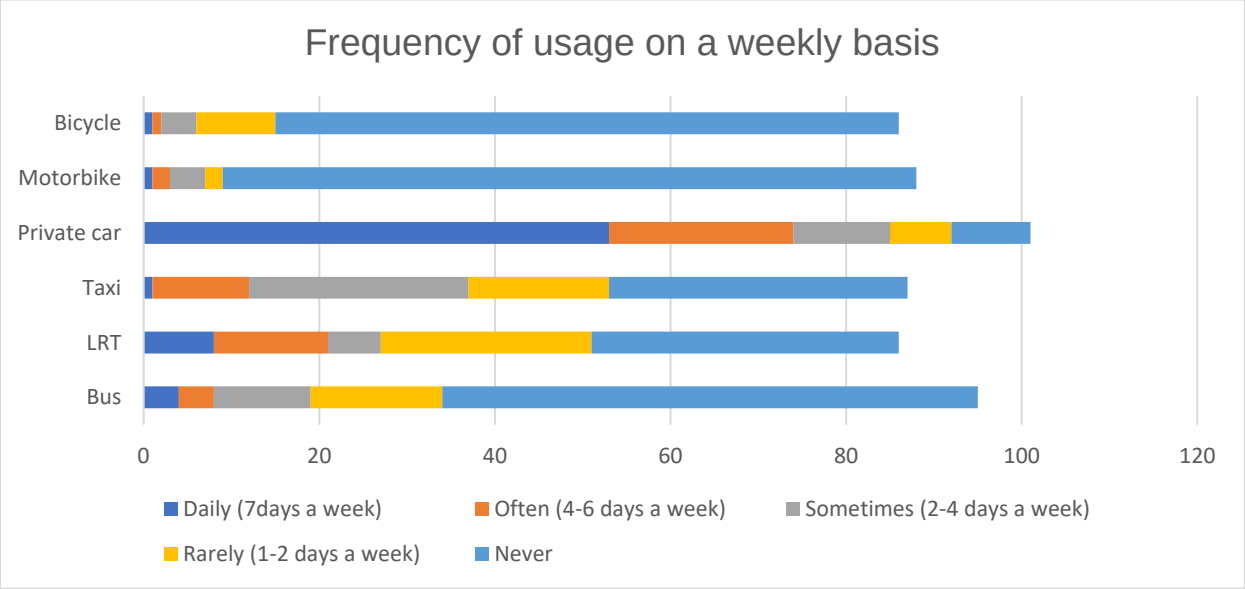

Figure 5. The frequency of different transport mode usage in KL, Malaysia.

In general, there was favouritism to private car transportation mode showing that 75 per cent of all respondents (n = 102) use their private car daily (7-days per week) and/or often (4–6 days per week) to commute, followed by LRT a long way behind at 21 per cent total across both of those categories. It also revealed that only 17 per cent of regular commuters use public transportation. Alarmingly—suggesting the importance of this research—bus usage was one of the least popular choices of daily (7-days per week) and/or often (4–6 days per week) transportation at 8 per cent. In fact, over 60 per cent of respondents had never used the bus system. Motorbikes and bicycles were the least favoured forms of transport in KL, as predicted during the user observation and largely reasoned because of the tropical climate and the safety issues associated with motorbikes. Malaysia has the highest road fatality risk (per 100,000 population) among the ASEAN countries, and more than 50 per cent of the road accident fatalities involve motorcyclists [36]. Kuala Lumpur is also aiming to restrict motorbikes in the city to reduce air pollution. Both

of these key factors further support the need for an improved sustainable transportation option for Malaysia.

When questions were asked about both the interior and exterior design of the current public bus system 78 out of 102 (80%) participants were dissatisfied. If the physical design of the bus (interior and exterior) is not appealing, there is a greater chance of potential users opting for alternate modes of transport. This result shows a need for immediate action in upgrading the bus design to appeal to future users.

When evaluating the HCD principles associated with the current bus system, convenience was the overwhelming majority of responses behind the choice of daily transportation; 98 out of 102 (almost 100%) respondents answered, "Improving the frequency of the bus with real-time display is very important", followed by improving the bus shelter location and access. This once again highlights that punctuality of the current bus systems is a key design issue requiring improvement, and like all issues identified, can be improved with much greater inclusion of HCD principles.

As observed within the field research related to the confusions in the different ticketing systems, 92 out of 102 (94%) respondents preferred to use a better ticketing system and the real-time displays, which indicates that the public wants a more intelligent and reliable ticketing system which has been common practice around the world. This is expanded on further within this discussion section of this paper. This is achievable and relatively easy to implement by designing an integrated bus shelter with real-time display systems linked to a universal ticketing system across all public transportation modes. Furthermore, 95 out of 102 (97%) respondents agreed that better integration between public transportation nodes is a necessity. Table 3 shows key attributes the public see as most important for the current bus service in Kuala Lumpur. These findings were used to guide design intervention discussed in Section 5.

Table 3. Ranking of attributes according to their importance.

	Very Important	Important	Somewhat Important	Possibly Important	Not Important	Sum
Frequency of the bus service	81%	15%	4%	0%	0%	100%
Better ticketing system	56%	34%	8%	2%	0%	100%
Comfort and safety when using the bus	77%	17%	5%	0%	1%	100%
Better connection with other modes of transport	75%	19%	6%	0%	0%	100%
Better environment (Less air and noise pollution)	62%	24%	11%	2%	1%	100%
Bus shelter design	45%	23%	23%	7%	2%	100%
Bus driver's attitude (Friendly service)	64%	26%	6%	3%	1%	100%
Bus shelter location and access	78%	14%	7%	0%	1%	100%

The overall findings of the questionnaire study show that the Malaysian bus system needs to focus much more on the HCD principles and address the identified issues to increase patronage. Many of the findings are not unrealistic and with successful leadership the Kuala Lumpur bus system could quickly improve. Table 4 summarises the key findings from the questionnaire to highlight clear actions categorised by service system and design.

Table 4. Service system and design improvements categorised by the questionnaire.

Service System Related	Design Related
Integrate the bus service and train service by planning the bus route system with fluent transition in mind.	Allocate an electronic display monitor at the bus shelter providing real-time information and/or develop an app that provides real-time information direct to the users' phone.
Upgrade and unify the ticketing system.	Design more ergonomic seating and include air conditioning, as this would encourage patronage in a sub-tropical climate such as Kuala Lumpur.
Dedicate bus lanes to increase speed and frequency of public bus system, as well as safety for pedestrians.	Redesign bus shelter with adequate shelter for weather protection and better lighting for safety.

The analysis of the questionnaire outlines the critical areas that need consideration when proposing an improved bus system for Kuala Lumpur. All improvements identified come from future users of such a system and should form a design platform to improve the current state of the Kuala Lumpur bus system. Currently, the attributes listed in Table 3 are rarely present in Kuala Lumpur. The analysis of the questionnaire study helped define the research objectives by narrowing the focus to areas of specific importance to Kuala Lumpur. The design improvements categorised by the questionnaire in Table 4 underpins the importance of this research by diverting usage away from private vehicles that will result in a more sustainable city. The current bus system in Kuala Lumpur has an unfavourable reputation [37], which is to be expected as evidenced by the research conducted in this paper. The system is outdated, does not meet the needs of the public, and fails to connect major transport nodes throughout the city. The dominance of private vehicles is understandable as the alternative modes of transport are inadequate.

However, to conclude the questionnaire the last question asked was the willingness of using a newly upgraded sustainable public bus system in which 81 out of 102 (83%) respondents answered yes. This strongly indicates positive modal shift if the recommended improvements were actioned, providing a system that is designed for the users. Motivation is a huge factor in positive social innovation [38]. By providing a viable alternative to private vehicles there will be much more motivation behind a modal shift because it aligns with social benefit and importantly, the alternative serves its purpose more so than what a private vehicle can offer. Such as commuting costs, parking availability, connectivity, comfort and efficient mode-to-mode delivery.

Findings specific to HCD principles derived from our research for the development of an improved bus system were focused on three key areas—The bus exterior, the bus interior and the bus stop/infrastructure. The evaluation of the design solutions achieved responding to these objectives are as follows:

4.3. Exterior of EV Bus Design

(a) 'Train-like' exterior design. Designed to mimic the look of a train which gives public transport users in Kuala Lumpur visual assurance of an efficient system. This aims to ensure the introduction of a new type of public transportation alternative is not too radical for user acceptance. It links to elements of design psychology by recommending a new system with known design parameters.

(b) Ingress and egress. This key design element both links to the exterior development and the interior development of the EV bus. Findings suggest a low-floor chassis to create a safer platform when entering and exiting the EV bus.

(c) Colour coded EV bus. A colour coded bus helps commuters identify the bus with the bus route. A major finding within the research was the confusion users have (particularly locals) with understanding the current system. Unlike rail, bus networks do not have an obvious route and many are deterred from using a bus system simply because they don't know where it's going.

4.4. Interior of EV bus design

(a) Colour coded seats. Green and red lights are used to indicate the vacancy of seats during peak hour travel to ensure patrons entering the bus can quickly determine if a seat is available. During congested travel periods this will avoid hesitated searching when entering the bus allowing for faster stops.

(b) Workstation integrated seating. Findings recommend 'workstations' to allow passengers to be productive during their commute. This is something that improves the experience over the comfort of a private car enticing people to use the EV bus to be more productive during their transit.

(c) Wheelchair access. The low-floor chassis of the bus allows wheelchair access and the interior design layout needs to provide provisions for wheelchairs during commuting.

These inclusive design elements help improve the overall system by allowing a wider demographic of users to the system.

4.5. EV Bus Stop

(a) Modular design. The EV bus stop is designed with modularity in mind to ensure efficient manufacturing and flexibility in construction specific to the context it will be installed in. The HCD principles suggest shorter walk times to access bus stops, meaning there will be more bus stops throughout the network. It is important to make these bus stops suitable to the context while considering cost of implementation. This supports earlier work from Calthorpe [39] claiming that 0.8 km is the desired walking distance between train stations and 0.4 km between bus stops. This is also emphasised by Jarrett [40], who claims that there are significant regional variations in the unglamorous but crucial struggle over the spacing between succeeding stops or stations on a transportation line.

(b) Real-time display and improved wayfinding. The inclusion of real-time displays and improved wayfinding with colour coded routes helps bus patrons plan their journey easier. These displays are powered by solar panels which make up the roof structure of each bus stop. In a country such as Malaysia, there is adequate sun to power these bus stops with battery back-up to power lighting and displays during the night.

(c) Sufficient lighting and security cameras. Adding adequate lighting and security cameras helps design against crime and will encourage more users to the EV bus system. The research showed a significant concern for safety making these design interventions critical to the overall success of this system.

(d) Medium strip as a bus shelter. Where applicable in the context of each bus stop, the medium strip of large thoroughfares can be used to position bus stops. This assists in developing 'bus-only' lanes by allocating more road area for the EV bus network.

Transit system changes such as what is shown above have been widely recognised as a success, as it is a lower-cost alternative to rail transit in offsetting traffic congestion and improving access between destinations. Within the literature system changes were reviewed in cities from around the world where public transport was made a priority. In all examples these created an improved public transport network and in some cases improved traffic flow throughout the city, even when private cars still dominated. For this research investment in a new bus network is key to an improved public transport environment. Kuala Lumpur does not have the population or money to justify the installation of rail. It is much more expensive than improving bus services, hence the argument for Kuala Lumpur to invest in this area. While Kuala Lumpur does have a rail network, it is the connection between nodes which needs priority—the best way to do this is by improving the bus system. The proposed EV bus system is put forward as a short-to-medium-term option to improve the ailing bus system in Malaysia. The long-term vision is to replace all fossil fuel-based buses with an improved EV system; however, this transition will take time. The findings specific to HCD principles derived from our research are intended as recommendations for improving the bus system. The design research methods focused on the implementation and execution of research findings in a format that is easily understood and promotes the contribution of new knowledge with impact to the city of Kuala Lumpur. While it is agreed that not all recommendations will be implemented, it is important to push the research intent into areas that lack envisagement by local municipalities who may not have the time or skills to conduct such a detailed study. The key recommendations to enable this are described in detail within Section 5 below.

5. Discussion

As identified during the user observation, bus lanes are not used by buses causing traffic congestion and an unsafe environment for pedestrians. Bus priority has been trialled in Kuala Lumpur, but it has not been strongly pursued, hence promoting unsafe drivers' behaviours [13]. To avoid such situations reinforcing dedicated bus lanes should

be provided [41], which would have minimal impact on the existing infrastructure. This is evidenced positively in Seoul, South Korea, where the bus service was improved by upgrading over 70 km of dedicated median-bus lanes resulting in nearly doubling the bus operating speed [42]. The geographic context and population density of Seoul is similar to Kuala Lumpur, which shows that with appropriate planning, government intervention and improved designs, similar improvements are possible.

The issue of safety is a crucial issue for passengers and appropriate plans are required to support them [43]. Considering pedestrians' safety and daily routine is essential when restructuring public transport systems, especially when the restructure is to enhance and promote better public transportation usage [22]. The quality of pedestrian paths and accessibility of bus services, as well as the bus network, bus transit time, and travelling time, are the significant factors that require greater design input to attract more public transport usage [3,11].

The manner in which bus fares were collected in different ways was also identified as one of the key current issues that requires intervention. Smart ticketing systems have been implemented throughout the world and have dramatically improved efficiency and travel times. According to Woodcock [28], the smart ticketing service contributes to a significant increase in the use of bus services. An example is the smart ticketing service introduced in Seoul in 2004, which integrated both bus and rail systems [44]. This smart ticketing allowed users to use both bus and rail service conveniently and discounted fares for regular users—a major factor in the uptake of this service [44]. Smart ticketing systems are now common practice in most major cities around the world and include the Oyster Card in London, the Octopus Card in Hong Kong and the Myki Card for Melbourne. However, Malaysia has yet to catch up and is still using outdated ticketing systems. As noted previously, prioritising and understanding the importance of service quality surrounding the bus system is essential.

Most of the outer suburban public transport users use the LRT as their main means of transport, with a large number of people using the 'park and ride' system. LRT system in Malaysia is the most popular means of transport [15] because of the reliability it provides which current bus systems fail to deliver. Inclusion of all of the aforementioned aspects regarding improved public transportation development is important when designing a system that promotes greater uptake [45]. This includes the condition of the pedestrian infrastructure and connectivity between transport modes. With continuous road works and constructions in Kuala Lumpur, the pedestrian infrastructure is poorly maintained, resulting in potentially dangerous conditions.

A study by [21] on the modelling of transport behaviour in Kuala Lumpur supports the results from the questionnaire by suggesting the need for an improved and efficient public transport system to attract vehicle owners and entice users away from personal vehicles [21]. This was supported in the questionnaire analysis when participants were asked their preferred mode of transport and the reason why. In this study, 'efficient' refers not just to punctuality but to the whole system experience, making it worthwhile for the commuters using public transportation systems. Major factors such as travel time and travel cost, distance from home to public transport and distance from home to work are the contributing factors that influence the modal shift from vehicle to public transport in Malaysia [21]. In a similar study by Memon et al. [46], participants also considered the environmental factor as the motivation for using public transport instead of personal vehicles.

Both user observation research and the online questionnaire emphasise the importance of including a HCD approach to influence the development of an integrated bus and bus shelter system. Figure 6 shows the design consideration of this project; derived from user observational research and the questionnaire. This diagram includes a modular bus shelter design, as well as critical elements surrounding the electric bus system.

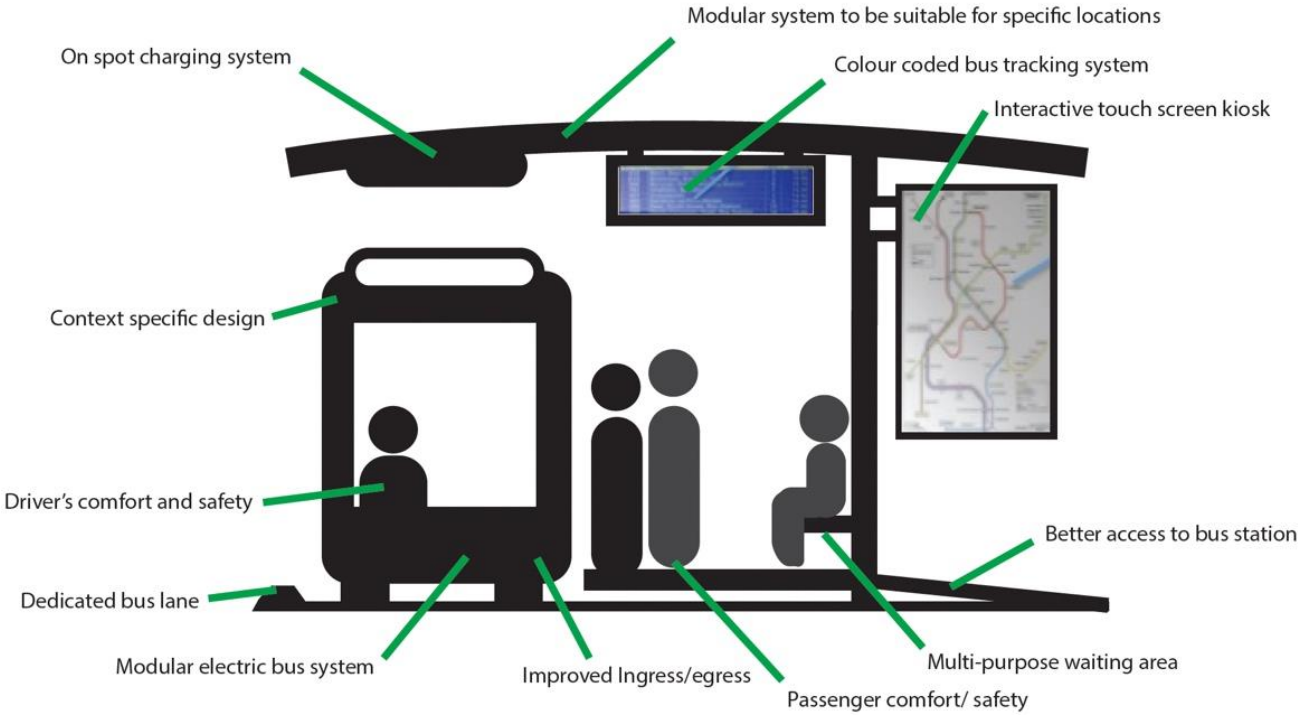

Figure 6. Proposed system diagram for an improved bus infrastructure.

The proposed design diagram includes the following layers of design considerations:

1. The user consideration (journey purpose)
2. The workstation (vehicle, controls, waiting area and communication systems)
3. The workplace (type of road, density of traffic and etc.)
4. The setting (weather, transport infrastructure, time of day, etc.)
5. External issues which driver and passenger may have little control over (such as sustainability, pollution, economics and etc.)

While it is understood that not all recommendations will be implemented due to factors such as political agendas, government priorities and public perceptions, the recommendations put forward are all feasible for implementation which have been validated by this research. It is important to push the research intent into areas that may not have been envisaged by local municipalities who simply do not have the time to conduct such a detailed study. This shows the importance of this research by thoroughly investigating problematic areas with recommendations on how to fix them.

The analysed questionnaire data validated that a HCD approach is importance for improving the disconnection between urban development and transport systems. One of the highly influential factors in user perception is the accessibility of public transportation [47]. A HCD approach also encourages the development of better waiting areas for the convenience and safety of passengers, which is one of the most important factors as emphasised during user observation and the questionnaire analysis. As witnessed during the user observation research, developing public transportation should not only be about the system itself but should have an inclusive approach to all aspects surrounding the system.

6. Conclusions

There is undeniable evidence from this study to support the literature in rationalising a HCD approach for an improved public bus system in Malaysia. The data supports the need to develop a viable bus system for Malaysia with key findings showing only 17 per cent of regular commuters use public transportation, with the remaining 83 per cent using a private vehicle. Alarmingly, over 60 per cent of respondents have never used the bus system in Kuala Lumpur showing; the overwhelming majority of potential

patrons are private car users; creating a large segment to target for a modal shift. In order to entice people from private vehicles to public transportation, improvements must be made. However, developing a public transport system needs to envisage more than just technological developments. In planning such systems, engineers and designers need to consider the everyday users of these systems to understand the intricacies of human interaction with such public transportation. This paper identified key areas that need improvement and approaches that need to be included in a public bus system which will lead to greater patronage. Through two research methods (user observation and a questionnaire), a greater understanding of the major issues is presented. By linking these issues with a HCD approach, it is anticipated that improved solutions can be developed that prioritise the user. The future direction going forward aims to convert this research into full implementation and as patronage increases, the system can continue to reinvest profits into future improvements. Users will consciously or subconsciously appreciate the HCD elements and will continue to use the system if it is a supportive and efficient environment. This will help promote user behaviour change within the public transportation network for Kuala Lumpur and aims to reduce to misconception that public transport usage in Kuala Lumpur is deemed the poor person's mode of transport. In doing this, a sustainable bus system can be developed that could change the modal shift from the privacy of one's car to the convenience of a bus system that 'actually' works. Ultimately, this research creates greater awareness of public transport usage in Kuala Lumpur and ensures the focus should shift from private car ownership to a more efficient public transportation solution. By pushing this agenda, we can create cleaner—more livable—cities through greater connectedness, greater usability and greater social norms.

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