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Shaping a New Level of Bus Service under a Novel Concept of Bus Interaction: A Meta-Review

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Abstract

Public transport services, particularly bus services, play an important role in a sustainable transportation system. However, despite various efforts, bus ridership has decreased. The appearance of shared and on-demand vehicle services is one of the main reasons for this issue. In addition, bus tourism services have been successfully developed to meet the exigent needs of tourists. Therefore, a new level of daily bus service is necessary to adapt to the changing demands of customers. Bus interaction (BI) plays an important role in bus services. Nevertheless, the conventional concept of BI mainly refers to users, physical interaction, and safety, but it does not address non-users, non-physical interactions, service quality, and other aspects. This study aims to elaborate on a new concept of bus services. Based on this, we developed a theoretical framework for BI. A meta-analysis was then conducted to identify the achievements and untouched aspects. The results of this study provide three main contributions. First, an unprecedented novel concept of BI is defined, including 13 types of interactions. Second, a comprehensive theoretical framework of BI is established based on the relationships between eight sustainable bus system sub-aspects and 13 BI types. Third, based on the theoretical framework and findings of the reviewed studies, a common finding comprehensive framework of BI is completed, which is accompanied by 1) key findings of the 13 BI types, 2) conclusions of traffic conditions affecting BI research, 3) BI research gaps, and 4) 16 main suggestions for future BI research.

Keywords

Bus Service, Bus Interaction, Human Demand, Sustainable Bus System, Traffic Condition

1. Introduction

Public transport services are a key factor in a sustainable transportation system [1]. Ideally, public transit ridership should increase if we aim towards sustainable cities [2]. Although bus services have been greatly improved by various measures, the number of passengers has not increased significantly [3], it has even declined in some places [4] [5].

The strong rise of mobility-as-a-service (MaaS) and mobility on demand can redefine public transport [6]. The appearance of on-demand vehicle and shared-vehicle services such as ride-hailing [7], car-hailing [8], demand-responsive transport [9], and ride-sharing [10] with their own advantages, have attracted customers from other modes. However, Maas is also one of the reasons for the decrease in the number of bus passengers [11] and there is no evidence that Maas contributes to sustainability goals [12].

Many traditional solutions have been proposed to improve the quality of bus services. However, bus services cannot fully satisfy the requirements of passengers, which has led to loss of bus passengers [13]. Raising bus ridership in local bus services by improving attributes such as travel cost, comfort, and flexibility is not cost effective [14]. Bus ridership has not increased, on the contrary, it has decreased with the continuous growth of the scale of the bus in recent years in China [3]. It seems that traditional improvements may not be appropriate for the emerging challenges. In a recent trend, bus services are being redirected and focused on on-demand services [1]. The advent of demand responsive bus [15] and customized bus [16] services seems to respond to the above demand. Nevertheless, the operational performance of these modes has some limitations regarding vehicle routing, the number of stops, and the length of detour times [15], and they are less cost-efficient [17].

Conversely, bus tourism services with their own characteristics are strongly developed and play an important role in serving the needs of tourists [18] [19]. Bus tourism is one of the most important factors in public passenger transport demand [20]. An "ideal journey experience" is also based on the concept of being able to relax, being engaged in sightseeing, and, in some instances, enjoying the company of others [18]. Therefore, switching daily buses toward tourism is a potential solution for increasing bus passengers.

Besides, according to the theory of human motivation [21], there are five motive levels. When a need is fairly well satisfied, the next pre-potent ("higher") need emerges and serves as the center of organization of behavior. The hierarchy of transit needs is composed of three types of attributes: functional, security, and hedonic [22]. In the first of the two levels of BRT, the travel demand of passengers is concentrated on frequency, reliability, accessibility, speed, cost, safety, and security. The highest level of hedonic state refers to the perception of passengers of accessory attributes such as vehicle cleanliness and physical condition, noise, smell, aesthetics, convenience and ease of use, user information, customer services, driver's courtesy, and image. There are also interactions between passengers and bus attributes.

These arguments and discussions show the central nature of the needs of bus passengers and pose a new challenge for traditional bus services. Conventional service needs to experience a breakthrough and achieve a new level in terms of adaptation to the changing demand of humans and the attraction of more passengers.

This study has three objectives: 1) To propose a new concept of improvement in bus services with a focus on the human aspect. 2) To develop a comprehensive framework for bus service development based on the proposed concept. 3) Based on the developed framework, to identify what has been done and what is needed for future studies.

This study is presented in the introduction section, **Section 1**, which reviews the status of the bus service and its recent declination; the impacts of emerging services (on-demand based) on the bus service as factors leading to the reduction of bus passengers; the efforts to improve and direct the bus service and their limitations; the success of bus tourism in attracting passengers; and the human motivation theory in bus service, and its connection to BI. Consequently, three main objectives are proposed. **Section 2** presents a research flow chart and the methodology for implementing the aforementioned objectives. **Section 3** deals with BI from the viewpoint of a sustainable bus system, including the key characteristics of a sustainable bus system, the roles and existing challenges for the bus system, and the importance of BI in bus system and dealing with the aforementioned challenges. **Section 4** introduces an unprecedented and elaborate novel definition of BI and describes its characteristics compared to the conventional understanding. **Section 5** presents the proposed comprehensive theoretical framework of BI and the creation of this framework. **Section 6** completes the common finding comprehensive framework of BI. From this framework, research gaps emerge, the key findings of 13 proposed types of BI are summarized, and a hypothesis of research results differentiated by traffic conditions is proven. In addition, 16 main suggestions for future BI research are proposed. Finally, **Section 7** discusses and concludes the paper.

2. Method

To determine the three objectives, a flow chart was built to present all the steps of the methodology, which is shown in **Figure 1**. First, the theory of human motivation is applied to public transport satisfaction. BI is strongly connected to human motivation and plays an important role in the bus system. From previous studies, the notions of "sustainable development", "sustainable transport", and "sustainable bus system" are stated. A novel concept of BI is elaborated based on three main pillars (human, vehicle, and environment), considering the theory of human motivation and sustainability. This includes some types of interactions between the dimensions of the three pillars, as listed in **Table 1**. The contents of this concept are described in detail in **Section 4**.

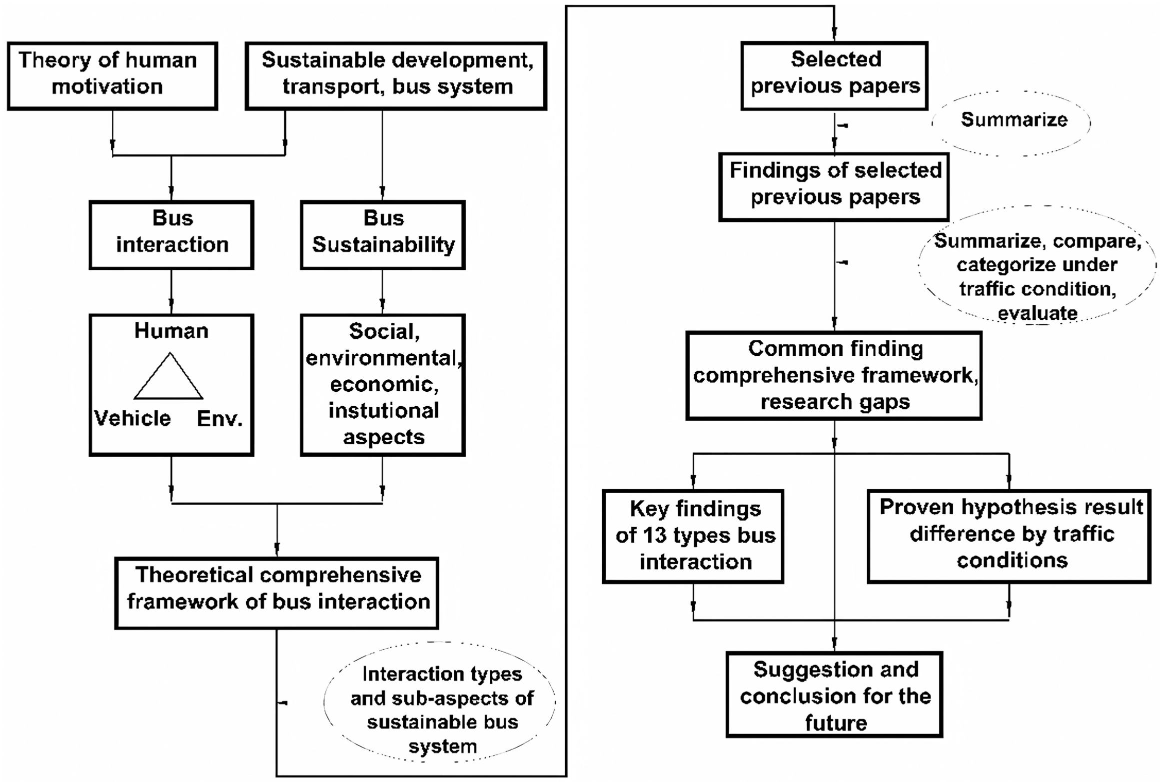

Figure 1. Flow chart of the study.

Table 1. Types of bus interaction.

No.	Interaction	Characteristics
1	Bus-bus driver	Driving behavior (DB), use of steering wheel, brake, clutch, gear, etc.
2	Bus-passengers	Passengers use bus components, sit, stand, hold grab handles, etc.
3	Bus-other vehicles	Movement of bus affects other vehicles and vice versa.
4	Bus-other drivers	Bus movements affect DB of other drivers and vice versa.
5	Bus-environment	Bus exposure to infrastructures, road surface, bus stops, weather, lights, etc.
6	Bus driver-passengers	Communication by gestures, actions, sounds, etc. in the interior of the bus.
7	Bus driver-other vehicles	Bus driver's perception of the movement of other vehicles.
8	Bus driver-other drivers	Perceptions of bus drivers about others. Communication by gestures, sounds, etc.
9	Bus driver-environment	Bus driver perception of existing infrastructures, bus stops, weather, lights, trees, buildings, etc.
10	Passenger-passenger	Communication by gestures, actions, sounds, etc. in the bus.
11	Passengers-other vehicles	Perceptions of passengers about movements and sounds of other vehicles.
12	Passengers-other drivers	Perceptions of passengers about others. Communication by gestures, sounds.
13	Passengers-environment	Passenger perception of existing infrastructures, trees, weather, lights, etc.

Then, a theoretical comprehensive BI framework table was developed using the cross-table method under a combination of BI types and sustainable bus system dimensions, as presented in **Table 2**. The importance of this content was

Table 2. Theoretical comprehensive bus interaction framework.

No.	Types of bus interaction	Sustainable bus system viewpoint							
		Society			Economy		Environment	Institution	
		a	b	c	d	e	f	g	h
		Safety and security	**Accessibility**	**Quality of service (Q.O.S)**	**Costs**	**Revenue and vehicle efficiency**	**Emission and noise**	**Planning and management**	**Public policy**
1	**Bus-bus driver**	Driving behavior (DB) affects safety and accidents.	DB (relating to floor ramp) affects to accessibility of passenger	DB affects to comfort, satisfaction of passengers.	DB affects fuel consumption, operating cost	Affecting average speed, bus delay, bonus, schedule, allowance	Directly affecting the amount of emission (CO, PM)	Bus drivers are affected by planning of infrastructure	Investments, subsidies, training ensuring bus drivers improve driving ability
2	**Bus-passengers**	Relation between bus components and injuries, effect of inner bus environment on health	Bus movement & its components (lowered-floor ramp) affect accessibility	Bus movement and its components affect comfort, satisfaction of passengers	Costs of maintaining and improving components	Effect on number of passengers, fare revenues.	Passenger load affects fuel consumption and emission	Bus provides on-board trip information	Investments, subsidies help to attract more passengers
3	**Bus-other vehicles**	Movements of bus and other vehicles affect safety, cause accidents	Other vehicles (ex. motorcycle, bicycle) prevent accessibility of passenger to bus at bus stop	Bus movement affects comfort, satisfaction of passengers	Cost of repairs, maintenance, and improvement of property	Effect on average speed and delay of bus	Movements of the bus and other vehicles generate noise, emission	Planning of bus stops, lanes, hubs affect interactions	Investments, promotion of bus, restriction of others, reduction in accident risk
4	**Bus-other road users**	Direct impact on perception and safety	Perception of others to bus movement affects to their reaction and accessibility	Bus movement affects to comfort, satisfaction of other road users	Interaction affects to accident risk and pollution costs	Interaction affects to ability of using bus of others, riderships	Bus movement affects to others perception & DB, emissions & noise	Planning of bus stops, lanes, hubs affect interaction	Restrictive and promotional policies reduce other road users
5	**Bus-environment**	Relation to risk and severity of traffic accidents, safety	Bus movements, its components, bus lanes, and bus stops affect accessibility	Environment affects satisfaction, comfort, transfer, and reliability	Relation to fuel, operating, accident, and materials costs	Effect on average speed of bus	Interaction generates noise and air pollution.	Planning of bus stops, lanes, hubs affect interaction	Investment in bus system and its infrastructure improve service quality
6	**Bus driver-passengers**	Communica-tion affects driving behavior & safety	Interaction around bus stop affect to accessibility	Communica-tion affects reliability, satisfaction, wayfinding	Interaction affects to DB & fuel cost	Communica-tion affects attraction of ridership	Communica-tion generates noise in bus	Information provision from bus driver to passengers	Promotion of bus use increases interactions
7	**Bus driver-other vehicles**	Perception of bus driver affects DB and safety	Perception of bus driver affects to DB & accessibility around bus stop	Perception of bus driver affects DB, comfort, and satisfaction	Perception and DB affects to fuel and operating cost	Effect on average speed of bus	Use of bus horn by driver induces noise	Planning of bus lanes affects interactions	Restrictive policies reduce interactions

Continued

8	**Bus driver-other road users**	Perception of bus driver affects DB and safety	Interaction affects to DB & accessibility around bus stop	Perception of bus driver affects DB, comfort, satisfaction	Perception and DB affects to fuel and operating cost	Effect on average speed of bus	Use of bus horn by driver induces noise	Planning of bus lanes affects interactions	Restrictive policies reduce interactions
9	**Bus driver-environment**	Perception of bus driver affects DB and safety	Perception and stopping pattern of bus drivers affect interaction	Perception affect DB, comfort, and satisfaction	Perception and DB affects to fuel and operating cost	Perception of bus driver affects average speed of bus	Perception affects to DB, generates emission& noise	Planning of bus stops, lanes, hubs affect interaction	Public investment increases interaction
10	**Passenger-passenger**	Passengers' behaviors affect security of other passengers	Passengers affect the accessibility of other passengers	Communications between passengers affect comfort, satisfaction	Interaction time when they get on/off affect to fuel & operating cost	Communication affects ridership attraction	Communication between passengers induces noise	Condition of bus stop & hub, information provision affect to interaction	Promotional policy increases interaction
11	**Passengers-other vehicles**	Other vehicles affect to safety when passenger get on/off at bus stop	Other vehicles affect passenger when they get on/off at bus stop	Perception affects comfort, satisfaction	Interaction time when they get on/off affect to fuel & operating cost	Conditions of other vehicles affect ridership	Interaction when getting on/off affects to DB, emission & noise	Location and condition of bus stop affect to interaction when getting on/off	Restrictive policies reduce interactions
12	**Passengers-other road users**	Passengers' behaviors affect other's DB behavior, safety	Perception of others affect to passengers when getting on/off	Perception affects comfort, satisfaction	Interaction time when they get on/off affect to fuel & operating cost	Conditions of other drivers affect ridership	Interaction when getting on/off affects to DB, emission & noise	Planning bus stop & bus land affects to others perception	Restrictive policies reduce interactions
13	**Passengers-environment**	Bus stop facility affects to safety when passenger gets on/off	Bus stop affects to accessibility when passenger gets on/off	Perception of passenger affects comfort, satisfaction	Interaction time when they get on/off affect to fuel & operating cost	High-quality outside environment attracts ridership	Interaction when getting on/off affects to DB, emission & noise	Planning of infrastructure, bus stop, information for passengers	Public investment increases interaction

validated by a group of specialists and political stakeholders [23]. The theoretical content of each cell of the framework shows the relationship between each column and row. **Section 5** provides more details on the theoretical framework of BI.

Subsequently, based on the above framework, BI-related studies were reviewed. The method of searching for previous studies is presented in **Section 6.1**. The findings of each study are summarized in **Table A1**. From this, the common findings of each relationship are attained up to the time of searching. These common findings are then collated with the theoretical content. They are replaced in each cell of the theoretical comprehensive framework of BI if they have any practical content. In this step, three cases are discussed in **Section 6.2** in more detail. A new framework is the common finding comprehensive framework of BI, as presented in **Table 3**. This table also presents the relationships that are either fully studied or lacking. This implies that there are many relationships between existing research gaps.

Table 3. Common finding comprehensive bus interaction framework.

No.	Types of bus interaction	Sustainable bus system viewpoint							
		Society			Economy		Environment	Institution	
		a	b	c	d	e	f	g	h
		Safety and Security	Accessibility	Quality of service (Q.O.S)	Costs	Revenue and vehicle efficiency	Emission and noise	Planning and management	Public policy
1	Bus-bus driver	Driving behavior (DB) is the biggest contributor to traffic safety and accidents. Neuro-transportation is a potential research direction for the future	DB (relating to floor ramp) affects to accessibility of passenger	Driving style, behavior contribute to passenger satisfaction.	Eco-driving training and good driving behavior regarding acceleration significantly improve fuel economy	Psychological symptoms, sensation seeking, aggression, smoking habit, alcohol usage affect bus speed	DB patterns, speed, brands of buses affect emission and noise. Engine generates noise. Number of stop & go cycles, and acceleration affect emission	Location and number of bus stops, camera surveillance, enforcement activities, manned and automated enforcement determine DB	Training and enforcement programs reduce hard braking and acceleration, aggressive patterns, unsafe lane change
2	Bus-passengers	Most injuries of bus passengers and severity of these injuries are commonly caused by impact with elements inside the bus.	Low and equal-size steps or no steps in bus entrance and well-designed handrails make boarding & alighting easier	The adequacy and quality of the bus components are the two main factors affecting comfort and satisfaction	Costs of maintenance and improvement of components	Cleanliness, air quality, high speed, decoration, temperature, and convenient payment increase ridership & revenue	Passenger load increases fuel consumption, emission, and noise. Boarding and alighting of passengers increase air pollution	Buses provide a real-time information system for passengers	Investments on bus design help attract more passengers. A car restriction policy increases public transport passenger
3	Bus-other vehicles	A wide range of vehicles, heavy vehicles, high speeds, old drivers result in a high possibility of severe collisions	Other vehicles (ex. motorcycle, bicycle) prevent accessibility of passenger to bus at bus stop	Optimal bus frequency results from a balance between passengers' crowding inside bus and congestion outside	Operating cost increases with traffic congestion. Accidents generate vehicle and general costs	Interaction between bus and other vehicles is the main reason for reducing bus speed	Bus and other movements in rush hour, mixed traffic cause higher total fuel consumption and emission	Bus priority schemes and techniques have proven to be effective for faster travel times	Limiting number and usage of cars are effective regulations for a sustainable public transport
4	Bus-other road users	The severity of bus accidents is positively related to vulnerable road users and illegal DB	Perception of others to bus movement affects to their reaction and accessibility	Bus movement affects to comfort, satisfaction of other road users	External costs such as accident risk and pollution are imposed on non-users	Interaction affects to ability of using bus of others, ridership	Bus movement affects to others perception & DB, emissions & noise	Planning of bus stops, lanes, hubs affect interaction	Restrictive and promotional policies reduce other road users
5	Bus-environ-ment	Infrastructure quality, road status, and road design have a certain influence on the speed and safety of buses	Bus movement, its components, bus lane and bus stop affect accessibility	Poor layout, infrastructure and road surface quality cause discomfort of passengers	The terrain type, road surface, and infrastructure quality have an impact on the operating cost	A good infrastructure design (number and location of bus stops, crossings, …) helps increase bus speed	Pavement type, thickness, void ratio, particle size, aging, and abrasion of road have influence on noise from tire/pavement interaction	Segregated and priority lanes, well-organized bus stops help enhance speed. In bus lines with more stops, speed is low	A high level of investments in the transportation system is a positive aspect to assure a good bus system

Continued

6	**Bus driver–passengers**	Conversations between bus driver and passengers reduce accident risk, but also reduce concentration	Interactions around bus stop affect to accessibility	Elderly, negative passenger have effects on mental fatigue and satisfaction of bus drivers	Interaction affects to DB & fuel cost	Effect of communication on ridership attraction	Communications (bus driver, ticket collector) generate noise in bus	Information provision from bus driver to passengers	Promotion of use of bus increases interactions
7	**Bus driver-other vehicles**	Age, inattention, village culture, and drink-driving behaviors affect the perception of the bus driver	Perception of bus driver affects to DB & accessibility around bus stop	Mixed traffic flow conditions are positively correlated with the levels of driving fatigue of the bus driver	Perception and DB affects to fuel and operating cost	Effect on average speed of bus	Heterogeneous traffic flows, horn events increase noise level by 0.5 - 13 dB as compared to homogeneous	Planning of bus lanes affects interactions	Restrictive policies reduce interactions
8	**Bus driver-other road users**	Age, gender, inattention, and drink-driving behaviors affect bus driver perception and DB	Interaction affects to DB & accessibility around bus stop	Slow drivers, pedestrians & over cutting make bus driver angry or frustrated	Perception and DB affects to fuel and operating cost	Affecting average speed of bus	Driver's bus honk induces noise	Planning bus lane affects interactions	Restrictive policies reduce interactions
9	**Bus driver-environment**	Poor infrastructure system, bad road terrain, inattention increase risk and severity of accident	Perception and manner of stopping of bus drivers in proximity of bus stops	Road conditions affect the satisfaction of bus drivers	Perception and DB affects to fuel and operating cost	Perception of bus driver affects the average speed of bus	Perception affects to DB, generates emission & noise	Failure to stop bus at bus stop because of its poor conditions and unplanned stopping of bus	Public investment increases interaction
10	**Passenger-passenger**	Security against crime, driverless shuttle buses, staff behavior are most important criteria for encouraging bus commuters	The presence of passengers standing inside the bus increases the boarding time	Too many passengers cause unwanted arousal & emotional states that reduce passenger satisfaction	Interaction time when they get on/off affect to fuel & operating cost	Excessively overcrowded buses may drive away anxious travelers	Communication between passenger and passenger cause air pollution and noise	Condition of bus stop and hub, information provision affect to interaction	A promotional policy increases the complexity of interaction
11	**Passengers-other vehicles**	Other vehicles affect to safety when passenger get on or get off at bus stop	Other vehicles affect passenger when they get on/off at bus stop	Perception affects comfort, satisfaction	Interaction time when they get on/off affect to fuel & operating cost	The condition of other vehicles affects ridership	Interaction when getting on/off affects to DB, emission & noise	Location and condition of bus stop affect to interaction when getting on/off	A restrictive policy reduces interactions
12	**Passengers-other road users**	Passengers' behaviors affect other's DB behavior, safety	Perception of others affect to passengers when getting on/off	Perception affects comfort, satisfaction	Interaction time when they get on/off affect to fuel & operating cost	The conditions of other drivers affect ridership	Interaction when getting on/off affects to DB, emission & noise	Planning bus stop & bus land affects to others perception	A restrictive policy reduces interactions
13	**Passengers-environment**	Bus stop facility affects to safety when passenger gets on/off	Bus stop affects to accessibility when passenger gets on/off	Perception of passenger affects comfort, satisfaction	Interaction time when they get on/off affect to fuel & operating cost	A high-quality outside environment attracts ridership	Interaction when getting on/off affects to DB, emission & noise	Planning of infrastructure, information for passengers	Public investment increases interaction

(dark shading)	Lack of research
(light shading)	Lack of some research aspects
Contents	Full research

From the common finding comprehensive framework, the key findings of 13 types of BI are summarized up to the time of searching. Simultaneously, a hypothesis for the differences in research results based on traffic conditions is proposed and proven by comparing some results of the same studies between the "car-based society" (CBS) and "motorcycle-based society" (MBS). Since then, research gaps have continued to appear.

Based on these research gaps, 16 main suggestions for future BI research are proposed and many other implicit suggestions are extracted from **Table 3**. The final part summarizes all contributions, discusses the research limitations, and provides solutions to address them. To approach a novel concept of bus interaction, first, we need to consider bus interaction under a sustainable bus system.

3. Bus Interaction under the Viewpoint of a Sustainable Bus System

Sustainability is a characteristic of a process that can be maintained at a certain level. "Sustainable development" is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [24]. A "sustainable transport" is a transport system that meets society's economic, social, and environmental needs [25]. Strengthening the public transport can enhance the productivity and efficiency of transport supply, improve traffic safety, reduce environmental pollution, and increase economic efficiency [26]. From the results of previous related studies, a "sustainable bus system" was established and validated. It covers many aspects of the society, environment, economy, and institutions, as shown in **Table 2** [23].

However, previous bus-related studies have been spontaneous, scattered, and mainly focused on accident prevention and speed improvement, but not on enjoyment. They are limited and do not support the quality of experience of passengers, bus drivers, other vehicles, and other road users. Therefore, these studies may lose the comprehensiveness of a sustainable bus system. In addition, previous bus-related works also focused excessively on the CBS, but not on the MBS. Strategies that help achieve sustainable transportation are not integrated within a holistic framework in developing countries [27].

Additionally, the change in travel habits and vehicle use after the Covid-19 pandemic [28], the increasing severity of natural disasters [29], the information technology revolution (machine learning, big data) [30], and new means of communications are challenges in the current transportation field [31]. These emerging issues significantly influence bus-related research methods, processes, and results.

Further, BI leads to the necessity of reorganization of the bus system (Kim and Dickey, 2006). In addition, interaction with passengers is one of the top two priorities for improving the quality of bus service [32]. In another study, coordinating bus dynamics with the surrounding traffic helped maximize bus service regularity [33].

In the past, the conventional concept of BI mainly referred to users, safety, and physical interaction [13] [34]. In recent years, there have been a few BI studies on non-users [35], quality of service, and non-physical interactions [36]. With such an important role in the bus system, to deal with the above-stated challenges of the bus system, BI needs to cover not only users but also non-users, not only physical interactions, but also non-physical interactions. It also needs to consider not only safety but also other aspects (service quality, costs, emissions, and noise). Therefore, an elaborate novel concept of BI is necessary to have a more comprehensive view of it and to provide a solid foundation to achieve a new level of bus service.

4. A Novel Concept of Bus Interaction

To move towards a sustainable bus system and meet needs of sustainable transport, within the sustainable development goals (SDGs), a new concept of BI should cover bus-related objects as much as possible. Therefore, BI is defined in this paper as all the interplays back and forth between factors inside the bus (bus interior), and the interactions between these factors (bus interior) and factors outside the bus (bus exterior) during bus operation, as shown in **Figure 2**. These interactions rely on three main pillars: people, vehicles, and the environment. People include bus drivers, ticket collectors, bus passengers, and other road users; vehicles include buses and other vehicles (cars, motorcycles, bicycles, etc.); and the environment consists of elements of the physical environment (infrastructure, trees, houses, buildings, light posts, traffic density, homogeneity, etc.). **Table 1** lists the 13 types of detailed BIs and their characteristics.

Conventional BI includes simple physical interactions such as bus-other vehicles, bus-passengers, and bus-environment [37] as shown by the pink solid

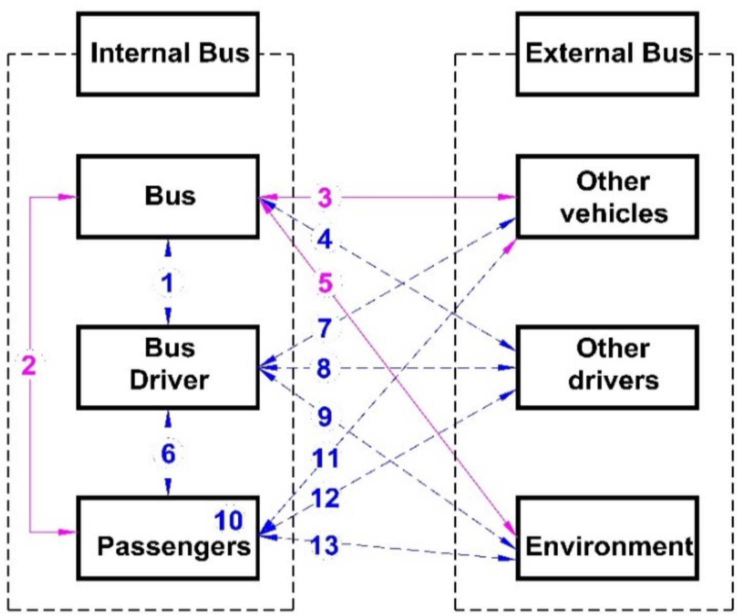

Figure 2. Interactions in the novel concept of bus interaction.

lines in Figure 2. The former concept has limitations; it is not possible to cover all the elements that may be related to the bus components when it is in operation. The new definition of BI covers 13 different types of both interior and exterior interactions as shown by both the pink solid line and blue dashed line interactions (new interactions in new definition of BI). The significant advances of the new definition compared to the former are as follows: 1) it considers human factors with non-physical interactions, and 2) it includes not only passengers but also other road users (potential passengers). The novel definition uncovers a comprehensive view of BI and its role in the bus system. This novel definition is in line with the orientation of the SDGs, which aim at a people-centered development. This is essential for achieving a sustainable bus system.

Based on this new concept, we need to understand what has been done in previous studies and what has not been done. Therefore, a comprehensive meta-analysis study from the viewpoint of sustainability is vital for drawing a general picture of bus interactions. Surprisingly, this type of research has not been conducted yet. The next section presents such a meta-analysis to consider the above contents.

5. Theoretical Comprehensive Framework of Bus Interaction

As mentioned above, a comprehensive meta-analysis from a sustainability perspective is necessary. A cross-table method was used to establish a theoretical framework.

Table 2 presents the comprehensive theoretical BI framework. This holistic framework was developed by combining the 13 proposed types of BI in rows and eight sub-aspects of the sustainable bus system viewpoint in columns. The 13 types of BI are discussed above. The eight dimensions of the sustainable bus system are safety and security, accessibility, quality of service, costs, revenue and vehicle efficiency, emission and noise, planning and management, and public policy. The safety and security dimension includes traffic accidents and personal security. Accessibility comprises bus stops and buses for disabled people and females. Quality of service includes bus frequency, user satisfaction, number of transfers, punctuality, reliability, comfort, and travel shops. Costs comprise fuel costs, operating costs, and accident costs. The revenue and vehicle efficiency dimension includes fare revenues, average speed, number of passengers, and vehicle occupancy. The dimension of emission and noise includes air (CO, particulate matter (PM) pollutants) and noise pollution. Planning and management comprises sub-aspects such as number of stops, location of bus stops, coverage rate, bus lanes, condition of bus stops, transfer hubs, and information provision. Public policy comprises public investment and training, public subsidies, restrictive policies, and promotional policies.

The contents of the cells in Table 2 are based on the theoretical possible relationship between each column and row. They aim to show the relationship and effects between each of the types of BI and each of the eight sub-aspects of the sustainable bus system and vice versa. These contents are stated based on the authors' experience and the results of previous studies. These contents are then elaborated for each cell.

6. Findings of Previous Studies under the Proposed Framework

6.1. Selection of Reviewed Papers

Based on the theoretical comprehensive framework of BI and its characteristics, 109 BI-related studies were searched globally.

Documents and academic studies related to this research were found in the following order. The 13 types of BI were proposed in this study for the first time, while the eight aspects of the sustainable bus system have been mentioned in previous studies. Therefore,

For ease of searching, related articles were searched by groups of the eight sub-aspects of the sustainable bus system. We outlined the appropriate groups of keywords for the search. These keywords include BI, bus passengers, bus DB, safety, security, accessibility, quality of service, costs, revenues, vehicle efficiency, emissions, noise, planning, management, and public policy. We then searched electronically in the copyright databases of Science Direct and Saitama University Library and the following online search websites: Google Scholar, Tandfonline.com, AgeLine, ResearchGate, and Web of Knowledge. The search period of papers was from the past to September 2021.

Two main criteria were applied for selecting articles: 1) To ensure the accuracy of results and information, only peer-reviewed papers from government projects, academic institutions, and academic universities could be selected. 2) The selected studies could be suitable not only for the considered context but also for as many contexts as possible (e.g., by region and time) to enable a comprehensive comparison and evaluation. Articles with similar results in different contexts were prioritized for searching and comparison. If two or more papers have the same content, only one paper and its finding is chosen as a representative. After selecting the expected papers, topic-related findings of the articles were extracted and classified according to eight hypothetical trends corresponding to the eight sub-aspects mentioned above. Table A1 presents the findings.

6.2. Summary of Reviewed Studies

Based on the BI-based findings of selected papers included in Table A1 of the **Appendix**, a common finding comprehensive BI framework was built by summarization, as presented in Table 3. As previously mentioned, three cases were determined. These cases were identified based on the comparison of the theoretical and studied practical contents in each relationship and the comparison between results under different traffic conditions (if any).

In the first case, if the results of previous studies are complete in comparison with the theoretical content under both traffic conditions (if any) in each cell of the framework, the full contents will be filled in the corresponding cell. This type of cell will be classified as a full research type.

In case 2, if the results of previous studies are not complete in comparison with the theoretical content or there is a lack of research under either of the abovementioned traffic conditions (if any) in each cell of the framework, the results will still be filled in the corresponding cell, but this type of cell will be categorized as a lack of research type. In other words, there are unresolved and missing aspects of this type of research. The background is marked with a purple color. Consequently, suggestions for future research emerge from this type of cell.

In case 3, if there is no study related to the theoretical content in any cell, this type of cell will be classified as a lack of research type. Its background is highlighted in orange color. As a result, this type of research will be novel and original, and future research on BI needs to focus on them.

From these results, the key findings of the 13 types of BI are summarized as follows.

1) Bus-bus driver interaction: DB is a major cause of road accidents. A good DB ensures comfort, reduces fuel consumption, increases average speed, and reduces noise and emissions.

2) Bus-passenger interaction: The bus components are entities that can cause injuries and determine the injury severity. A good set of components is a key factor that facilitates the access of passengers when boarding the bus, makes them feel comfortable when using the bus, and helps to increase passenger numbers, although it can also increase fuel consumption, noise, and emissions.

3) Bus-other vehicles: The more different types of vehicles there are in the traffic flow, the higher the chance of a collision between buses and other vehicles, the higher the costs, the lower the speed, and the higher the total fuel consumption and emissions.

4) Bus-other users: Bus movement causes negative pressure and increases the accident risk and pollution costs toward others.

5) Bus-environment: Infrastructure quality and road design are two major factors affecting passenger safety, comfort, material costs, bus speed, and air and noise pollution.

6) Bus drive-passengers: Conversations between bus drivers and passengers have both positive and negative effects on safety.

7) Bus driver-other vehicles: Poor perception of bus drivers regarding other vehicles is one of the main causes of the increased risk of traffic collisions. Horn use increases the noise level, and bus drivers experience more fatigue in heterogeneous traffic flows.

8) Bus driver-other road users: Poor perception of bus drivers regarding other road users is one of the main causes of the increased risk of traffic accidents. Slow drivers, pedestrians, and drivers swerving in front of the bus make bus

drivers feel angry.

9) Bus driver-environment: The traffic infrastructure system is the main factor that affects the attention, observation, reaction, and behavior of the bus driver.

10) Passengers-passengers: Buses with an excessive number of passengers negatively affect passenger satisfaction, comfort, and accessibility. This makes passengers feel unsafe, causes noise and air pollution, and temporarily worsens their emotional state.

11) Passengers-other vehicles: No previous research.

12) Passengers-other users: No previous research.

13) Passengers-environment: No previous research.

These key findings partially represent the common trends of the 13 types of BI. The relationships in many cells in Table 3 have not been fully studied, indicating that there are still many missing aspects and research gaps. Therefore, these key findings are only temporary and will be improved and consolidated in the future once the results of further BI studies become available.

6.3. Differences in Bus Interaction Findings

Regarding BI, previous studies have often ignored one of the vital factors that influence the research results, the context factor. In this paper, a CBS area can be understood as an area where cars are the main vehicles in the traffic flow. In addition, there are other vehicles such as buses, motorcycles, and bicycles. An MBS area can be understood as an area where the primary vehicles in the traffic flow are motorcycles. Besides, there are other vehicles such as buses, cars, and bicycles. The difference between CBSs and MBSs is not just the type of vehicles, but it also relates to infrastructure conditions, travel culture, policy, and especially the number of vehicles in the heterogeneous traffic flows (buses, cars, motorcycles) in Asia. The infrastructure for the MBS is low-tech and non-well-equipped compared with that for the CBS. The MBS traffic flow is much more complex than that in CBS areas. CBS cities with car traffic flows are easier to control than MBS cities. Thus, BI in CBSs is more technologically-based, whereas it is human-based in MBSs.

According to the above summary of findings, it is clear that the number of studies in CBSs is much higher than that in MBSs. In addition, in some cases, the results of studies on CBSs differ from those on MBSs. Therefore, the hypothesis of differences in research results by traffic conditions (CBS and MBS) was proposed. The proof of this hypothesis helps us recognize the importance of traffic conditions in BI studies, have a holistic viewpoint of BI in traffic conditions, and avoid misunderstanding, especially in complicated traffic flows such as those in MBSs. Table 4 presents a comparison of the same BI studies between CBSs and MBSs. Because the number of studies on MBSs is limited compared with that on CBSs, only five types of BI were considered in this comparison.

Table 4 lists the relative differences in the results when the same studies were performed under different traffic conditions, such as those in CBSs and MBSs.

Table 4. Comparison of findings between CBS and MBS.

Type of bus interaction	CBS	MBS
Bus-bus driver	Focused on factors related to drivers or speed	Concentrated on traffic flow (homogeneous/heterogeneous).
Bus-passengers	Car was rated higher than bus on feeling of security. Service frequency and availability are two of the most important factors influencing service quality	Passengers feel safer in a bus than in a motorcycle. Commuting experience was the most influential attribute on overall bus service quality
Bus-environment	Safety is related to road design. Mean travel time is shorter than that in an MBS	Safety is related to traffic flow and infrastructure quality Mean travel time is larger than that in a CBS
Passengers-passengers	Ride security is the most important criterium for encouraging passengers	Ride security is the least influential attribute on overall bus service quality
Bus driver-other road users	A heterogeneous traffic flow increases noise level by 0.5 - 13 dB as compared to a homogenous flow	A heterogeneous traffic flow increases noise level by 0.5 - 13 dB as compared to a homogenous flow

In other words, future research on BI should consider the aspects of CBS and MBS under different traffic conditions. In addition, the lack of BI studies on MBSs leaves a large research gap, and this comparison of findings could be complemented and expanded to other types of BI in the future.

6.4. Suggestions for Future Studies

Based on the results in Table 3 and a comparison between Table 2 and Table 3, the research gaps in each relationship are extracted. Sixteen outstanding and potential suggestions for future BI research are proposed as follows:

A) *Research directions that have never been adopted*

1) In-depth research on neuro-transportation in both the CBS and MBS.

2) Interaction between bus and bus stop design and perception of drivers when approaching bus stops to enhance accessibility.

3) Passenger perception of other vehicles, other road users, and the environment for enhancing comfort and satisfaction.

4) Passengers' perception of the conditions of other vehicles and other road users encourages the use of the bus.

5) Provision of bus journey information to passengers by infrastructure planning.

6) Bus driver-other vehicles interaction affects the average speed of the bus.

7) Investment in bus components, subsidies to attract more passengers.

B) *Research directions that have been partly addressed*

1) Perception of buses by other road users and their interaction in terms of safety.

2) Bus driver-passenger interaction in the MBS in terms of safety and satisfaction of passengers.

3) Interplay bus-other vehicles, which causes sudden accelerations and decelerations of the bus, and its effect on comfort and satisfaction, especially in MBSs.

4) Effect of road conditions on the comfort and satisfaction of bus drivers and passenger in MBSs.

5) Studies on costs such as operating costs, vehicle costs, general costs, and external costs in MBSs.

6) Effect of bus-road surface interaction and heterogeneous traffic flow on bus average speed.

7) Influence of driving patterns, passenger loads, and road surface quality on fuel consumption and noise/air pollution of buses and other vehicles in MBSs.

8) Studies on bus stop arrangement, number of bus stops, bus lane location, and exclusive bus lanes affecting bus-other road user interactions in MBSs.

9) Effect of eco-training and enforcement programs on the number of private vehicles (cars and motorcycles) in MBSs.

7. Conclusions

This meta-analysis presents a summary of BI findings for a sustainable bus system. This study makes three major contributions to the literature.

The first contribution of this work is that it is one of the first studies to elaborate on the concept of BI under sustainability, as presented in Section 4. The novel concept of BI and its 13 types open a new comprehensive viewpoint on BI in bus journeys. This new concept extends and covers more objects than those in the usual understanding of BI. This is important because BI focuses on customers under this novel concept. It not only considers the user, physical interaction, and safety aspects, but also the non-user, non-physical interaction, and quality of service dimensions. They also indicate the nature of the deep-rooted demand for passengers. This is the fundamental foundation for proposing effective solutions to adapt to ever-increasing human needs.

The second result is the development of a comprehensive theoretical framework of BI, as presented in **Table 2**. This highlights the relationship between thirteen new types of BI and sustainable development. These types of BIs are considered in detail under the sub-aspects of a sustainable bus system. This unified holistic framework clarifies and demarcates the boundaries between the BI types. This has an important implication in helping researchers, planners, and policymakers to have a systematic view of the study of BI. Accordingly, they can accurately implement the necessary policies to improve and enhance the service quality of the bus, depending on their desired purposes. Finally, this framework lays the foundation for a new level of bus service and steers future studies on BI toward a sustainable bus system.

The third achievement of this study is the completion of the common finding comprehensive framework of BI, as presented in **Table 3**. According to the theoretical relationships, several aspects have been investigated in previous studies. However, these previous studies have been scattered, and these aspects have not been fully studied. The results of this review play a vital role in identifying what has been done, what has not been done, and what is needed for future studies to achieve a sustainable bus system. In addition, in a comparison between this framework and the theoretical framework considering traffic conditions (CBS and MBS), many missing and untouched aspects emerged. The common finding comprehensive framework also plays an important role in summarizing the lack of research on BI at the time of searching. From this, the key findings of 13 types of BI in previous studies at the time of searching were also extracted and summarized. Based on these missing aspects, researchers, planners, and policymakers can perform further research on BI toward a sustainable bus system.

In addition, the hypothesis that the difference between CBSs and MBSs leads to different research results was demonstrated based on the results of previous studies, as presented in **Table 4**. This result has created many other research gaps. It is recommended that we consider the traffic conditions when conducting BI research in the future. The final contribution of this study consists of 16 suggestions for future BI studies, as discussed in Section 6.4. These suggestions help avoid the currently scattered and unbalanced studies between CBSs and MBSs. The results of these potential studies, especially those that have never been conducted, will contribute to achieving a new level of bus services and a sustainable bus system development.

One of the outstanding suggestions is to study the passengers' perception of other vehicles, other road users, and the environment. According to **Table 3**, there is no research on the bus passenger-external environment interaction. This type of interaction plays a vital role in the success of bus tourism services. Under the BI viewpoint of the bus service, bus tourism services have focused on the interplay between the tourists in the bus and the attributes of the environment external to the bus, such as image of the region, local beauty spots, countryside [18] [19], scenic villages, and sightseeing [38]. This characteristic makes bus tourists comfortable and relaxed in their bus journey. Nevertheless, it seems to be novel and untouched for daily scheduled bus services thus far.

This study opens up a new perspective for future BI studies. However, it only includes interactions within the bus journey of passengers (when passengers are on the bus and approach to the bus at the bus stop). It does not cover the interactions at the bus stop or the process of customers going to the bus stop. In addition, the results of previous studies were only evaluated for the time of search. Due to the lack of studies on MBSs, these results have not been completed. They will be updated from that time to the present.

To address these limitations, first, future studies of BI should expand to cover all objects in the bus system, not only on-bus related but also bus stop-related objects and interaction with objects while customers go to the bus stop. In addition, these studies should take into account bus passengers not only at their origin or destination, but also during their travel journey. Buses could play a combined role as means of transportation and sightseeing. Passengers would not only be bus users, but also tourists, and they will enjoy life along the street. Second, the results of upcoming studies on BI need to be updated systematically, considering both CBS and MBS traffic conditions, and focus on the missing aspects to complete the above presented common finding comprehensive framework of BI. Therefore, to ensure the sustainable development of the bus system in both CBSs and MBSs, in-depth studies on BI are essential, especially in the post-COVID-19 situation and under unforeseen disaster circumstances.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix

Table A1. Findings of selected papers.

Findings	Note
Safety and security	
Driver behavior (DB) is a major cause in the majority of road accidents [39]	India, 2021
Driver, DB, & traffic type (homogeneous/heterogeneous) affect the safety of intersections [40]	India, 2020
Drivers accelerating excessively (>1 m/s^2) may cause severe injuries that require hospitalization or the development of fear of falling, particularly by older people [41]	UK, 2020
Altruism, excitement seeking, and normlessness directly predict bus drivers' attitudes toward traffic safety [42]	Italy, 2015
While aberrant DBs have a direct effect on accident involvement, psychological symptoms have an indirect effect mediated by driver behaviors [43]	Türkiye, 2003
For older adults, neuroticism & agreeableness are associated with a decreased likelihood of driving; while extroversion, openness, & conscientiousness do the opposite [44]	USA, 2015
Driving while drowsy results in a 4 - 6 times higher near-crash/crash risk. Drivers engaging in visually and/or manually complex tasks have a 3-times higher near-crash/crash risk [45]	USA, 2006
Texting, dialing, reaching were found to significantly increase this likelihood of involvement in a safety-critical event [46]	USA, 2012
Drunk driving is associated with more severe bus/minibus accident outcomes [47]	Ghana, 2018
Poor cabin ergonomics, rotating shift patterns cause bus drivers ill health, result in accidents [48]	UK, 2006
Accident severity is positively related to high-speed limits, the bus, and other drivers [49]	Denmark, 2014
The driver and security service are very important for the elderly [50]	China, 2019
The type of bus (express bus; school bus, single- or double-deck express bus, low or high floor) could have an influence on passengers' perception of their safety on buses [51]	Malaysia, 2018
The perception of traffic safety is better in a driverless shuttle bus than in a conventional bus with a driver. However, they lack in-vehicle security personnel [52]	Finland, 2018
Factors associated with a greater likelihood of fatal or severe injuries in collision incidents: elderly female passengers, standing passengers who lost balance, buses out of driver control, double-decker buses, collisions with vehicles or objects, and less urbanized areas [53]	China, 2020
Poorly positioned handrails, lack of compartmentalization (restraint), and objects with sharp edges and corners cause serious injuries [54]	UK, 2019
Wheelchair-seated passengers were more positive & safer towards the rearward position [55]	Sweden, 2007
The existence of significant omissions in the design of the interior of a bus may be the cause of multiple injuries [56]	Serbia, 2012
Most injuries of bus passengers were commonly due to impact with the seat in front or metal fitments (usually hand rails) [57]	UK, 1994
Bus right hook crashes could be attributed to the concurrence of lack of attention of drivers and speed difference between the bus and a passing vehicle [34]	Taiwan (China), 2020
Bus crashes with all vehicles (except motor vehicles) and weekend crashes have a high rate of fatality. Factors that increase the risk of fatality in bus-involved crashes on weekends are: darkness of roads and the occurrence of multi-vehicle crashes in high-speed zones [58]	Australia, 2021

Continued

Similar vehicle pairs maintain less lateral clearance than dissimilar vehicle pairs. If a vehicle interacts with two vehicles (one on each side) simultaneously, lateral clearance is reduced and safety of the vehicles is compromised [59]	India, 2017
A novel conceptual model to assess the movement and interaction between a bus and a motorcycle, when they are changing their lanes, was introduced [36]	Vietnam, 2020
A novel conceptual model for bus service managers to assess the movement and interaction between buses and motorcyclists was introduced [36]	Vietnam, 2020
Bus accident severity is positively related to the involvement of vulnerable road users, other drivers crossing in yellow or red light, crossing intersections in yellow or red light, night hours, open areas, and a slippery road surface, occurrence of injuries is positively related to the involvement of heavy vehicles [49]	Denmark, 2014
Safety in an adjacent lane can be negatively affected by buses entering & leaving bus bay [60]	China, 2021
Road design affects speed management, enhances road safety [61]	Netherlands, 06
"Skidding and overturning" is associated with injury severity of seated passengers [62]	China, 2016
Passenger scouting, fare collection, and money counting result in loss of concentration of drivers [63]	Nigeria, 2016
Bus driver conversation with a passenger appeared to reduce risk of a crash or near crash [64]	Euro, 2015
The inattention of bus drivers to other vehicles causes aberrant DB, affecting safety [65]	Taiwan (China), 2019
Village culture and drink-DBs lead to bad perception of the bus driver of other vehicles, affecting traffic behaviors [66]	Vietnam, 2017
The factors that increase the risk of bus crashes with non-motor vehicles are: old bus driver, collision with pedestrians at signalized intersection, and presence of vulnerable road users [58]	Australia, 2020
Commercial electronic variable message signs used for outdoor advertising influence driver safety, including possible attention and distraction effects [67]	USA, 2009
The absence of a road median, night-time conditions, bad road terrain (curved, wet, and rough roads), and a big bus are associated with a more severe accident outcome. For minibuses, the absence of a road shoulder, accidents in intersections, and the presence of traffic control are associated with less severe bus/minibus accidents [47]	Ghana, 2018
Road geometry is an indirect factor influencing the bus driver's behavior, which in turn influences passengers' perception of their safety on buses [51]	Malaysia, 2018
'Riding security' was the least influential attribute on overall bus service quality [68]	Bangladesh, 07
Passengers feel unsafe because of drunk people travelling by bus at night, and experience unwanted arousal due to excessively crowded buses [69]	UK, 2007
The availability of polices or emergency assistance points increases security against crime [70]	Vietnam, 2021
Staff behavior/attitude is one of the most important criteria for encouraging urban commuters to shift from private vehicles to public transport [71]	India, 2014
Passengers feel that driverless buses lack in-vehicle security more than conventional buses [52]	Finland, 2018
Accessibility	
Low and equal-size steps and well-designed handrails in the bus entrance make boarding and alighting easier [72]	Sweden, 1993
The existence of two steps at the front door makes the boarding process slower [73]	Australia, 2013
Passengers boarding form two queues through a single door and the presence of passengers standing inside the bus increase the boarding time [73]	Australia, 2013

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Quality of service	
Driving style might influence the risk of losing balance for standing passengers [74]	Sweden, 2019
DB in developing countries leads to poor passenger experience, especially older passengers [75]	UK, 2016
Convenience and driver service are essential for travel satisfaction of the elderly [50]	China, 2019
There are not enough handrails inside a bus, which causes discomfort [68]	UK, 2007
Buses with fewer seats is better than the optimal number (e.g., to increase capacity), the frequency should be increased to compensate for the discomfort [76]	Australia, 2014
Ride comfort is worst for standing passengers & least uncomfortable for sitting passengers [77]	Singapore, 19
Special lights showing passengers the right door for boarding, ceiling lights showing available seats, free internet access for passengers, and sockets for laptops are innovative ergonomic solutions to enhance passenger comfort [78]	Italy, 2016
Improvements in cleanliness, comfort will likely increase the perceived passenger satisfaction. Perceived service convenience represents a central dimension concerning how bus customers assess overall satisfaction with service provision [79]	UK, 2016
Boarding/alighting times increase with an increase in the number of alighting passengers, the number of boarding passengers, or the number of passengers on board the bus [80]	USA, 2019
Year of manufacture and location of the engine, as a source of noise, cause a negative effect on passenger's comfort [81]	Brazil, 2008
Ambient scent strengthens some relationships: travel experience and emotions, emotions and memory, and emotions and passengers' future behavioral intentions [82]	Portugal, 2021
Summer was generally found to have higher in-bus fungal concentrations than winter. That affects passengers' health [83]	Korea, 2005
Passenger seats, engine, and wheels of a bus are major sources of vibration inside buses [84]	Iran, 2014
Available seats, clean onboard environment, convenient design for transfers, and air-conditioning are the key determinants of overall satisfaction with the bus service [85]	China, 2016
The passenger load, not surprisingly, will increase passenger waiting times [86]	N. Zealand, 17
The interaction between staff & passengers in bus systems is poorly appreciated [87]	Taiwan (China), 2006
Bus passengers face stress, fatigue, headaches, and other disorders because of seat design [88]	Bangladesh, 2016
Optimal bus frequency results from a trade-off between the level of congestion inside buses, *i.e.*, passengers' crowding, and the level of congestion outside buses, *i.e.*, the effect of frequency on slowing down both buses and cars in mixed-traffic roads [76]	Australia, 2014
The road layout affects discomfort threshold of passengers concerning lateral accelerations [77]	Singapore, 2019
A larger transport infrastructure leads to a poor experience for older passengers [75]	UK, 2015
Raised pedestrian crossings, chicanes, speed bumps, mini-roundabouts affect the comfort scale of bus passengers [89]	Italia, 2014
Influence of road roughness wavelengths on bus passengers' oscillatory comfort: The best oscillatory comfort is that of a passenger in the middle part of the bus, whereas the worst is that of a passenger in the rear part of the bus [90]	Serbia, 2019
There is a good regression relationship between the bus ride index (BRI) and the international roughness index (IRI) to assess bus ride comfort [91]	Vietnam, 2019

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An increase in the number of elderly passengers on a bus and mix traffic flow will lead to higher levels of mental fatigue for a city bus driver [92]	Taiwan (China), 2019
Driving under negative passenger behavior affects the satisfaction of bus drivers [93]	Korea, 2019
Road condition pressure affects the satisfaction of bus drivers [93]	Korea, 2019
Buses are too crowded cause unwanted arousal of passengers [68]	UK, 2007
In terms of passenger load, 8 - 18 (people) is a threshold below which momentary mood gets worse, and 19 - 29 (people) is the other threshold beyond which momentary mood deteriorates considerably. Further, regarding bus micro-environmental indicators, the optimal exposure level to noise is in the 0 - 65 dB range [94]	China, 2020
A timetabling method that considers passenger satisfaction (reducing crowding) is proposed for optimizing the bus frequency and headway in Beijing [95]	China, 2019
Costs	
Bus drivers who received eco-driving training significantly improved fuel economy [96]	UK, 2015
DB can lead up to 27% of fuel saving in a bus route in Rome [97]	Italy, 2013
The high correlation between aggressiveness and energy consumption implies that particular attention must be paid to limiting high-speed accelerations of city buses [98]	Finland, 2018
The bus operating speed has the greatest influence on the fuel consumption costs of intercity buses [99]	Serbia, 2017
Vehicle costs and general costs related to accidents involving vehicle repairs, unavailability of vehicles, towing, travel delay [100]	Australia, 2014
Bus operating costs increases due to the cost of the additional time when congestion occurs [101]	USA, 2003
Fluctuation of traffic volume has an impact on the fuel consumption costs of buses [99]	Serbia, 2017
External costs such as accident risk and pollution are imposed on non-users; Traffic congestion results in incremental vehicle operating costs; Operating costs for drivers comprise oil and tire wear costs [102]	Canada, 2010
Bus movement implies materials costs (e.g., tire lubricants, tire wear) [103]	Italy, 2016
Planning of a suitable bus lane infrastructure will help reduce the bus operating cost [104]	China, 2017
Deteriorating riding quality and poor infrastructure cause higher vehicle operating costs [105]	South Africa, 2015
Terrain type, road surface, and IRI have an impact on the fuel consumption costs of buses [99]	Serbia, 2017
The average bus stop density and percentage of bus lanes have significant influences on cost-inefficiency differentials [106]	China, 2017
Revenues and vehicle efficiency	
Psychological symptoms, sensation seeking, and aggression predicted the preferred speed [43]	Türkiye, 2003
The number of passengers has little direct influence on the predictive power of acceleration behavior [107]	Sweden, 2007
Bus passenger boarding/alighting times increase with an increase of the number of alighting passengers, the number of boarding passengers, and the number of passengers on board bus [80]	USA, 2019
Service (frequency and speed, cleanliness, space, temperature, proximity, and fare), comfort (travel experience), and personnel (behavior of the staff—safety and courtesy) affect the number of passengers [108]	Spain, 2013
Bus layout designs (wheel position, number of doors…) affect attractions of passengers [109]	Euro, 2014
Increasing the speed and reducing the abrupt breaking of autonomous buses will enhance users' experiences and attract passengers [110]	Norway, 2021
Substantial time savings can be obtained if payment methods are upgraded [73]	Australia, 2013

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The effect of satisfaction of passengers on their evasion behavior impacts bus revenues [111]	Colombia, 2021
Simply decorating buses with famous animation characters can increase ridership [112]	Korea, 2020
People who use a bus with good air quality are willing to pay more [113]	China, 2017
Bus speeds could change with time (peak/off-peak hour) in urban transportation network [114]	Qatar, 2016
Bus operations are often hindered by traffic signals and car queues. Transit signal priority (TSP) strategies play a significant role in bus operation at intersections. The benefits of implementing TSP alone can be larger than a dedicated bus lane [115]	China, 2020
In Beirut, BRT (bus lane without other vehicles) reduces road congestion by 9%, improves traffic speed by 24%, and reduces the road congestion externality by 18% [116]	USA, 2021
Bus delays at stops evidently increase when the arrival rate is more than 85 buses/hour [117]	China, 2015
The operational speeds of buses are limited by the number of bus stops and interferences along the way, such as at level crossings [118]	Brazil, 2012
Speeds could change with location and travel direction in urban transportation networks [114]	Qatar, 2016
Bus delays can often be shortened by placing the bus stop downstream of its neighboring signalized intersection, rather than upstream of it [119]	China, 2014
Buses that travel in mixed traffic have not only a larger mean travel time but also a larger variability than buses that travel in bus lanes and segregated busways [120]	Chile, 2016
Dramatic improvements can be made to the performance of a bus system as a result of a better understanding of its operation, which leads to simple changes in design of infrastructure [121]	UK, 2005
Excessively overcrowded buses may drive away anxious travelers and make them reluctant to take buses [122]	China, 2016
Emission and Noise	
Most of the traffic simulation models developed for intersections lack modelling interaction between DB and emission behavior [40]	India, 2020
The use of the combined mixing and displacement ventilation and also the combined mixing and underfloor ventilation types are capable of reducing the concentration of carbon monoxide and particulate matter inside the bus passenger compartment [123]	Malaysia, 2015
Year of manufacture and location of the engine are two factors that highly contribute to the level of noise [81]	Brazil, 2008
A hazard assessment was carried out for three brands of passenger buses common in Ukraine, in which the driver is exposed to the dangers of heat, vibration, noise, harmful impurities in the bus cabin, and emotional load [124]	Ukraine, 2020
The minimum values of CO and NOx can be reached when speed is approximately 50 - 60 km/h. Number of stop & go movements & acceleration phase can play an important role [97]	Italy, 2013
Driving speed is one of emission factors of a vehicle [125]	Euro, 2014
Noise/air pollution can be reduced by limiting speed and adequate road paving [126]	France, 2016
Buses cause noise during their acceleration [127]	Sweden, 2019
The average weekly noise exposure of front-engine bus drivers was greater than that of rear-engine bus drivers; the weighted average of vibration acceleration was 0.85/m (2); Age, diabetes, and the level of noise emission were risk factors for noise-induced hearing loss [128]	Brazil, 2005
Vehicle emissions are correlated with engine load demand, which is a function of factors such as vehicle load, speed, and acceleration [129]	USA, 2013
Passenger load increases fuel consumption and emissions [130]	China, 2017

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Boarding and alighting of passengers are among the factors that would increase the concentrations of PM1, PM2.5, and PM10 inside the passenger compartment [131]	Malaysia, 2015
A 20% system-wide increase in ridership leads a 1.1% increase in total emissions and a 13% decrease in per capita emissions [124]	Ukraine, 2020
Roadway type affect the in-vehicle CO exposure of bus passengers [132]	Lebanon, 2009
The total fuel consumption and emissions of a feeder bus during peak hours have an increasing trend compared with the values during off-peak hours [130]	China, 2017
Mixed-mode traffic flow is one of the emission factors of a vehicle [125]	Euro, 2014
Pavement type, pavement thickness, void ratio, maximum nominal particle size, aging, and abrasion of road have influence on noise from tire/pavement interaction [8]	China, 2021
Exhaust emission and fuel consumption factors depend on road category, gradient, load factor, and traffic flow conditions [133]	Germany, 1995
The engine and wheels are major sources of noise inside buses [83]	Iran, 2014
In heterogeneous traffic conditions, horn events increase the noise level by 0.5 - 13 dB as compared to homogenous traffic conditions [134]	India, 2016
Active and public-transport commuters are often at risk of higher air pollution and noise exposure than private car users [135]	Finland, 2017
Regarding bus micro-environmental indicators, optimal exposure level to noise is in 0 - 65 dB range. In-bus noise has negative overall correlation with passengers' momentary mood [94]	China, 2020
Planning and management	
The location and number of bus stops are key to the operational efficiency of commercial speed [136]	Chile, 2013
Drivers were found to reduce the speed before the camera and immediately started to increase the speed after the camera [137]	UK and Poland, 2018
Police surveillance and enforcement activities can have a significant effect on the compliance of traffic rules and regulation [138]	Netherlands, 1982
Manned enforcement provides specific deterrence targeted at high-risk drivers; automated enforcement provides a deterrence effect on a broad spectrum of the driving population [139]	Canada, 2009
A good discovery method of DB parameters, which aims to provide real-time operation recommendations for the bus stop accessing procedure [140]	China, 2018
Index application provides information and fair and equitable mobility conditions for passengers regarding sustainable mobility policies [118]	Brazil, 2012
A real-time information system displaying information about departure times, alternative routes, news is necessary to achieve an environmentally friendly bus [78]	Italy, 2016
Bus priority schemes and techniques on urban roads and highways have proven effective for increasing reliability, efficiency, and faster travel times [141]	Israel, 2016
Segregated lanes enhance speed. When buses have more stops, the average speed is low [118]	Brazil, 2012
The increase of interaction between buses and passengers and bus-stop layout and operation contribute to congestion [142]	UK, 1989
Bus drivers sometimes fail to stop the bus at the bus stop; instead, they take passengers further from the bus stop and realize unplanned stopping of buses [143]	Sri Lanka, 2006

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Public policy	
Eco-training reduces the number of hard braking events and hard accelerations [144]	Portugal, 2014
Drivers' awareness of high-visibility implementation of enforcement programs has the potential to decrease aggressive DB patterns, especially unsafe lane change [145]	USA, 2020
The passenger decision-making algorithm can be effectively used to evaluate a new design of a bus layout using agent-based simulation techniques estimating the parameters that measure quality of service [146]	Spain, 2013
A car driving restriction policy increased public transport passenger volume by 5% - 25%, but it could not radically improve the traffic mode split [147]	China, 2019
Quantity control limiting the number of vehicles that may operate on a particular route, to reduce interaction between vehicles, is an effective regulation for sustainable public transport in developing countries [143]	Sri Lanka, Pakistan, Tanzania, 2006
Method to reduce congestion (charging and variable road taxes, parking restrictions) and prevent car pollution (low emission zones, access limited to zero/low-emission vehicles) [148]	UK, 2015
The high level of investments in the maintenance of the transportation system is another positive city aspect [118]	Brazil, 2012