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Passengers preferences for using emerging modes as first/last mile transport to and from a multimodal hub case study Delft Campus railway station

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ABSTRACT

Emerging access/egress transport modes to and from railway stations may play a vital role in the future performance and usage of public transport. To learn about these modes, their acceptability, and attractiveness, we performed a case study at Delft Campus train station in the Netherlands, using a stated preference experiment. We investigated travellers' preferences towards shared bicycles, shared e-steps, shared e-scooters, automated vehicles (individuals and shuttles), and the importance of time, costs, and availability of these modes to access or egress this small-sized hub. Furthermore, we studied the impacts of two contextual situations: weather conditions and carrying luggage, affecting mode choice.

The results indicate that travel costs have much higher importance than travel time for accessing or egressing from a small hub, and Autonomous Vehicles (AVs) usage is positively valued as first/last mile transport modes compared to other alternatives. Increasing 10% time and cost of all modes indicate that the demand for individual and collective AVs falls sharply, whereas the change in demands of shared bikes is negligible. A significant impact of context effect variables in the utility of travellers was also observed when these variables interacted with the leading travel attributes. The potential market share of the modes indicates that shared bike usage will continue to be strong, and automated vehicles will find their position at future stations. These findings could provide critical criteria for designing future small/medium multimodal hubs.

1. Introduction

Transport literature highly values public transport (PT) systems as increasing use of this mode (PT) can be the answer to congestion, pollution, and better use of infrastructure (Newman, 1995, HiTrans, 2005, United Nations economic commission for Europe, 2015, Yañez-Pagans et al., 2018, Van Oort and Yap, 2021). Public transport systems will be an inseparable part of urban life for the foreseeable future. To have more liveable and sustainable cities, the ongoing challenge of improving PT systems, including the first and last-mile of PT trips, should be considered (Van Kuijk et al., 2021). The availability and effectiveness of the access/ egress modes may have essential impacts on the uptake of public transport systems and may persuade more people to shift from private modes to PT. These factors need further and more detailed analysis for the case of small and medium multimodal stations and hubs. Furthermore, there is also a lack of understanding of contextual factors such as the impact of weather conditions and carrying luggage on how people may choose their first last mile modes.

Ridership of public transportation is highly influenced by travel time (Murray et al., 1998; Murray, 2001), distance, costs (Arentze & Molin; 2013, Yap et al., 2016; Lau and Susilawati, 2021; Van Kuijk et al., 2021), and service-quality attributes (Arentze & Molin; 2013) such as the quality of access and egress (Givoni and Rietveld, 2007; Brons et al.,2009; Abe 2021). The first two factors highly depend on the accessibility of the public transportation system (Goel and Tiwari, 2016). In addition, the first/last mile of the trip plays a determinant role in transportation mode preferences (Wang and Odoni, 2012). As a general term, mobility hubs are defined as the main transit access points in multimodal transportation planning processes (Hochmair, 2015). Transport planners have realised that for a hub to thrive, it must offer a seamless multimodal trip. A multimodal trip is more than one mode in a traveller's trip, including walking or cycling, and this change of modes between the main travel modes. A multimodal hub as a type of a transit mobility hub refers to a station that is usually served by train or metro,

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with direct connections to different types of transport modes, such as a car (private and shared), bicycle (private and shared), other public transport and walking, which provides an integrated and a sustainable mobility network (Venhoeven, 2012). Thus, these hubs can offer multiple modes for different users and different travel purposes, where people can transfer from one mode to another directly (Henry and Marsh, 2008).

Personal shared mobility replaces, complements, and integrates transport modes on urban networks (Kong et al., 2020). In addition, supplying shared-micro-mobility at the last mile benefits transit riders (Baek et al., 2021). Different researchers have argued that new transportation concepts such as bicycle sharing (Wu et al., 2019; Ma et al. 2020), e-scooter sharing (Baek et al. 2021), car-sharing (Correia and Antunes, 2012; Jorge and Correia, 2013) and automated vehicles (Chen et al., 2020; Abe, 2021) are crucial to providing a seamless door to door journey experience to passengers (Scheltes, 2015). The introduction of these new services at the first/last mile of the trip potentially improves the attractiveness of multimodal hubs due to their favourable characteristics, such as flexibility. However, Scheltes and Correia (2017) believe that this access/egress stage is still not well-utilised, and travellers struggle with inconvenient transport modes for the first/last part of their journey.

Although the preferences of travellers on transport modes have been studied (Ohnemus and Perl, 2016; Yap et al., 2016; Shaheen and Chan, 2016; Scheltes and Correia 2017), still there is limited knowledge about automated vehicles (Abe 2021) and shared modes preferences in the first-last mile of the trip (Van Kuijk et al., 2021). It is not clarified yet how passengers' modal choice would differ by introducing emerging modes. In addition, influential factors to modal choice such as the impact of context variables (weather and amount of hand luggage) on travellers' preferences for different types of access/egress modes remains a gap in the literature, which will be discussed in this work.

This research aims to empirically reveal travellers' (stated) preferences regarding potential new access/egress modes connected to a local hub. The research objective of this paper is to look at the role of these access/egress modes in passengers demand of multimodal hubs and analyse the preferences of urban rail users for their first-last mile. In this study, one relatively well-known access/egress mode (bicycle sharing) and four emerging access/egress modes, namely shared e-scooters (both standing and sitting), individual automated vehicles, and collective automated vehicles (in the form of driverless vans or minibuses), and their related attributes are considered. Furthermore, we introduce two context variables (weather and amount of luggage) to capture travellers' preferences on different access/egress modes from a local hub under varying conditions. Therefore, this study may add to our understanding of factors contributing to the (re)development of the local hub areas regarding access/egress facilities and services.

To determine people's preferences for new transportation modes for access/egress from hubs, a stated choice experiment as the most suitable method has been performed. A stated choice survey provides a hypothetical situation for respondents, who are required to decide a preferred transport mode, even a not existing mode, considering different attributes and contexts from a range of available options.

This study uses the Delft Campus railway station in Delft, a bicycle-friendly city in the West of the Netherlands, as a case of an emerging small multimodal hub that is located close to TU Delft University. This case study aims to see the impact of emerging modes on travellers' choice to use PT and if the contextual situations significantly impact their behaviour. Therefore, this case study aims to evaluate how emerging modes and the context indicators impact the modal choice of travellers in multimodal hubs, which help to predict access/egress mode choices of travellers at small-medium sized stations for a short time distance. Furthermore, with this case study, we aim to provide insight for transport planners and public transport providers on how the merging access egress modes may facilitate higher utilisation of PT.

The paper will outline the characteristics of the multimodal hub concept and passenger behaviours accessing/egressing the station in the literature review section. The case study and survey are discussed in the third section, which presents the methodology of this paper. The analysis of the collected surveys and the discrete choice model results will be discussed in section 4, and conclusions and the discussion will be presented in the last section.

2. Literature review

In this research, we seek to find the impact of emerging modes and the context indicators such as weather and luggage on the modal choice of travellers in multimodal hubs. We reviewed 40 relevant publications between the years 2010–2021. This section provides a brief review of the different aspects relevant to this topic.

We will first describe the characteristics of a multimodal hub based on literature to understand its essential role in future transport systems. Secondly, the passenger behaviour accessing and egressing from multimodal hubs will be explained in two terms: socio-demographic characteristics and unobserved or latent variables that reveal travel characteristics. Subsequently, we consider the characteristics of the access/egress trip, the impact of weather and luggage on the access/egress trips, and finally, the role of technology; emerging alternative modes and their impact on travellers' access/egress decisions. The considered aspects are relevant and essential for designing the survey in this study.

2.1. Characteristics of multimodal hubs

A multimodal public transport trip generally consists of three stages. The first and the last stages are described as access and egress miles, and the central part is the middle of the trip. Access modes and egress modes refer to transport modes used in the first part and the last stage of a journey, respectively, which can be walking, cycling, bus, tram, metro, taxi, shared car, and soon collective or personal automated vehicles (Krygsman, 2004, Yap et al., 2016, Shaheen & Chan, 2016).

According to (Bertolini 2008)*,* a hub is composed of two aspects, a (network) *node* (for interchanges with other types of mobilities) and a *place* (for serving services for passengers). A multimodal station as a significant node can offer multiple modes for different users and different travel purposes. This primary mode is usually train or metro, and multiple other modes, such as walking, cycling, cars, and public transport, where people can access from one mode to another directly (Henry and Marsh, 2008).

A multimodal hub is a place where the access/egress services, modes and transportation systems are connected, and interfaces occur among them (Henry and Marsh, 2008). Generally, the idea behind a multimodal hub is to seek optimal travel efficiency by taking advantage of different modes while minimising their negative impacts (Pitsiava-Latinopoulou & Iordanopoulos, 2012). Multimodal hubs may improve community liveability by incorporating land use, demographic, socio-economic, environmental, health, security, and public policy issues together in a holistic transport policy approach (Scott et al., 2013). For instance, providing facilities at a multimodal hub increases access and choice by positively coordinating between different modes (Scott et al., 2013). A well-designed multimodal hub plays a role in developing the station's surroundings and attracting many users and is a catalyst for urban development in metropolises, medium and small cities (Triggianese et al., 2018).

Generally, multimodal hubs can be divided into three areas: the arrival/departure area of the primary mode, the facilities area, and the access/egress area possibly containing multiple (new) modes. The last two areas can be designed based on the offered services, transportation modes and allocated spaces, and expected hub usage, which means passengers' user preferences and choice behaviour.

2.2. Passenger behaviour accessing to and egressing from multimodal hubs

Scheltes (2015) states that although the last part of the trip is a relatively small distance, a high proportion of total travel time is spent at this stage. Furthermore, it is mentioned that inflexibility, unavailability, and the absence of a seamless mobility experience for passengers cause considerable disutility in a public transport trip in order for it to be competitive with a car.

Influential factors to modal choices for accessing and egressing the railway stations are essential (Halldórsdóttir et al., 2017). Therefore, access/egress mode choice has recently been getting more attention in transport literature. However, there is no uniform approach or definition of access/egress modal choice by passengers. It depends on the aim/scope of each research (De Witte et al., 2013). An overview of the selected literature for this study considering access/egress mode choice factors published after 2010 (except for some references regarding carrying luggage) is presented in Table 1.

The literature that focuses on the home-end and activity-end stages of a multimodal trip can be classified into the following two categories:

1) Literature focuses on socio-demographic characteristics, such as *gender, age, occupation/income, driving license, vehicle ownership, car availability, household size, number of workers, other motorists, season ticket, and type of train user*.

Creemers et al. (2014) showed that women tend to use private cars and hesitate to use slow access/egress modes of transport. Ji et al. (2017) noted that women like to use private bicycles rather than public bicycles to access railway stations. Men tend to use buses less in activity-end trips (Halldórsdóttir et al., 2017), they prefer to ride motorcycles (Tran et al., 2014). Van Kuijk et al. (2021) concluded that age is considered a reliable determinant for using shared mode

Table 1
Overview of literature focusing on access/egress modes.

Authors	year	Country	Type of station	Multimodal stages (HE/MS/AE)[1]	modes	
Abe	2021	Tokyo	Railway stations	HE, MS, AE	6	Bus, car driver, car passenger, bicycle/motorcycle, walk and AV
Baek et al.	2021	Seoul	Subway	AE	3	Town bus, e-scooter sharing, walking
Kim & Cho	2021	Seoul	–	–	1	shared bicycles
Lau & Susilawati	2021	Malaysia	Light Rail Transit (LRT) and Mass Rapid Transit (MRT	HE, MS, AE	2	Shared Autonomous vehicles, PT
Van Kuijk et al.	2021	Netherlands	Bus & tram	MS, AE	4	shared bicycles, e-bikes, e-scooters, and e-mopeds
Aguilera-García et al.	2020	Spain	–	–	9	Private car, private moped/motorcycle, bike, walking, Public transport, car-sharing, scooter-sharing, bike-sharing, taxi and Ridesourcing
Alonso-González,	2020	Netherlands	–	–		Pooled on-demand services
Chen et al.	2020		Metro	HE	1	Autonomous vehicles
Kong et al.	2020	USA	–	–	2	Shared bicycle, PT
Jiao & Bai	2020	Austin, TX	–	–	1	shared e-scooter
Van Mil et al.	2020	Netherlands	Railway stations	HE, MS	1	Bicycle
Yan et al	2020	China	metro station		1	dockless bike-sharing service
Wu et al.	2019	Taiwan	Metro-train stations	–	1	Shared bicycle
Ton et al.	2019	Netherlands	–	–	4	Car, PT, bicycle and walk
Stam	2019	Netherlands	Railway stations	HE, MS, AE	9	Private bicycle, Shared bicycle, Private e-scooter, Shared e-scooter, Private on-board vehicle, Shared car, Bus, Individual on-demand rides, Collective on-demand rides
Bronsvoort	2019	Netherlands	Bus stations	HE, MS, AE	4	Express bus, Bus, shared bicycle, Flexi
Mo et al.	2018	Singapore	Mass rapid transit (MRT) station	HE, AE	3	Walking, bus and LRT
Shelat et al.	2018	Netherlands	Railway stations	HE, MS, AE	1	Bicycle
Frei et al.	2017	USA			3	Traditional Transit, car, flex
Halldórsdóttir et al.	2017	Copenhagen	Railway stations	HE, AE	5	Walking, bicycle, car driver, car passenger and bus
Brand et al.	2017	Netherlands	Bus stations	HE, AE	4	Bus, BRT, walking and cycling
Ji et al.	2017	China	Railway stations	HE	5	car, bus, walk, private bike and shared bike
Shaheen & Chen	2016	–	–	–	4	Shared mobility; Car sharing, bike sharing, on-demand ride services, and micro-transit
Yap et al.	2016	Netherlands	Railway stations	AE	4	BTM, bicycle, AV car-sharing and AV automatically driven
Goel & Tiwari	2016	India	Metro stations	HE, AE	7	Walking, bicycle, cycle-rickshaw, auto-rickshaw, 2 W, car and bus
Scheltes	2015	Netherlands	Railway stations	HE, AE	1	Automated vehicles
Puello & Geurs	2015	Netherlands	Railway stations	HE	1	Bicycle
Tran et al.	2014	Vietnam	Mass transit stations	HE	4	Walking, bicycle, motorcycle (driver) and motorcycle (passenger)
Ryley et al.	2014	UK	–	–	3	Bus and DRT
Creemers et al.	2014	Belgium	Railway stations, BTM stations	HE, MS, AE	3	Car, BTM and slow
Chakour & Eluru	2013	Canada	Railway stations	HE	4	Drive alone, shared ride, transit and active transportation
De Witte et al.	2013	–	–	HE, MS, AE	–	Different modes
Arentze & Molin	2013	Netherlands	Stations	HE, MS, AE	4	Walking, bicycle, bus/tram and PT bike
Wen et al.	2012	Taiwan	High-speed rail (HSR) stations	HE	8	City bus, train, car driver, car passenger, motorcycle driver, motorcycle passenger, taxi and shuttle bus
Correia & Antunes	2012	Portugal	Carsharing stations	–	1	Carsharing
Wang and Odoni	2012	–	Rail station	–	1	Different
Martin & Shaheen	2011	Canada and USA	–	–	1	Car sharing
Molin & Timmerman	2010	Netherlands	Railway stations	AE	7	Public transport, taxi, train taxi, PT bike, bike in a train, bike at station and Greenwheels
Martin et al.	2010	USA	–	–	1	Carsharing

[1]home-end (HE) stage, main stage (MS) and activity-end (AE) stage can be defined for any multimodal trips.

in the last mile. Moreover, Yan et al. (2020) discovered a positive correlation between young age and shared bicycles in the last mile. Jiao and Bai (2020) found that young, male, and highly educated people are willing to use shared e-scooters. Although walking and riding motorcycles are more popular for older people as access modes to stations (Tran et al., 2014), Ji et al. (2017) found that shared bikes are not a popular mode between older and low-income groups. On the other hand, Frei et al. (2017) interestingly found that older travellers who earn $150,000 per year are significantly likely to use flexible and traditional transit.

Furthermore, there is a direct relationship between income and the use of private cars as opposed to public transport (De Witte et al., 2013). There is a negative correlation between income and willingness to use shared e-scooters and e-steps (Jiao and Bai, 2020); (Aguilera-García et al., 2020). Full-time students are willing to use buses (Halldórsdóttir et al., 2017) with no preference for bicycles at home-end trips (Puello and Geurs, 2015). While possession of a driving license typically increases private car usage (Creemers et al., 2014), owning a vehicle or car's availability also increases the shares of car use for the first/last mile of the trip (Halldórsdóttir et al., 2017; Goel & Tiwari, 2016). In addition, motorcycle ownership decreases the probability of walking choice, and car availability also decreases the share of cycling (Puello and Geurs, 2015). De Witte et al. (2013) concluded car ownership as the second determinant for modal choice after the age when a car is available.

Having a season ticket encourages passengers to use public transport since it is valid (Halldórsdóttir et al., 2017). Employees could also be motivated to use public transportation since they provide transit passes (De Witte et al., 2013). Yap et al. (2016) presented that first-class train users prefer to experience automated vehicles (AVs) at stations if they are available. By contrast, bicycles and BTM (Bus, Tram, Metro)are the first preference by second class train users in general. Finally, families with more children dislike cycling and motorcycles (Tran et al., 2014).

2) Literature has addressed unobserved or latent variables that reveal travel characteristics such as *travellers' attitudes, perceptions, and preferences/habits*.

Alonso-González et al. (2020), who studied the attitudes towards demand-responsive transport and mobility-as-a-service, discovered that young users have more positive attitudes towards sharing and multimodal lifestyles in general. De Witte et al. (2013) compared the perception of car usage and public transport in terms of freedom, independence, speed, price, protection and prestige, and concluded that public transport is regarded less favourably. Yap et al. (2016) argued that when examining the use of AVs, which are not very common yet, two psychological factors are important, 1) perception of trust and 2) attitude of passengers towards the sustainability of AVs. They also claim that in-vehicle time is perceived differently in an automatically driven vehicle than in a manually driven AV, with the former viewed less favourably. Arentze & Molin (2013) described travellers differently perceiving the time attributes and travel costs. Paulley et al. (2006) argued that waiting time is also differently perceived and affected by comfort, cleanness, safety, and weather.

In addition, attitude towards the environment of the hub, the perceived connection of departure stations, and the perceived quality of facilities for bicycles highly promote the use of cycling (Puello and Geurs, 2015). The travel experience in the first and last mile effects on satisfaction and willingness of people to use PT (Van Kuijk et al., 2021).

Passengers usually prefer quality services such as reliability, safety, comfort, health, convenience, and image/status (Arentze and Molin (2013). Drivers who are not satisfied with driving for reasons such as traffic would be potential targets for flexible services, as Frei et al., 2017 noted.

2.3. Characteristics of the access/egress trip

De Witte et al., 2013 argued that faster transport modes are preferred for longer distances in general. Thus, increasing distance to/from transit nodes will increase the shares of motorised transport modes (Stam, 2019). For example, buses are preferred for longer access/egress distances (Mo et al., 2018). In contrast, the choice of PT over the car is directly related to increasing trip distance (Goel & Tiwari, 2016). Molin & Timmermans (2010) found that distance and the probability of walking have an opposite relationship, whereas with increasing distance, the choice of PT increases. Generally, passengers would travel shorter distances at the last mile by walking; conversely, longer first miles are accepted by cycling (Brand et al., 2017). However, Wu et al. (2019) presented that trips of shorter distances are more likely to be completed by cycling (bike-sharing) and e-step sharing (Baek et al., 2021) relative to other transit services. In general, it can be seen that as the distance increases, the probability of cycling to the railway station decreases (Puello & Geurs, 2015).

Based on a literature review by De Witte et al. (2013), a trip's purposes are the first determinant of modal choice. Although different access/egress modes can be selected for different trip's purposes such as shopping, leisure and work (Halldórsdóttir et al., 2017), cars and taxi alternatives are generally used in business trips, Greenwheels for recreational trips (Molin & Timmermans, 2010), and shared bikes for school- or work-related trips (Ji et al., 2017). Travelling with a companion decreases the probability of bicycle, walking, and bus choices and increases the chance of car usage (Halldórsdóttir et al., 2017). Moreover, according to the research of Molin and Timmermans (2010), travelling with others increases the choice of slow transport modes and cars.

Departure time determines the access mode to the station (De Witte et al., 2013). Molin & Timmermans (2010) found that the share of public transport and slow transport are decreased in off-peak hours like evening, due to low-level services and lack of convenience.

Generally, distance, travel time, and travel cost have direct mutual effects. (Chakour & Eluru, 2013; Halldórsdóttir et al., 2017 believed that long travel time negatively affects passengers' modal choice. Ryley et al. (2014) valued cost, travel time, and wait time for DRT as the most valuable attributes to use current modes. Lau and Susilawati (2021) research showed that the use of shared AVs directly relates to waiting time and cost; decreasing waiting time and cost for shared AVs results in increased shared AV's ridership. They also concluded that by dedicating a meagre price for riding shared AVs, passengers prefer to use only shared AVs, not only for the first/last mile but also for the whole trip, not combining with local PT (Lau and Susilawati, 2021). In addition, Ryley et al. (2014) noted that arrival time is an essential factor for a successful DRT service. Halldórsdóttir et al., 2017 found that decreasing travel time of buses' walking, cycling, and in-vehicle time increased the chance of them being used as access/egress modes in the first/last mile trips. Moreover, Frei et al. (2017) highly valued travel time and discussed that a significant shift from the car toward transit would increase travel time by car.

Wen et al. (2012) stated that the cost of access modes determines the modal choice for the majority. Van Kuijk et al. (2021) found that travel cost negatively affects willingness to use a shared mode in the last mile trip. By the way, the value of travel time and costs are captured by the psychological factors as Yap et al. (2016) discussed along with the level of services (e.g. comfort and convenience, safety, protection, and security) (Ortuzar & Willumsen, 2011). However, Jorge & Correia (2013) depicted a direct relationship between service characteristics and demand patterns for car-sharing services.

Chakour and Eluru (2013) use the term availability of transit services by addressing the 'supply' of transit, and they further study the effects of availability on modal choice at both the origin and destination. Other studies refer to the availability of modes as an essential indicator to assess an urban area's commitment to transit (Kriger et al., 2015).

McNally (2008) and Jayasinghe et al. (2017) argued that various available modes play a crucial role in planning an urban transportation system and predicting travel demand. Camagni et al. (2002) argued that by increasing mode frequencies, the share of public transport would be increased and the comparative efficiency of public transport. Furthermore, fleet size directly affects the availability of vehicles, especially at railway stations. The availability of bicycles at stations increases the utility of this mode as well (Bronsvoort et al., 2020). Wang and Odoni (2012) concluded that the unavailability of services at the last mile negatively affects the use of public transport in urban areas, especially for students, seniors, and disabled users.

2.4. Impact of weather and luggage on the access/egress trips

Slow transit modes mainly cover the first and the last mile of the trip; accordingly, weather plays a vital role in modal choice as an environmental issue (Keijer and Rietveld, 2000; Rietveld, 2000). Changing weather conditions will change access to transport modes, significantly affecting modal choice since non-motorised modes are considered (De Witte et al., 2013). Besides weather, temporal variations also determine bike-share ridership (Kim and Cho, 2021). Fyrhi and Hjorthol (2009) compared summer activities done mainly by bike and winter activities by walking. Ton et al. (2019) found that summer activities are positively associated with walking, and cycling has no significant relationship. Ton et al. (2019) concluded that weather has a limited impact on active mode use such as walking and cycling.

On the other hand, slow transport modes such as walking and cycling are preferred in dry weather, on familiar routes with no heavy luggage (De Witte et al., 2013; Molin & Timmermans, 2010). Molin & Timmermans (2010) argued that weather conditions travel companions, and amount of luggage are the influential and prominent variables on mode choice decisions because of the need for transferring. They identified that carrying heavy luggage on trips increases the need for motorised modes, especially taxi alternatives instead of slow modes, and decreases train and consequently multimodal trips. Regarding the luggage, Frei et al. 2017 pointed to it as a negative attribute for transit commuters who would walk to the station and wait in the cold weather or busy transit.

De Witte et al. (2013) concluded that variables such as weather conditions and luggage are not often considered in the modal choice research papers but should be given more attention in simulation models of traffic flows (Molin & Timmermans, 2010).

2.5. Technology; emerging alternative modes and their impact on access/egress

To improve urban mobility problems, from a technological perspective, the development of cleaner energies and more efficient transportation systems have been considered in recent decades (Martinez and Viegas, 2017). Accordingly, due to the new technological developments in recent years and also environmental concerns, the access/egress transport alternatives have been changed from private vehicles to more shared systems (passengers or vehicles) (Wu et al. 2019), as well as automated mobility (parking less), and electric mobility (Stam, 2019). Lau and Susilawati (2021) found that integrating shared AVs and PT shifts from car to shared AVs and increases PT ridership. Bike-sharing has a competitor and a complementary role to public transit, which can be a good option with high potential for the last mile of the trip (Kong et al., 2020)—providing AVs in the first/last mile help passengers to access to and egress from stations/stops in the networks of urban transit (Abe, 2021). Chen et al. (2020) assumed that compared to headway-based feeder buses, AVs are more flexible. They emphasised that to reduce walking distance, pickup points should be considered at bus stops and close to parking lots (Chen et al., 2020). Yap et al. (2016) also concluded that introducing automated vehicles specifically for the last mile has potentials. Understanding these potentials is essential for sustainable transportations and cities with AVs (Abe, 2021). The fleet size, variety of alternatives, related facilities, and locations are essential for increased hub use.

Besides the classic instrumental variables such as the time people spend during access and egress (waiting time and in-vehicle time), travel cost, and socio-demographic, some new influential factors should be taken into consideration, such as the mode availability and booking time which relates to reliability and flexibility (Bronsvoort et al., 2020).

Booking factors, as well as departure delay and travel time deviation, negatively impact mode choice. Travellers would like to spend less time on access and egress trips (Bronsvoort et al., 2020). Jorge and Correia (2013) emphasised that shared vehicles' utility is valued much higher than private vehicles due to less time spent on the road and parking places. So, they could be alternatives to private car ownership (Correia & Antunes, 2012).

Regarding bike-sharing, it is reported that this system decreases the share of private cars in the modal split in the US (Shaheen & Chan, 2016). In the same study, it was found that bike-sharing could be a bus alternative in large cities and access/egress mode to/from bus stations in smaller cities in the US. Another study showed that the option of cycle-hire facilities promoted bike shares in the last mile distance (Brand et al., 2017).

The emerging access/egress modes such as shared, electric, and automated vehicles are more environmentally friendly, flexible, cheaper, and faster than the current modes. The emerging modes such as bicycle sharing systems (Brand et al., 2017; Scheltes 2015; Bronsvoort et al., 2020; Shaheen & Chan, 2016), E-bikes in stations (Scheltes 2015), and car-sharing programs (Correia and Antunes 2012; Jorge and Correia 2013, Scheltes 2015, Martin et al. 2010, Martin and Shaheen, 2011), as well as the short term application of automated vehicles (Scheltes 2015; Yap et al. 2016), can compete with private cars.

Although there are different influential factors on passenger preferences regarding access-egress modes, among the mentioned factors, the impacts of travel time, travel cost and availability of emerging modes in different weather conditions and carrying/no luggage is not thoroughly investigated at multimodal hubs, which is the aim of this research.

3. Research methodology

3.1. The research approach

The research approach is formulated to address the main research question that is defined as how emerging modes and the context indicators impact the modal choice of travellers in a multimodal hub. This case study may help predict access/egress mode choice decisions at stations. In order to reach the answer, a literature review has been undertaken as a first step to find influential factors on modal choice at multimodal hubs. Then, a stated preference survey was designed based on five alternatives, three attributes, and two contextual situations and conducted at Delft Campus train station as an example of a small-medium multimodal station with high demand for passengers, accessing the technical University nearby.

A stated choice survey was selected to determine people's preferences for new modes of access/egress from hubs. Stated choice experiments are widely used in transport literature to understand travellers' choices regarding various modes. Respondents who receive hypothetical choice situations (Louviere et al., 2000; Train, 2009) are required to decide a preferred transport mode, considering total travel time, travel cost, and availability of modes from a range of available options. This method was selected for several reasons. Firstly, the new transport modes are not yet available for daily use. There is no available data on the revealed preferences of people. Secondly, our research intends to include context scenarios such as weather and luggage to test the impact of these context effects on mode choices. Stated preference offers an opportunity for the researcher to create context effects for respondents and test the impact on people's choices.

The most common (and simplistic) model to extract the participants' choice behaviour in the stated preference studies is the Multinomial logit (MNL) model. These models are based on the theory of utility maximisation and the assumption that the respondents maximise their utility when choosing among alternatives in a given choice set. In MNL, the assumption of independence of irrelevant alternatives (IIA) is considered (McFadden, 1986).

However, given the similarities (and thus expected correlations in choice behaviour) among some alternatives in our stated experiment, we apply Nested Logit (NL) models. In these models, the assumption of IIA is relaxed by allowing correlation between the non-observed utilities of groups of alternatives (Hensher et al., 2005).

3.2. Selection of Delft Campus station (in the Netherlands) as a case for this research

Scheltes (2015) studied the modal split of the access/egress trips for the coming years in the Netherlands and found that almost half of people are interested in new, emerging, and future modes. This study evaluates how emerging modes affect the modal choice of travellers in a multimodal hub which helps to predict access/egress mode choice decisions at stations.

The Netherlands has one of the densest rail networks globally, transferring more than 1.2 million passengers per day (Van Hagen & Exel, 2012), travelling 21.6 billion kilometres by public transport users in 2014 (CBS, 2015). Currently, up to 17% of these trips are considered multimodal trips, using at least two different transport modes for medium-distance transferring (20–40 km) between urban areas in the Netherlands (Van Nes et al., 2014). Moreover, more than half of them (61%) are covered by train as the principal transport means (Kennisinstituut Voor Mobiliteitsbeleid, 2014). For this reason, the role of railway stations as transit nodes is crucial and well investigated by several researchers (see, for example, Molin & Timmermans, 2010; Puello & Geurs, 2015; Shelat et al., 2018; Van Mil et al., 2020; Yap et al., 2016).

Depending on trip direction (home-end and activity-end), bicycle, walking, and public transport are used differently in the Netherlands. According to Kennisinstituut Voor Mobiliteitsbeleid dataset 2017, at the home-end trip, the modal split is bicycle 43%, walking 23%, and public transport 19%, and at the activity-end trip, cycling is decreased to 13%, and walking and public transport are increased to 45% and 33% respectively. Based on these percentages and the decreasing trend of classic public transport modes such as bus, tram, metro, it is assumed that the transportation sector should provide more transport alternatives in the last mile of trips (Fig. 1).

In recent years, the primary Dutch Railway operator in The Netherlands (NS) has offered two new alternatives mode in the stations, 'OV-fiets' (a bike-sharing system) and 'GreenWheels' (a car-sharing system). The evidence shows that shared services are becoming trendy in the Netherlands, evidenced by a 23% growth in 2017 (CROW-KpVV, 2017). It is reported 8,627 that types of autonomous electric vehicles (AEVs) were welcomed in 2017 (Rijksdienst Voor Ondernemend Nederland, 2018).

Delft-Campus train station (see Fig. 2), which ProRail (2012) introduces as a so-called 'Basis station[1]' with around 5000 passengers per working day (Boor, 2019), has connection only to bicycles, shared bicycles, and car parks, and can be considered a small hub. It is one of the two train connections to Delft and the central train station for Delft University of Technology (TU Delft). Due to its proximity to the University and the science park, the Delft-Campus train station can be developed as an important multimodal hub that is considered the case study in this research.

Although approximately 35% of daily users of Delft Campus station are TU Delft University students or staff, the public transport connections between Delft-Zuid and the university campus are not optimal. Fig. 3 provides additional information on the mode share in this station (https://dashboards.nsjaarverslag.nl/reizigersgedrag/delft-zuid, 2019). Walking and cycling are the main access/egress modes in this 2-kilometre walking distance, and lack of public transport modes (Scheltes and Correia, 2017) makes it an exciting candidate small hub at which to ask the users and travellers what they would foresee as suitable access/egress modes in the future.

3.3. Survey and sample

This paper explores people's preferences on adopting bicycle sharing, shared e-scooters (both standing and sitting), individual automated vehicles, and collective automated vehicles among passengers. The Delft-Campus train station is selected as an example small-medium multimodal station. A survey was conducted to capture influential factors socio-economic, travel-related, and behavioural, and personal preferences in this study that are not captured through revealed data.

Our survey was conducted in an online survey in English and Dutch. The flyers, including QR codes, a link to access the survey, and a short explanation of the purpose of the research, were distributed at Delft-Campus station among travellers who access or egress from the station between 18 June and 1 July 2019.

The questionnaires begin with a short introduction about emerging new modes as access and egress modes combined with the train in Delft-Campus. This travel demand survey was conducted in three parts: 1) reveal preferences, 2) stated choice experiment and 3) socio-economic characteristics in Delft Campus train station as a case study. Only respondents who travelled via this station were allowed to answer the questionnaire.

The first part was presented to participants to collect data about the current situation related to the first/last trip, such as the trip's purpose, the approximate distance between the origin and the destination, position (access or egress stage), and the modes of transportation they used. This part of the experiment aimed to find out the revealed preferences of the subject. The questionnaire ended by asking socio-economic characteristics of the respondents. Table 2 shows these socio-economic variables and categories.

3.4. Stated choice experiment

The second part of the questionnaire featured a stated choice experiment. At the beginning of the second part, which was about future transportation modes and trips, five new transport mode options were introduced in an overview Table 3 and presented in Fig. 4.

Although it would be interesting to examine how emerging modes fare against more traditional modes (e.g. walking), this research only looks at the relative preference to find their potential for future stations. The respondents were further informed that the following condition applies for the modes in Table 3:

- Walking and private bicycles are out of the scope since we would know passenger's opinion regarding emerging modes.
- The modes can be booked via a mobile App before taking the trip.
- They (in the case of the first three modes) can be left anywhere (dockless station) as long as it is in an admissible region (geofencing).
- The availability of transport modes is different. Availability was presented as the probability of finding a mode present when the passenger arrives with the primary mode and wants to shift mode and egress from the station. For instance, if the availability is set to 90%, the respondent can find the mode 90% upon arrival at the station, while 10% of the time, it is not available at the station.
- The additional information regarding waiting times until the next available mode can be checked via a mobile app.

[1] ProRail named stations with 1000–10,000 passengers per day as 'basis station' in The Netherlands (Spoorbouwmeester, 2012).

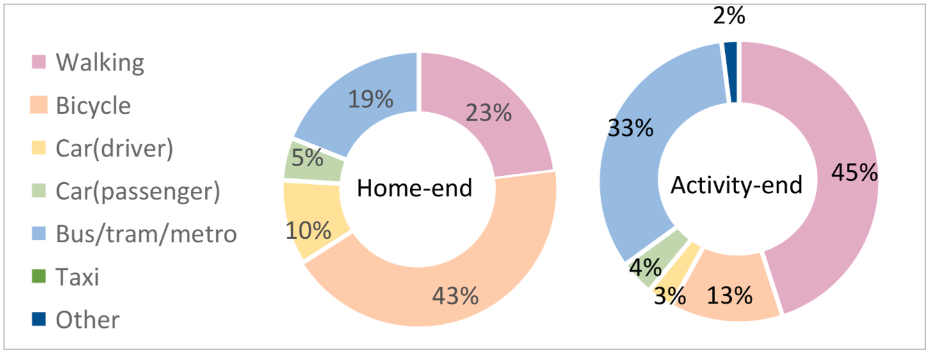

Fig. 1. Modal split (2014) of the 20 busiest railway stations in the Netherlands (Kennisinstituut Voor Mobiliteitsbeleid, 2017).

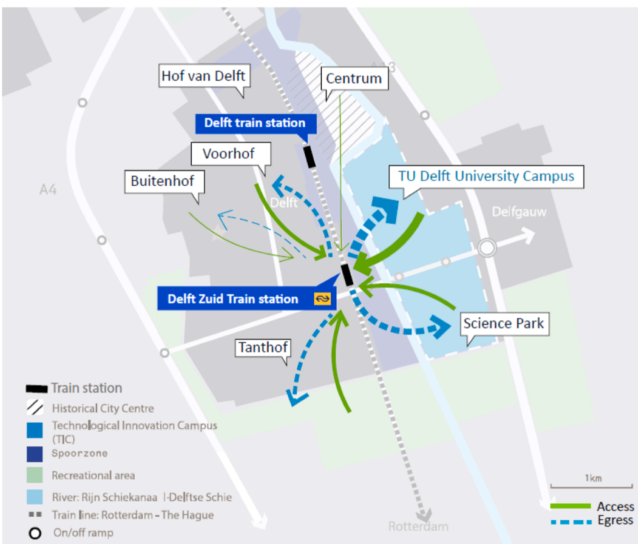

Fig. 2. Map of Delft presents Delft central and Delft Campus train stations, including access/egress passengers (Boor, 2019).

When the choice sets were offered to the respondents, a different contextual situation (i.e., scenarios) were also introduced to the respondents to see how these contextual situations would play a role in respondents' choices for alternative access/ egress modes.

Each contextual situation is composed of a weather element and a luggage element. Six different contextual situations were developed, which are as the following:

1) Imagine that the weather is sunny and you do not need to carry a luggage
2) Imagine that the weather is rainy, but you do not need to carry a luggage
3) Imagine that the weather is cold (<5 °C), but you do not need to carry a luggage
4) Imagine that the weather is sunny and you do need to carry luggage of 10 kg or more
5) Imagine that the weather is rainy and you do need to carry luggage of 10 kg or more
6) Imagine that the weather is cold (<5 °C) and you do need to carry luggage of 10 kg or more

These contextual situations are summaries in Table 4 below:

Therefore, participants were asked to decide which mode they prefer as an access-egress mode for their trip to/from Delft Campus station based on the attributes and characteristics of the five alternative transport modes plus considering one of the six contextual situations (Scenario) that was shown in Table 4. The contextual situations were randomly distributed to the respondents, but we made sure that the contextual situations were equally distributed among respondents.

3.5. Alternatives and attributes and choice sets

Considering all alternatives and attributes in a stated preference experiment provides many choice sets that are not practical. Three different instrumental attributes, such as total travel time, travel cost, and availability of modes in three corresponding attribute levels, have been used in the SP experiment, disaggregated by different modes (Table 5). In order to make alternatives more credible and imaginable for respondents, most attribute levels came from literature or existing services (Bronsvoort et al., 2020). The five alternative modes and three attributes were selected not to exceed the cognitive load of respondents in the experiment. This would allow respondents to compensate for the attributes and weigh the alternatives appropriately even though there is a chance that respondents may use simple heuristics to make the choices (e.g. always choosing the lowest costs or fastest mode, or the most

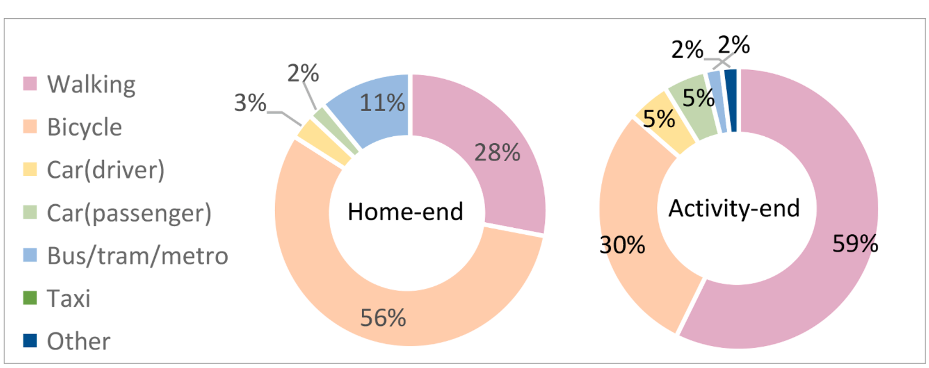

Fig. 3. Current access/egress modal split in Delft-Campus train station (NS, https://dashboards.nsjaarverslag.nl/reizigersgedrag/delft-zuid, 2019).

Table 2
Overview of socio-economic variables and their categories used in the experiment.

Socio-economic variable categories						
Birth year						
Gender	Female	Male	Others			
Gross income (€/year)	<€10.000	€10.000-€39.999	€40.000-79.999	>€80.000	I do not know	I prefer not to say
Education level	≤Pre-vocational secondary(VMBO)	Secondary vocational education (MBO)/pre-university	≥University education (HBO, WO)	Other, please specify		
Most frequent trip purpose	From/to work	Education/Business	School/ study	Social/ recreation/sports	Healthcare	Other, please specify
Origin/Destination	TU Delft	Schieweg Noord	Schieweg Zuid	Voorhof	Tanthof oost	Other, please specify zipcode.
Transport stage	Access	Egress				Other, please specify
Current used main transport mode	Walking	Private Bik	Shared Bike	Car(driver)	Car (Passenger)	

Table 3
Overview of the alternative characteristics.

	*Shared bike*; can be used by several people at different times.
	*Shared e-step*; can be used by several people at different times. You have no seat; you should stand in an open area and pedal to move normally.
	*Shared e-scooter*; can be used by several people at different times. You have a guaranteed seat in an open area, and you do not pedal to move.
	*Individual automated vehicle*s; can be used by several people at different times. It looks like a private taxi (flexible route, flexible schedule) but is driverless and cheaper. You have a guaranteed seat.
	*Collective automated vehicle*s; can be used by several people at the same time. The shuttle has a flexible route and flexible schedule and is cheaper than taxis due to being driverless. You are inside but do not have a guaranteed seat.

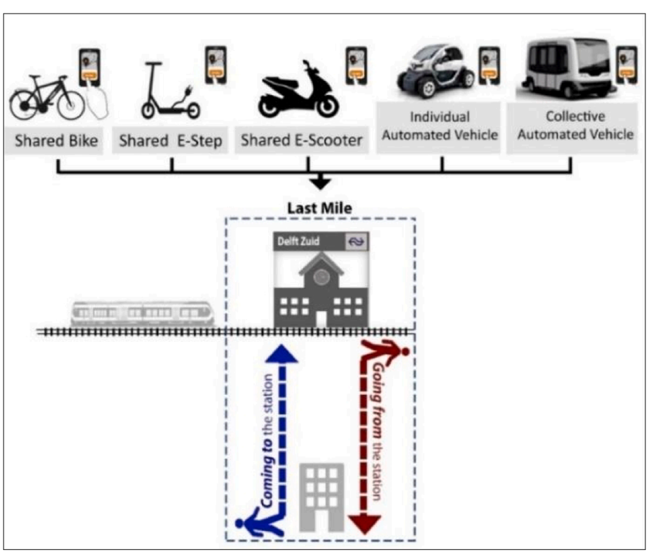

Fig. 4. Overview of trip future alternatives incorporated in the SP experiment.

Table 4
The context effects were provided for the respondents.

Contextual No.	Context conditions Weather situation + Luggage
context 1	Sun + No Lug
context 2	Rain + No Lug
context 3	Cold ≤ 5 °C + No Lug
context 4	Sun + Lug ≥ 10 kg
context 5	Rain + Lug ≥ 10 kg
context 6	Cold ≤ 5 °C + Lug ≥ 10 kg

modern mode).

Attribute levels have been obtained by looking at the overall market values when conducting surveys for the known modes (i.e. shared bike, E-bike, scooter). For the other less known modes to the markets (i.e. AVs), recent transport literature has been used to obtain the cost and travel times for AVs where they are considered for similar access/egress purposes, for instance, the study of Yap et al. (2016), Ashkrof et al., (2019).

Travel cost of an alternative denoted the paid cost for using a specific means during the trip for renting or parking, and they are based on prices at Dutch stations. The lowest and highest prices are assumed for shared bikes (€0.5, €1, €1.50) and individual AV (€3, €4, €5) respectively. Due to some maintenance and the battery, the cost of e-step and e-

Table 5
Overview of attributes and attribute levels used in SP experiment.

Attribute	Attributes levels		
Travel cost-shared e-step	€1	€1.50	€2
Travel cost-shared e-scooter	€1.5	€2	€2.5
Travel cost-shared individual AV	€3	€4	€5
Travel cost-shared collective AV	€2.5	€3	€3.5
Travel time shared bike	4 min	6 min	8 min
Travel cost-shared bike	€0.5	€1	€1.50
Travel time shared e-step	3 min	5 min	7 min
Travel time shared e-scooter	3 min	5 min	7 min
Travel time shared individual AV	4 min	6 min	8 min
Travel time shared collective AV	5 min	8 min	11 min
Availability shared bike	70%	80%	90%
Availability shared e-step	70%	80%	90%
Availability shared e-scooter	70%	80%	90%
Availability shared individual AV	80%	90%	100%
Availability shared collective AV	80%	90%	100%

scooter was considered as more than the cost of bike-sharing. AVs are not yet operational in the Netherlands, but these prices have been extracted from recent studies (Yap et al., 2016; Scheltes, 2015; Scheltes and Correia, 2017).

Total travel time, defined as door-to-door travel time including waiting time, was calculated based on distance and speed using google maps. It is assumed that shared e-step and e-scooter are the fastest modes (3 min, 5 min, 7 min), and collective AVs take the most time (5 min, 8 min, 11 min).

The attribute of 'availability' is rarely used in terms of varied transit modes in the literature and mainly uses car ownership. Here, availability denoted the accessibility of the alternatives. Nguyen-Phuoc et al. (2018) used attribute levels of 'yes' and 'no' for ownership/availability of motorcycles and bicycles in their studies. In our choice experiment to present the comparative attribute, we would develop and extend the availability attribute level into availability percentage, probability of finding a mode upon arrival at the station. 90% availability means that once a passenger arrives at the station, they can successfully access a mode 9 out of 10 times. 100% availability is provided only for AVs to investigate whether the increasing availability of AVs for the last mile can specifically make them more attractive for passengers.

The choice sets in the SP survey were based on an efficient design since they are preferred to the traditional orthogonal designs. These designs are developed to 'minimise the elements of the AVC [Asymptomatic Variance-Covariance] matrix for the design (Bliemer and Rose, 2009, p. 611), and also to minimise the standard errors (D-error). These designs were constructed using the Ngene software (ChoiceMetrics, 2012). In order to develop efficient designs, some priors are needed. These preliminary (estimated) values of the coefficients (Rose et al., 2008) were obtained from a pilot study for access-egress modes that assumed no prior estimates and used orthogonal designs.

Since it was challenging to obtain priors from a pre-test or another study, we conducted our pilot study to obtain priors for the efficient design. The pilot survey was performed prior to the primary survey, and then the efficient design was generated. There was no bias in selecting the respondents for the pilot, and the pilot was performed among the random passengers at the Delft campus station.

The pilot study used orthogonal design and was collected from 57 fully completed surveys. The priors were generated based on the MNL model (fitted on the pilot sample), and the coefficients were used to develop the primary survey's efficient design.

Given five alternatives, three attributes, three levels mentioned in Table 5 and considering three kinds of weather and two luggage context conditions, 36 scenarios (choice sets) were developed. One of the efficiency measures, namely: the' estimate' indicated by the Ngene software, calculates the minimum required sample size to have statistically significant coefficients (at the 95 % level). For our selected design, the S estimate was estimated to be 6.8. This means that the whole experiment (i.e. the 36 scenarios) must be repeated roughly seven times.

For practical reasons and to keep the time required to fill in each questionnaire at a manageable level, each respondent was assigned only six choice sets out of the 36 choice sets, and each respondent was assigned only a fixed context setting to prevent confusion.

Since the whole experiment (the 36 choice sets) should be repeated seven times, the minimum sample size of respondents would be 224 completed choice sets.

Participants were asked to choose between the five alternatives, and they were not allowed to opt out.

Fig. 5 shows an example of these choice sets, the combination of attributes levels and all alternatives in a specific context.

4. Data collection and analysis results

In this section, we provide descriptive statistics of the collected data and contemplate the representativeness of the sample that the survey has obtained. Afterwards, we present two MNL models (with and without socio-economic parameters) to demonstrate the choice preferences of the respondents in choosing access/egress modes from a small multimodal hub in the presence of the context indicators.

In order to relax the IIA assumption of the MNL models, we introduce two NL models (again, with and without socio-economic parameters). Afterwards, we discuss the model fit of these logit models and evaluate which model can better describe and predict respondents' choices on access/ egress modes, given the two context indicators. Furthermore, the market share is predicted, and the elasticities of different transport modes are calculated.

4.1. Data collection

In total, 480 people started the online survey, and from those, 293 respondents completed the survey (61% completion rate) with an average time of approximately 14 min. This equals 1758 filled choice sets, which is much higher than the minimum required (i.e. 224).

Table 6 compares the socio-economic variables between our sample of respondents and the Dutch population from NS Klimaat VI Personenonderzoek (NS, 2019a,b). To analyse socio-economic characteristics, it should be considered that the experiment has been performed at Delft Campus station, which is located in the neighbourhood of TU Delft.

Regarding the socio-demographic characteristics of the sample, it contains higher shares of young (82% <39 years), university-educated (84%), and low economic level 31% <19.999 euro) users who travel most often for work/school-related purposes (68%) compared to the general Dutch sample. Looking further into the general Dutch sample shows an over-representation of respondents aged 40 to <64 years (45%) who are not highly educated and travel for leisure-related purposes. The table compares current modal split transportation modes with the NS modal split figures last at access and egress stages.

Although we have made every attempt to sample passengers arriving at the Delft-campus station randomly, the final sample may be biased, since many passengers at this station are heading to a particular destination (Delft Technical University) which might not represent the population of Delft (or The Hague or Rotterdam).

Delft-Campus train station is located close to TU Delft University. It is the largest and oldest public technical University in the Netherlands and one of the highest-ranked universities in the world. So, in the sample, TU Delft University has a dominant role for people who use this station in terms of socio-economic characteristics and trips and travel modes, and where the only available public modes are shared bikes (such as OV fiets and Mobike). The sample is reflected in no shares of BTM and a small share of cars and shared bikes. On the other hand, respondents much more often use private bikes for access and egress trips, 51% and 50% respectively. Compared with the overall model split in the Netherlands, BTM allocated a 24% share of transportation modes at access and egress trips. Generally, NS reported bikes (30%) are used as the first preference

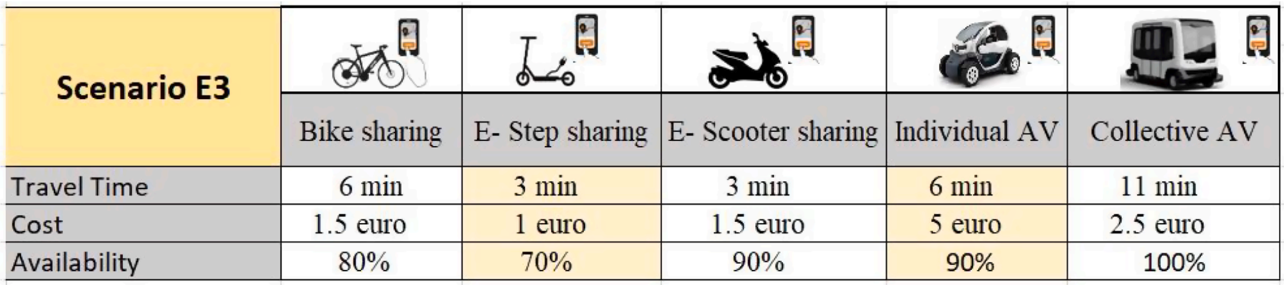

Fig. 5. Example of giving a choice set to respondents in the survey.

Table 6
Comparison between sample and NS customer population for different socio-economic variables.

Socio-economic variable	Category Share sample NS customers		
Last trip purpose	From and to work	38%	14%
	Business	8%	6%
	School/ study	30%	8%
	Social/recreation/sports	19%	58%
	Healthcare	1%	–
	Other	3%	14%
Age	<20	3%	–
	20 to <39	82%	31.7%
	40 to <64	10%	45.8%
	65 to <79	4 %	17%
	80≤	–	5.5%
Gender	Female	44%	53%
	Male	54%	47%
	Other	2%	–
Education level	Pre-vocational secondary education (VMBO) or below	1%	27%
	Secondary vocational education (MBO) or pre-university education (VWO)	10%	39%
	University education (HBO, WO) or above	84%	35%
	Other	4%	–
	I prefer not to say	2%	–
Total family gross annual income	Less than 19.999 euro	31%	–
	19.999–39.999 euro	16%	–
	40.000–59.999 euro	11%	–
	60.000–79.999 euro	7%	–
	More than 80.000 euro	7%	–
	I don't know or prefer not to say	29%	–
	Average income (€/month)		€ 1,830
Position	I am Coming To Delft Campus station (access)	66%	–
	I am Going From Delft Campus station (egress)	34%	–
Access mode	Walk	33%	22%
	Private bike	51%	–
	Shared bike	5%	–
	Bike (private/shared, folding)	–	30%
	BTM	–	24%
	Car (private/shared, driver/passenger)	7%	21%
	Other	4%	3%
Egress mode	Walk	34%	58%
	Private bike	50%	–
	Shared bike	6%	–
	Bike (private/shared, folding)	–	8%
	BTM	–	24%
	Car (private/shared, driver/passenger)	4%	7%
	Other	6%	4%

of travellers at home-based trips and 58% walking share at activity-based trips.

4.2. Discrete choice model results

We first estimated a main effect only MNL model (i.e. no interaction effects) and then the full MNL model (i.e. with main and interaction effects). The main effect parameters (the three attributes) were significant (the third attribute was significant at $p < 0.10$), and they have the right sign, i.e. travel time and ticket price were negative, and availability had a positive sign.

The initial model was compared with the full model via the likelihood-ratio test. This test indicated that complete modal (final log-likelihood: −2283.86) with interaction effects fitted the data significantly better than the initial primary effect model (final log-likelihood: −2432.21). The likelihood-ratio test with 18 degrees of freedom for the 18 interaction effect parameters that are estimated is found to be well significant, $\chi 2 = 298 > 34.80$, (d.f. = 18, $p = 0.01$). Therefore, the context effects interacted significantly with the three attributes.

As explained before in section 3.4 (and shown in Table 4), six contextual situations are imposed on the choice sets. These six contextual situations (scenarios) are effect coded, as shown in Table 7.

The addition of the demographic variables on the MNL model also proved to be a significantly better fit model compared to the MNL model without demographic explanatory variables. We will not discuss the MNL model further because the NL model shows a better fit, judging by the adjusted R^2 and the likelihood-ratio test (adjusted R^2 for MNL was 0.196 and MNL with socio-economic was 0.236 and that of NL was 0.201 and 0.241, respectively). Therefore, we provide further detailed descriptions of the interaction of the context indicators with the main attributes in the next section.

4.2.1. Nested logit (NL) model

Based on the formulation of the alternative access egress modes, we hypothesised that the currently available access and egress modes (shared bike, e-step, and e-scooter) might have commonalities, and the same would be valid for the two AV alternatives. Thus, we tested this hypothesis with two nested logit models. Table 8 shows the estimated parameters for an NL only (model A) and the other with NL model plus socio-economic (model B) variables. In these models, the three modes

Table 7
The effect coding of the contextual situations (for full explanation of the contextual situation see Table 4 and section 3.4).

Contextual situation	Indicator 1	Indicator 2	Indicator 3	Indicator 4	Indicator 5
context 1	1	0	0	0	0
context 2	0	1	0	0	0
context 3	0	0	1	0	0
context 4	0	0	0	1	0
context 5	0	0	0	0	1
context 6	−1	−1	−1	−1	−1

Table 8
The parameter estimates of the two NL models.

Main effects	NL (model A)		NL + Socio-economic (model B)	
	Estimate	*t*-value	Estimate	*t*-value
ASC Bike sharing	0	(Fixed)	0	(Fixed)
ASC E-step sharing	−0.275**	−4.70	−0.229*	−1.89
ASC E-scooter sharing	−0.350**	−4.02	−0.116	−0.84
ASC Individual AV	0.160	0.81	0.0691	0.21
ASC Collective AV	0.081	0.49	−0.668	−1.62
Travel Time	−0.109**	−8.45	−0.117**	−8.33
Ticket price	−0.614**	−9.67	−0.644**	−9.43
Availability	0.00537**	2.41	0.00564**	2.5
Interaction effects				
Travel Time * context 1 (Sun + No Lug)	−0.0927**	−3.13	−0.0787**	−2.65
Travel Time * context 2 (Rain + No Lug)	0.0172	0.91	0.00179	0.09
Travel Time * context 3 (Cold ≤ 5oc + No Lug)	0.0099	0.48	0.0175	0.82
Travel Time * context 4 (Sun + Lug ≥ 10 kg)	0.0189	0.82	0.0141	0.59
Travel Time * context 5 (Rain + Lug ≥ 10 kg)	−0.019	−0.95	−0.0184	−0.84
Travel Time * context 6 (Cold ≤ 5oc + Lug ≥ 10 kg)	0.0664		0.06371	
Ticket price* context 1 (Sun + No Lug)	−0.732**	−8.40	−0.662**	−7.62
Ticket price* context 2 (Rain + No Lug)	0.260**	5.24	0.207**	3.91
Ticket price* context 3 (Cold ≤ 5oc + No Lug)	0.0166	0.29	0.0105	0.18
Ticket price* context 4 (Sun + Lug ≥ 10 kg)	−0.089	−1.59	−0.0683	−1.17
Ticket price* context 5 (Rain + Lug ≥ 10 kg)	0.217**	4.00	0.169**	2.78
Ticket price* context 6 (Cold ≤ 5oc + Lug ≥ 10 kg)	0.327		0.3438	
Availability* context 1 (Sun + No Lug)	0.0081**	2.91	0.0078**	2.77
Availability* context 2 (Rain + No Lug)	0.00657	1.41	0.0051	1.07
Availability* context 3 (Cold ≤ 5oc + No Lug)	−0.0139**	−2.44	−0.0134**	−2.31
Availability* context 4 (Sun + Lug ≥ 10 kg)	0.0002	−0.05	0.0009	−0.02
Availability* context 5 (Rain + Lug ≥ 10 kg)	0.0009	0.21	0.000396	0.09
Availability* context 6 (Cold ≤ 5oc + Lug ≥ 10 kg)	0.0010		0.00096	
Socio-economic variables				
Age above 26 and under 45 e-step sharing			0.234**	3.14
Age 26 and younger e-scooter sharing			−0.193*	−1.87
Age above 26 and under 45 e-scooter sharing			0.205**	2.38
Age above 45 e-scooter sharing			−0.012	
Age 26 and younger Individual AV			−0.391**	−2.39
Age above 26 and under 45 Individual AV			0.513**	4.08
Age above 45 Individual AV			−0.122	
Age above 26 and under 45 Collective AV			1.13**	7.55
Female E-scooter sharing			0.165**	2.83
Low Education e-scooter sharing			0.549**	2.69
Middle-income e-scooter sharing			−0.237**	−2.57
Low-income Individual AV			−0.359**	−2.77
Middle-income Individual AV			−0.517**	−4.29
High-income Individual AV			0.876	
Low-income Collective AV			−0.444**	−3.75
Middle-income Collective AV			−0.444**	−4
High-income Collective AV			0.888	
Nest parameter, λ			Nest Value	t-value
Non-AV nest (bike sharing, e-step sharing, e-scooter sharing)			1.00	(Fixed)
AV nest (Individual AV, Collective AV)			0.55	4.04
Model fit				
Initial log-likelihood	−2868.02		−2790.76	
Final log-likelihood	−2269.70		−2068.52	
R^2	0.209		0.259	
Adjusted R^2	0.201		0.241	
likelihood-ratio test	Compared to the model a $\chi^2 = 28 > 6.63$, d.f = 1p = 0.01		Compared to the model b $\chi^2 = 30 > 6.63$, d.f = 1p = 0.01	

(Bike sharing, E-step sharing, and E-scooter sharing) are nested with each other as "Non-AV" nests, and the two alternatives of Individual AV and Collective AV are nested as "AV" nests.

The nest parameter (0.55) is significant (t-value = 4.04) compared with the MNL model. This means that the nesting of the alternatives has successfully captured commonalities among the alternatives within the nests. The nested parameter indicates the level of correlation between the error components of the alternatives within the nest. Since the parameter is getting close to zero, there is more correlation between the unobserved components of the alternatives within the nest (Train, 2009).

Interaction of travel time with context indicators

The interaction of travel time with context indicators provides exciting results. We observe that the utility slope increases for two interactions: 'sunny + luggage' and 'cold ≤5 °C + luggage' contexts. The significant issue here is that the increase in the slope of utility probably indicates that with the presence of luggage, there is again in using the five alternative modes to access or egress from the station versus not using these modes. Therefore, the longer travel time to access or egress the station is acceptable for passengers with luggage.

It should be mentioned that there is an exception in our finding, and that refers to rainy weather conditions. Surprisingly, the utility slope decreases from the 'Rain + No Lug' condition to "Rain + Lug ≥ 10 kg". This result is not consistent compared with the other two contexts. Furthermore, only one interaction effect, namely travel time and "Sun +

No Lug", was significant (t-value = −3.13 or −2.65) in our analysis. Therefore no generalisation to the entire population can be inferred. Nevertheless, the findings provide insight into how passengers' utility curve changes with travel time and using the alternative modes under different weather situations and carrying luggage.

Interaction of travel cost with context indicators

We observed exciting findings by examining the ticket price with context effects indicators. First and foremost, interactions of context effects with the ticket price attribute were significant in most cases.

Looking at the interaction effects, it can be seen that there is a gain in utility slope when combining the ticket price with the context 'Sun + Lug > 10 Kg' compared to when there is no luggage and the weather is sunny. The gain in utility slope also happens when it is 'cold ≤ 5∘C + Lug > 10 kg' compared with cold and no luggage. We can surmise that when passengers have luggage, they are more willing to pay the ticket price and use the transport modes than when they do not have luggage. However, this finding is not valid for people with luggage (>10 kg) and want to access or egress from the station in rainy weather. There is a slight drop in utility slope when people have luggage compared with when they do not.

Another critical finding here is that, in general, people are more willing to pay the ticket price (positive utility slope) when the weather is rainy or cold (with or without luggage).

Interaction of availability with context indicators

For the interaction of the availability and the context effects, we see a drop in utility slope when examining the availability with the context 'Sun + No Lug' compared to when there is luggage and the weather is sunny. The drop in utility slope also happens when 'Rain + No Lug' compared with 'Rain + Lug > 10Kg'. One can interpret this as passengers without luggage deem it essential to have the next mode ready and available to access or egress the station quickly.

It is surprising and counterintuitive that there is a loss in utility slope (-0.0139, or −0.0134) when the weather is 'Cold ≤ 5∘C + No Lug'. This may be related to sampling errors.

4.2.2. Impact of demographics

We tested the impact of the following socio-economic indicators in model b and model d: age, gender, income, and level of education. Several of these indicators were significant, providing more insight into their underlying impact on the utility obtained from each alternative than the bike alternative. Bikes are set as default for these socio-economic indicators. Here, we will contemplate only those socio-economic indicators that are significant.

In model d, younger (<26) respondents gained less utility from shared e-scooters and individual AVs. However, the middle group of respondents (between 26 and 45) gained more utility from all alternatives than bikes. The senior group of our respondents (>45) gained slightly less utility from shared e-scooter and individual AVs.

Regarding the gender indicator, women gained utility from shared e-scooters compared to shared bikes.

The respondents' education level indicated that those with a high school or lower level of education gained utility from shared e-scooters. However, middle and higher education passengers were not willing to use shared e-scooters. Income has probably played an essential role in the utility of the respondents for the two AV alternatives. This claim is based on the estimated parameters and their t-value. Low- and middle-income respondents both lost utilities from the two AV alternatives. However, the high-income group gained utility from the two AV alternatives. The middle-income group also lost utility from the shared E-scooter alternative compared to the shared bike alternative.

4.3. Prediction of the market share

One of the critical initial steps to estimate the market share of the new modes is to calculate the value of time (VOT) for the respondents. We used the NL models to generate the VOT since they fit better than MNL models. VOT is calculated by $\frac{\beta_{traveltime}}{\beta_{ticketprice}} = -0.117/-0.644 = 0.181$ euros per minute or around 10.9 euros per hour (based on model d) for an access/egress trip. This is in the range of other access egress studies (Yap et al., 2016).

4.3.1. Market share

The NL model estimates the market share (choice probabilities) of the five alternative access and egress modes based on estimated coefficients (Betas). It should be mentioned that this market share prediction is under the assumption that the presented modes in the experiment are the only available modes and do not consider traditional modes (e.g. walking, private bicycle or regular bus), which is the limitation of this research. These market shares are provided in Table 9.

As shown in Table 9, the first multimodal hubs option would be shared bikes (with 59% market share). Multimodal hubs (at least in the Netherlands) should reserve significant access/egress modes for shared bicycles. Based on model B, AVs (individual and collective) would collectively meet 10% demand for access/egress modes if they were present today. Model B also estimates reasonably high demand for the motorised modes, especially shared e-step (21.4%) and e-scooters (9.6%), representing one-third of the market share. However, we need to emphasise that these predictions are based on a relatively biased sample towards the higher educated and relatively young sample of respondents and may not be extrapolated exactly t the total population.

4.3.2. Elasticities

By calculating elasticities, one can predict the percentage of market share one mode may lose by increasing travel time or travel cost by a specific percentage. In our case, we have increased time and cost by 10% and estimated a decrease in the market share of that given mode. Table 10 presents direct elasticities per mode based on model B.

Based on elasticities in Table 10, shared bikes will not be mainly affected by time or cost increase. On the other hand, individual or collective AVs are the most elastic alternatives from a cost perspective. Individual AVs may lose a much more significant market share than collective AV, given a negative percentage change of −3.32 and −2.54. Comparing cost and time, we can observe that for these access/egress alternatives, the cost attribute has an enormous impact on AVs than the time attribute. This has important implications for AV producers and operators in the future since they need to keep costs competitive with incumbent modes.

5. Conclusion and discussion

Currently, a limited set of modes has been used in stations but, in the future, there is ample potential for using emerging modes for better access/egress at multimodal hubs while also increasing the sustainability of travel. Recently, access/egress transport modes for the first/last mile of public transport trips have been attracting more attention in research and practice. By studying user characteristics of the emerging

Table 9
The predicted average probability of different alternatives based on model B (NL + socio-economic).

Alternatives	Average probability from model B
Shared bike	0.589 (59%)
Shared e-step	0.214 (21.4%)
Shared e-scooter	0.095 (9.6%)
Individual AV	0.043 (4.3%)
Collective AV	0.057 (5.7%)

Table 10
Direct elasticities per mode based on model B.

	Model B	
	Time Elasticity	Cost Elasticity
Shared bike	−0.366	−0.350
Shared e-step	−0.703	−1.065
Shared e-scooter	−0.803	−1.834
Individual AV	−0.882	−3.322
Collective AV	−1.129	−2.617

modes and travellers' preferences on the first/last mile trip modes, this paper provides insights regarding the share of these new modes, which can be valuable for dynamic design for every multimodal hub considering passengers demands and behaviours.

We investigated the potentials of emerging transport modes as new access/egress modes at a small-hub train station (Delft-Campus in the Netherlands). We obtained passengers' preferences towards different travel attributes (travel time, travel costs, availability of different modes) and investigated the impact of weather and carrying luggage on travellers' choices for the access and egress modes. We conclude that travel cost is more important than travel time. Further, the importance of the availability of transport modes is inconsiderable.

The models show that the use of (individual and shared) AVs are positively valued as first/last mile transport modes compared to other alternatives. This case study's findings also provide insight into how passengers' utilities change with different weather conditions and the presence or absence of luggage. We can also contemplate that when it is cold (e.g. ≤ 5 °C) or rainy, people are more willing to pay the higher ticket price for using AVs and tolerate longer travel time to use more comfortable access/egress modes.

The middle group of respondents (between 26 and 45) gained more utility from all alternatives than bikes regarding socio-economic demographics. Passengers who are middle-aged or with low/middle education level or female are more likely to use motorised vehicles, especially shared e-scooters. In contrast, the older passengers or high-income groups gained utility by choosing the AV alternatives. Low-middle income groups also lost utility from the shared e-scooters and AV alternatives compared to the shared bike alternative.

Looking at the potential market share of the alternative access and egress modes, it seems that the demand for shared bikes is strong, and it would be the first option at small multimodal hubs, even by increasing 10% of its travel costs. Our model predicted more market share for the motorised modes, especially shared E-step (21.4%) and E-scooters (9.6%), constituting one-third of future market share.

AVs are more likely to increase the utility of high income and highly educated segments of society, an exciting mode for the first/last mile trip in coming years. However, the sample increases by 10% travel time, and cost drastically reduces the AVs' demands.

Given the sampling limitations and bias (i.e. highly educated and young population), one should caution making general forecasts for public policy. The modal share and the market predictions are a product of our sample and thus are indicative results and may not be generalisable for the wider public, which is a significant limitation when using these results.

In conclusion, as general policy advice, besides characteristics of travellers, trips, modes, and built environment, the impacts of technology-emerging alternative modes should be given more attention by policymakers, planners, and designers in the coming years. It can be generalised that although emerging modes with their characteristics affect modal split and passenger preferences differently, a good combination of emerging modes at stations, besides walking, cycling, and buses, can provide attractive multimodal hubs. However, these modes need to be time-wise and incredibly price-wise competitive with the current access/egress modes, especially short-distance trips. This means that introducing emerging modes and increasing their utilisation may require some support from authorities to get them fully active and functional.

As the general advice for bicycle-friendly countries like The Netherlands or countries with suitable topology, future small-medium sized multimodal hubs should supply and reserve at least half of their access/egress modes only for shared bicycles as the first option and then consider other emerging modes as well. This calls for the designers and station owners/operators to pay more attention to bikes and e-bikes facilities.

Our study explored travellers' preferences for using five emerging modes as first/last mile transport at a multimodal trip. It is recommended to explore the impacts of the emerging modes on the spatial design of multimodal hubs for future research.

CRediT authorship contribution statement

Fatemeh Torabi Kachousangi: Conceptualization, Methodology, Validation, Investigation, Resources, Formal analysis, Writing – original draft, Writing – review & editing. **Yashar Araghi:** Methodology, Software, Validation, Formal analysis, Data curation, Writing – review & editing. **Niels van Oort:** Resources, Supervision. **Serge Hoogendoorn:** Supervision.

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