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A people-environment framework in evaluating transport stress among rail commuters

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ABSTRACT

Transport stress is a pervasive phenomenon in big cities, and can lead to various negative impacts on health and well-being. However, the associated stressors have not been clearly understood. This study proposes a people-environment framework, which incorporates personal stressors, environmental stressors, and travel impedance to capture the "total travel experience" of passengers. In the context of Hong Kong, an online questionnaire survey among Mass Transit Railway (MTR) passengers was conducted in 2021; a total of 629 responses were collected. A factor analysis and a multiple linear regression were conducted to examine the relationship between stressors and perceived transport stress. Apart from service unpredictability and crowding, poor station environment and uncomfortable train compartments are also major stressors. During the pandemic, the anxiety of being infected by COVID-19 is significantly associated with transport stress. The findings shed important light on alleviating transport stress through improving public transit environment by micro-management strategies.

1. Introduction

While public transport is essential to transit-oriented development (TOD) and sustainable transport, negative travel experiences on public transport have become widespread worldwide. In 2011, the World Health Organization (2011) highlighted that travel *per se* can be a stressful event and lead to negative consequences on health and well-being. Increasing research has examined passengers' stress levels on public transport (Gatersleben and Uzzell, 2007; Jimenez-Vaca et al., 2020; Rissel et al., 2014). Empirically, a wide range of public transport factors, including crowding (Cox et al., 2006; Haywood et al., 2017), excessive waiting for transit services (Friman, 2010; Lunke, 2020), traffic congestion (Huang and Loo, 2022; Wu et al., 2019) and service delays (Rezapour and Ferraro, 2021), led to stressful and unpleasant travel experiences. In the long term, transport stress is expected to become more serious in large cities with growing population and human activities, as well as higher traffic intensity and longer commutes (PAHO, 2009). Promoting quality public transport services and a comfortable transit environment is a key component in promoting a sustainable transport system (Loo and Tsoi, 2018; United Nations, 2020). Hence, further investigation into transport stress and its associated stressors is needed.

Overall, it is well-established that travelling, in particular commuting, can create biological stress (Jimenez-Vaca et al., 2020) and perceived stress (Evans and Wener, 2006; Gottholmseder et al., 2009). Stressful experiences on transport can directly lead to bad mood (Chatterjee et al., 2020) and emotional instability (Gimenez-Nadal and Molina, 2019; Stone and Schneider, 2016; Wiese et al., 2020). Moreover, experiencing prolonged stress during travel can lower subjective well-being (Künn-Nelen, 2016; Stutzer and Frey, 2008).

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More importantly, transport stress can also trigger negative spillover effects in other life aspects (Adam et al., 2018; Brömmelhaus et al., 2020; Morris and Zhou, 2018; Wener et al., 2005). The associated undesirable experience on public transport can, in turn, reduce people's willingness and loyalty to use public transport in the long term (Imaz et al., 2015; van Lierop et al., 2018). Therefore, providing a less stressful public transit environment is paramount in maintaining the attractiveness of public transport and achieving the goal of sustainable transport.

While transport stress is worthy for further investigation, most of the existing studies have only examined selected factors of transport stress (e.g. travel impedance, crowding and unpredictability). In this study, transport stress of 629 rail commuters in Hong Kong and the associated stressors are examined. There are three objectives. Firstly, we aim to develop a people-environment framework to synthesise (i) personal stressors, (ii) environmental stressors and (iii) travel features in explaining transport stress. Secondly, specific environmental stressors of rail transport, as well as the impacts of commuting under the COVID-19 pandemic upon transport stress, are captured. Thirdly, different potential strategies are put forward to mitigate transport stress, hence providing policy insights to the management of rail or metro transit operators. In relation, this study is both of theoretical and practical significance. Theoretically, it is the first study to develop a people-environment framework to provide a holistic understanding about relevant factors of transport stress (also known as stressors) from the perspective of the "total travel experience" (Loo, 2021). It highlights the need to scrutinise potential encounters of stressors during the entire travel journeys. Empirically, it provides evidence on the level of commuting stress experienced by metro users in one of the most efficient metro systems in the world. The findings pinpoint specific measures for overcoming associated environmental stressors. This allows researchers, policymakers, and transit operators to formulate effective strategies to mitigate transport stress.

The structure of the rest of the paper is as follows. Section 2 defines the concept of transport stress and outlines the conceptual framework. Section 3 describes the survey method, data and methodology. Section 4 presents the results. Section 5 discusses the findings and Section 6 concludes the paper.

2. Literature review

2.1. The concept of transport stress

The concept of transport stress could be dated back to the 1980s when a wealth of studies started to examine stress along commuting journeys (Costal et al., 1988; Novaco et al., 1979; Schaeffer et al., 1988). Within the transport system, it can be understood as the stressful conditions or situations that commuters encounter on a daily basis, which can affect their decisions in transport (e.g. mode choice) and non-transport domains (e.g. choice of residential locations) (Costal et al., 1988; Novaco et al., 1990). In a broader sense, transport stress can be interpreted as one of the core negative affective experiences in travel as induced by a wide range of potential stressors (Chatterjee et al., 2020; Gatersleben and Uzzell, 2007). The resulting transport stress can be measured in terms of biological stress (e.g. through collecting and analysing salivary cortisol samples from respondents) (Evans and Wener, 2006; Wener et al., 2005) and perceived stress (e.g. self-reported stress levels) (Brutus et al., 2017)).

Transport stress is closely related to the broader theme of travel well-being. Well-being can generally be understood as the perceptions and affective appraisals of individual experience (Chatterjee et al., 2020; Reardon and Abdallah, 2013). Although well-being can be operationalised in different ways, it is suggested that travel experience can affect well-being in both short term and long term (De Vos et al., 2013; Mokhtarian, 2019). In relation, transport stress as a negative affective experience in travel can lower travel satisfaction and emotional well-being during or soon after travel, and in turn it can trigger negative spillover effects to other life aspects (Chatterjee et al., 2020; Clark et al., 2020, De Vos et al., 2013). Therefore, alleviating transport stress that an individual encounters in one's daily travel episodes can improve both short-term and long-term well-being. Moreover, it is noted that the above relationship can be bidirectional (De Vos and Witlox, 2017; Mokhtarian, 2019), meaning that the well-being in other life domains can also affect the affective travel experiences (e.g. stress).

2.2. Stressors of travelling on public transport

In the wake of earlier research, a wide array of studies have emerged to examine the factors of transport stress, which are generally called stressors. Transport stressors can be understood as multiple conditions relating to different forms of travel and travel-related environment that might threaten physical and psychological well-being (Novaco et al., 1990). In other words, stressors are the potential obstacles one encounters and cause one to feel stressed during travel (Koslowsky et al., 1996; Koslowsky, 1997), and they can be related to the multiple dimensions of affective experiences during travel (Anable and Gatersleben, 2005; Chatterjee et al., 2020; Legrain et al., 2015; Liu et al., 2022). It is noted that transport stressors can be analysed from the perspectives of drivers (Montoro et al., 2018; Tse et al., 2006; Tucker et al., 2018) and passengers (Gatersleben and Uzzell, 2007; Jimenez-Vaca et al., 2020; Rissel et al., 2014). To achieve our research objectives of examining potential stressors among rail commutes, this section reviews stressors from the perspective of public transport passengers.

2.2.1. Travel parameters

Travel distance and travel time, also known as travel impedance, are the major travel-related stressors. Empirical evidence generally suggests that both distance and time are positively associated with transport stress (Evans and Wener, 2006; Koslowsky and Krausz, 1993; Rüger et al., 2017). Longer waiting time can contribute to higher transport stress (Mijares et al., 2016). However, there are some complementary and contradictory results depending on specific contexts. For instance, some studies suggest that public

transport commuters (e.g. rail and bus commuters) reported a lower stress level than car commuters (LaJeunesse and Rodríguez, 2012; Wener and Evans, 2011), whereas Gatersleben and Uzzell (2007) found that public transit users felt the most stressed when compared to users of private and active modes. Similarly, Handy and Thigpen (2019) found that commute stress for university students and staff is the highest for bus, followed by car, train and other active modes. Furthermore, trip purpose can be a potential stressor. Notably, commuting tends to be more stressful than travelling for shopping and other discretionary activities (Wang and Zacharias, 2020).

2.2.2. Personal attributes

Transport stress can be attributed to personal characteristics in two ways. Firstly, the sociodemographic features are examined in relation to commute stress, such as gender, age, income and occupation. The results vary according to the specific geographical and modal contexts (Evans et al., 2002; Ohta et al., 2007; Roberts et al., 2011; Rüger et al., 2017). Secondly, personal stressors in other life domains can affect the travel experience, though this has not been widely studied in the literature. Essentially, the living and working conditions (i.e. the non-transport elements) can interact with commute stress (Costal et al., 1988; Cox et al., 2006; Novaco et al., 1990). For instance, flexible working hours can allow commuters to have better control of travel time and reduce commute stress (Lucas and Heady, 2002). Moreover, evening commuters can experience a higher level of stress from crowding as they feel exhausted after work (Haywood et al., 2017).

2.2.3. Environmental stressors

(a) Crowding

Crowding is a predominant environmental stressor in transport. Empirically, crowding is associated with discomfort and a higher level of transport stress (Cantwell et al., 2009; Cox et al., 2006; Mahudin et al., 2012). This can be due to over-closeness, standing throughout the journey and time wasted for not being able to accomplish other things (Haywood et al., 2017). As pointed out by an extensive review of transport stress (Norgate et al., 2020), overcrowding situations tend to be associated with higher transport stress. Similar findings were observed in London Underground (Kim and Gustafson-Pearce, 2016) that overcrowding heightened both anxiety and stress levels.

(b) Service unpredictability

Service unpredictability is a common stressor when people feel uncertain about their journey time, such as knowing how long the travel duration is and the time of arrival (Sposato et al., 2012). Research generally uses “predictability” as a proxy of control. Empirically, service unpredictability is positively associated with stress levels (Cox et al., 2006; Evans et al., 2002). Some typical examples of unpredictability include congestion and delays caused by heavy traffic, disruptive behaviour of other road users and poor infrastructure of public transport (Abou-Zeid and Ben-Akiva, 2011; Gatersleben and Uzzell, 2007; Higgins et al., 2018; Stokols et al., 1978; Tenorio et al., 2019). Moreover, transfers can also increase unpredictability (Wener et al., 2005).

(c) Service-related stressors

Service-related environmental stressors are largely mode-specific. Lunke (2020) evaluates the stress level of public transit commuters in Oslo and suggests that transport stress varies across various public transport modes due to the different surroundings and settings (e.g. open view, seat availability and congestion). A bus-related study illustrates that a variety of affective factors, ranging from hygiene, safety, convenience to scenery viewing, is associated with transport stress (Stradling et al., 2007). Similarly, a rail-based study demonstrates that ill-designed train compartments and stations can give rise to a perception that travelling on rail is crowded and stressful (Cox et al., 2006). Other related environmental stressors include service accessibility (Chng et al., 2016), traffic noise (Patania et al., 2013; Kim and Gustafson-Pearce, 2016), thermal discomfort (Liu et al., 2016) and other passengers’ undesirable and/or aggressive behaviour (Kim and Gustafson-Pearce, 2016; Tenorio et al., 2019).

2.3. Conceptual framework and research questions

The above literature indicates that travel characteristics, personal characteristics, and public transit environment can be potential stressors in a transport system. Nonetheless, there are still two fundamental research gaps. Firstly, the three types of stressors (including different personal, environmental and travel-related factors) have seldom been analysed holistically in a single conceptual framework. Yet, as highlighted in previous psychiatry studies of stress (Billings and Moos, 1981) and geriatric depression (Lam et al., 2020), the interplay of personal and environmental stressors is vital in affecting people’s cognitive appraisal and stress. A holistic consideration of different stressors is critical to the formulation of specific interventions on public transport.

Secondly, the analysis of stressors, in particular for public transport, has mainly focused on in-vehicle travel time, crowding and service unpredictability. Yet, environmental stressors are place-dependent (Cantwell, 2009; Liu et al., 2022), suggesting that transport stressors are highly affected by the transit environment and travel modes that one uses. The idea is also pinpointed by Wang and Zacharias (2020, pp. 216-217) that environmental stressors are related to how one interacts with the surroundings “with sight, hearing, smell, touch, temperature, proximity to others and the physical setting”. Hence, it is essential to employ a people-centric approach to examine transport stress, especially from a commuter’s personal experience (Loo, 2021; Norgate et al., 2020).

In view of the research gaps, we come up with a people-environment conceptual framework of transport stress (Fig. 1). Rail-specific environmental stressors, personal stressors, and objective travel impedance are integrated as major factors of transport stress. Environmental stressors are primary concerned with all possible environmental encounters that may increase one's stress levels during a travel journey, including stressors at stations, interchanges, train compartments and time-related factors. In this study, we also include the anxiety of being infected by COVID-19 during rail commutes as an environmental stressor. This helps to supplement the literature by identifying different environmental factors that can affect the affective experience during travel (Chatterjee et al., 2020; Lombardi and Ciceri, 2021) so that more effective interventions can be formulated. Personal stressors include the major socio-economic attributes (e.g. age, gender, income and health status) and stress levels in other life domains. In particular, different personal factors beyond travel can affect transport satisfaction (De Vos and Witlox, 2017; Mokhtarian, 2019). Objective travel impedance mainly comprises of the general travel characteristics such as travel time and travel distance. Essentially, this geographic framework is built upon the conceptual idea from an earlier study that both transport environment and personal stressors (i.e. home and work domains) can contribute to subjective impedance in commuting and stress outcomes (Novaco et al., 1990). Based on the holistic people-environment framework, this study examines the transport stress of rail commuters in Hong Kong, where one of busiest metro systems is located. There are three major research questions.

- What are the major environmental stressors of rail commutes?
- To what extent are the personal stressors, environmental stressors, and travel impedance associated with the perceived transport stress?
- What are the possible strategies to reduce transport stress for rail commuters?

3. Data and methodology

3.1. An online questionnaire

An online questionnaire survey was developed to collect primary data from full-time workers who travel to work by the Mass Transit Railway (MTR) regularly. As of today, MTR Corporation Limited (MTRC), as the sole rail operator in Hong Kong, operates 98 stations and 10 railway lines. In 2020, MTRC served an average daily total of 3.16 million passengers, capturing a mode share of over 35% for its heavy rail operation (Transport Department, 2021). The questionnaire survey consists of four major sections, including the respondents' (i) travel behaviour, (ii) level of perceived transport stress along the commuting journey, (iii) actual experiences of encountering potential environmental stressors, and (iv) self-reported stress levels in other life domains relative to transport stress (i.e. work, family, relationship and money). Moreover, respondents were asked to report their basic personal particulars, including gender, age, household composition, occupation, and working hours. The survey was advertised on the smartphone application of MTRC (i.e. an e-banner in MTR Mobile) between April 2021 and July 2021. Ethical approval was obtained from the authors' university. A total of 629 valid responses were collected. Fig. 2 shows the number of respondents by the boarding and alighting stations for their morning commute journeys. In general, major boarding stations of our survey respondents were situated at the northeast and southeast regions of Hong Kong (Fig. 2a), where major new towns are found. For the workplace locations (Fig. 2b), they were mainly located in the central business district (CBD) and urban cores.

3.2. Methodology

Fig. 3 illustrates the overall methodological framework. Firstly, a factor analysis is conducted to identify the major types of environmental stressors of rail commutes. Then, a multiple linear regression is developed to analyse the relationship between transport

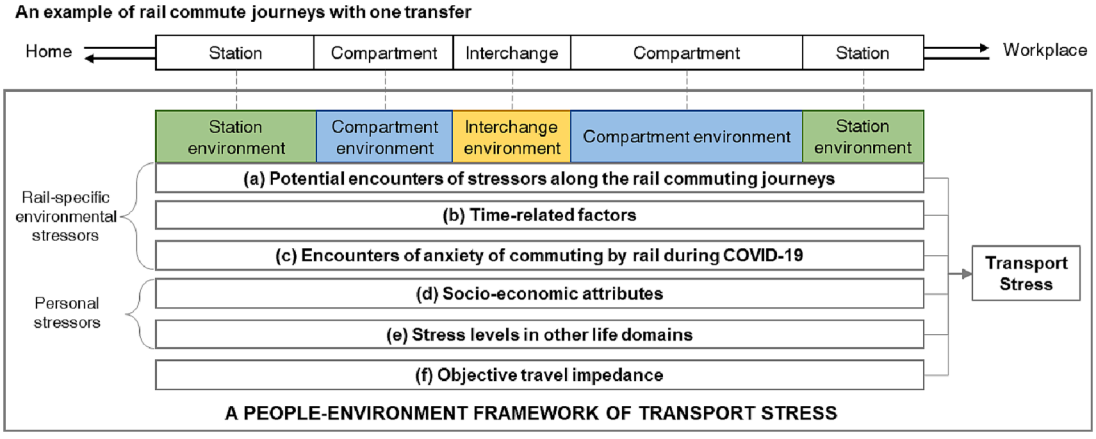
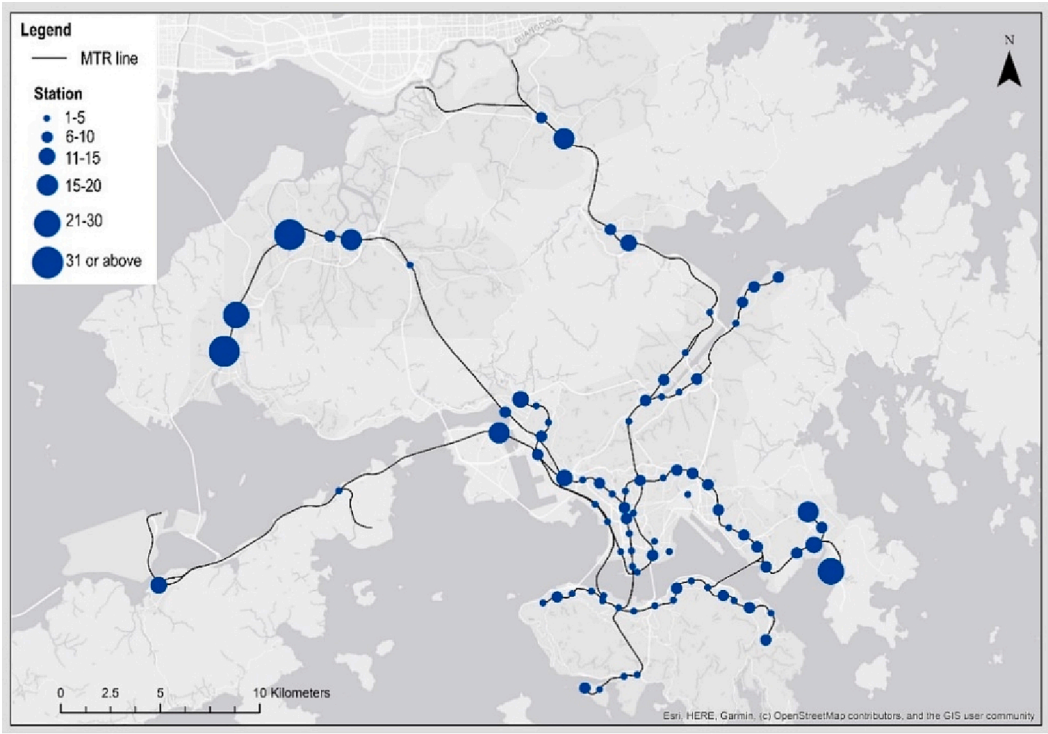


Fig. 1. A people-environment framework of transport stress.



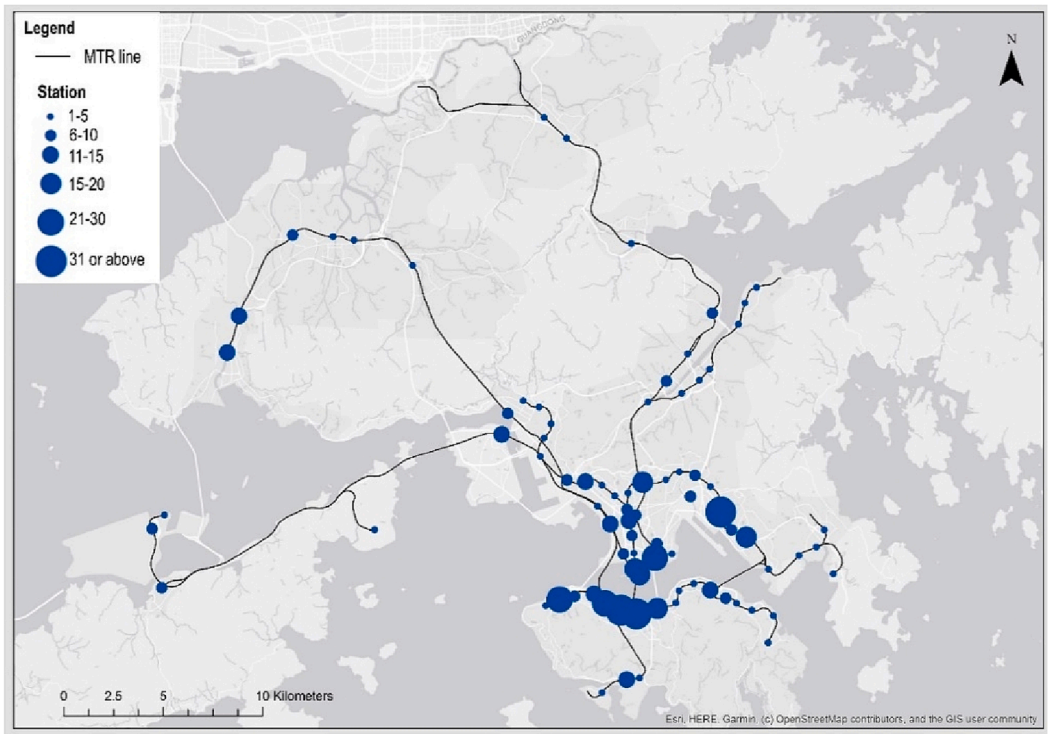


Fig. 2. A (up). Boarding stations of the respondents in the morning commute Fig. 2**b (bottom).** Alighting stations of the respondents in the morning commute.

stress and stressors in the people-environment framework. Finally, policy implications of alleviating transport stress are discussed.

3.2.1. Factor analysis of rail-specific environmental stressors

To scrutinize the possible environmental stressors of rail commutes, respondents were asked to indicate how often they encounter certain environmental stressors during their commuting journeys on the MTR. A total of 35 statements were developed based on the local context of rail-transit environment in Hong Kong. They statements refer to the passengers' encounters of environmental stressors regarding the (i) MTR stations, (ii) interchanges, (iii) compartments, and (iv) time-related factors. Following a similar study on transport stress asking respondents to evaluate how frequently they encountered certain obstacles on their actual commuting journeys (Novaco et al., 1990), respondents were asked to indicate how often they encountered those stressors/items during their commutes (a scale of 0–5, indicating never, seldom, sometimes, often, frequently and always, respectively). Details of the statements are shown in the results (Fig. 5).

Based on the 35 Likert-scale items of rail-specific stressors (including stations, interchanges, compartments, and time-related factors), a factor analysis was conducted to identify the latent environmental factors specific to rail commutes. Two tests of Cronbach's Alpha and Kaiser-Meyer-Olkin (KMO) were conducted before the factor analysis to ensure internal consistency and sampling adequacy. The factor analysis and statistical tests were executed on SPSS27. Factors with an Eigen value of > 1 are retained for further analysis. Then, for each identified factor, we follow the major protocols of other stress-related studies (Hämmig, 2018; Liu et al., 2019) by applying a sum score method to average the item scores for each factor. Only highly loaded variables for each factor (i.e. factor loadings of > 0.5) are included in the calculation of means. Using the average scores (instead of the individual item scores) can maintain the original scale and allow easier interpretation of results. These mean scores are then considered as potential explanatory variables in the multiple linear regression model that explains transport stress (Section 3.2.2).

3.2.2. A multiple linear regression model for transport stress

One research question is to examine the relationship of transport stress and other stressors. Hence, following the people-environment conceptual framework (Fig. 1), a multiple linear regression is developed to model the associations between transport stress and the three major types of stressors (environmental stressors, personal stressors and travel impedance). The dependent variable is the level of perceived transport stress for morning and evening commutes on the MTR. Following other common studies of

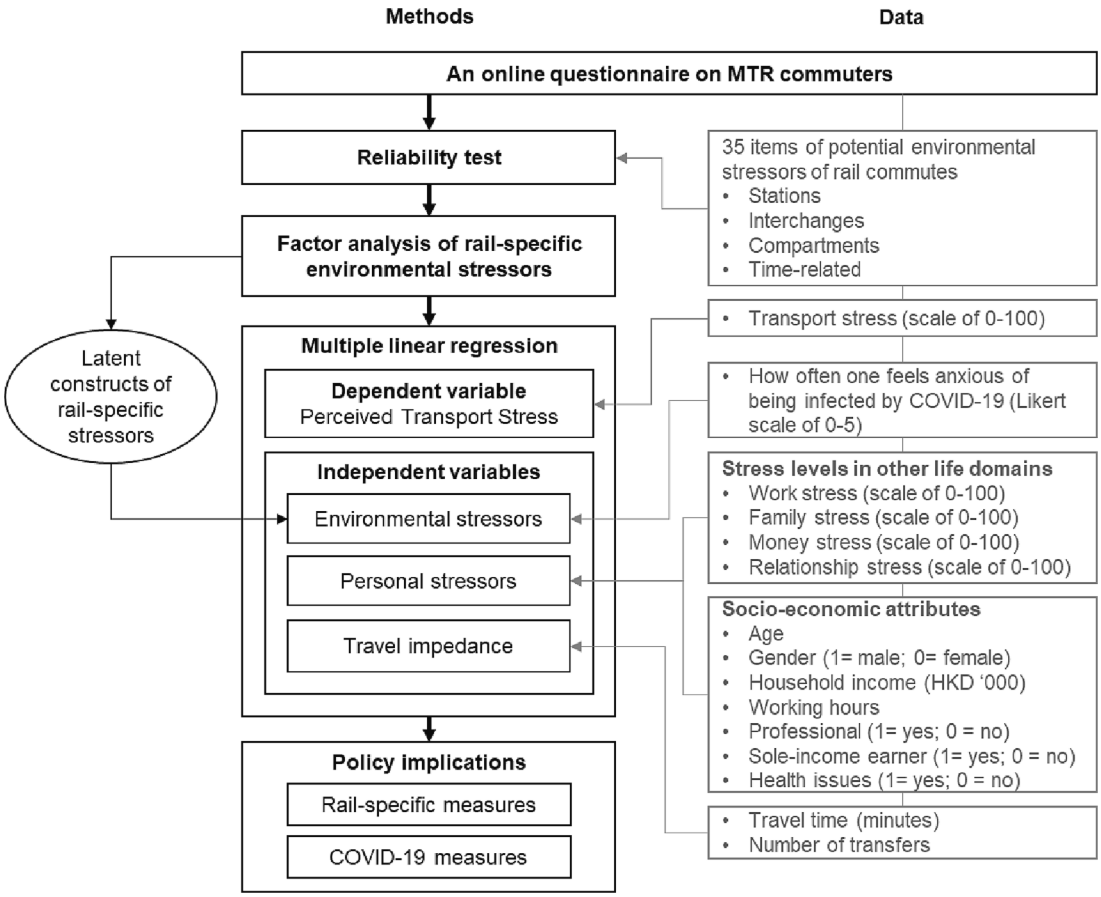


Fig. 3. Methodological framework.

perceived stress (Afshar et al., 2022; Fisch et al., 2020; García Pagès et al., 2023), the perceived transport stress is measured on a scale of 0–100 (from no stress at all to extremely stressful). The main hypothesis is that the more frequent they have encountered the environmental stressors, the higher the perceived stress of the rail commutes. A baseline model (i.e. only with travel impedance and socio-economic attributes) and a full people-environment model will be developed to compare the explanatory power of both models. The independent variables are listed below:

(a) Environmental stressors

Firstly, the rail-specific environmental stressors derived from the mean factor loading scores in Section 3.2.1 are incorporated as the independent variables. Secondly, since the survey was conducted towards the end of the 4th wave of COVID-19 outbreak (Dec 2020 – Feb 2021), anxiety of being infected by COVID-19 is integrated as a possible environmental stressor. Respondents were asked to indicate how often they feel anxious about being infected by COVID-19 or an infectious disease during commute (0–5; from "Never" to "Always").

(b) Personal stressors

Stressful experiences in other life domains, including (i) family, (ii) money, (iii) relationship (other than family) and (iv) work are integrated as the explanatory variables of personal stressors. Similar to transport stress, respondents were asked to report their levels of stress in these four life aspects based on a scale from 0 (no stress) to 100 (very stressed). Moreover, seven socio-demographic variables were collected for each individual. They are age, gender, household income, whether the respondent is a sole-income earner of the

Table 1
Socioeconomic variables of respondents.

	Survey		**TCS2011**	
	n	(%)	*n*	(%)
Gender				
Male	307	48.8	589,083	53.7
Female	281	44.7	508,614	46.3
Prefer not to answer	41	6.5	–	–
Age				
0–19	8	1.3	10,578	1.0
20–29	174	27.7	248,664	22.7
30–39	222	35.3	287,636	26.2
40–49	108	17.2	292,696	26.7
50–59	56	8.9	209,659	19.1
≥60	19	3.0	48,465	4.4
Prefer not to answer	42	6.7	–	–
Occupation				
Manufacturing and Construction	31	4.9	155,113	14.1
Trade and Logistics	42	6.7	130,462	11.9
Education and Health	80	12.7	84,018	7.7
Retails and Services	63	10.0	248,090	22.6
Professional and Finance	104	16.5	262,405	23.9
Administrative and Clerical	167	26.6	127,469	11.6
Others	26	4.1	90,142	8.2
Prefer not to answer	116	18.4	–	–
Income				
≤9,999	14	2.2	57,020	5.2
10,000 – ≤ 19,999	72	11.4	248,816	22.7
20,000 – ≤ 29,999	84	13.4	281,387	25.6
30,000 – ≤ 39,999	99	15.7	198,001	18.0
40,000 – ≤ 59,999	92	14.6	184,952	16.8
60,000 – ≤ 79,999	60	9.5	68,540	6.2
80,000 – ≤ 99,999	38	6.0	29,860	2.7
≥ 100,000	40	6.4	29,121	2.7
Prefer not to answer	130	20.7	–	–
Household member(s)				
1	0	0.0	63,771	5.8
2	47	7.5	222,656	20.3
3–4	222	35.3	610,468	55.6
5–6	131	20.8	186,732	17.0
7 or above	83	13.2	14,071	1.3
Prefer not to answer	21	3.3	–	–
Sole income earner				
Yes	123	19.6	–	–
No	393	62.5	–	–
Prefer not to answer	113	18.0	–	–

household, whether the respondent is a professional (i.e. education and health, professional and finance), the number of working hours a day, and the health status.

(c) Travel impedance

Travel time and the number of transfers are the impedance-related stressors. Based on the reported boarding and alighting stations of the respondents' commuting journeys, the travel time of each respondent is estimated according to the travel time provided by MTRC. Moreover, the number of transfers is also incorporated since interchanging can lengthen travel time and create extra stress (Wener et al., 2005). We capture this information by asking the respondents to name their transfer station(s) directly.

4. Results

4.1. Descriptive statistics

Table 1 summarises the socioeconomic attributes of the respondents. To reflect a more representative sample of working population in Hong Kong, the survey data were weighted based on the Travel Characteristics Survey 2011 (TCS2011) that records the socio-demographic characteristics (i.e. gender and age groups) of the working population travelling on MTR in Hong Kong. TCS2011 is the latest territory-wide survey that records the travel diaries of individual samples (Transport Department, 2011). The weighted total samples of MTR commuters are 1.1 million (Table 1). Overall, the study's samples are comparable in terms of gender and age composition, where slightly more samples were male and belonged to the 20–39 age cohorts. In both surveys, a household structure of 3–4 members was the most common. One significant difference is the occupation composition, where administrative and clerical respondents took up over a quarter of the samples in our survey, followed by professional and finance (16.5%), and education and health (12.7%). On the contrary, the highest share in TCS2011 was professional and finance (23.9%), followed by retails and services (22.6%) and manufacturing and construction (14.1%). Moreover, our survey tends to be inclined towards the higher income groups (HKD 30,000–49,999). These sampling biases are corrected with the data weighting procedures before further data analysis (Fowler, 1993; Hautzinger, 1997; Richardson et al., 1995).

For travel characteristics, respondents on average travelled for 27.66 min ($SD = 14.39$) and had 1.2 transfers ($SD = 1.03$), with a reported transport stress score of 47.49 out of 100 ($SD = 27.70$) (Fig. 4). When compared to other personal stressors, work stress was the highest ($M = 61.18$, $SD = 26.86$), followed by money stress ($M = 57.32$, $SD = 28.84$), family stress ($M = 46.77$, $SD = 26.36$) and relationship stress ($M = 45.69$, $SD = 26.53$). Although transport stress ($M = 47.49$, $SD = 27.70$) was not the most significant stressor among those from other life aspects, it should still be carefully examined given that its average score has a ratio between 0.96 and 1.29 to that of other personal stressors.

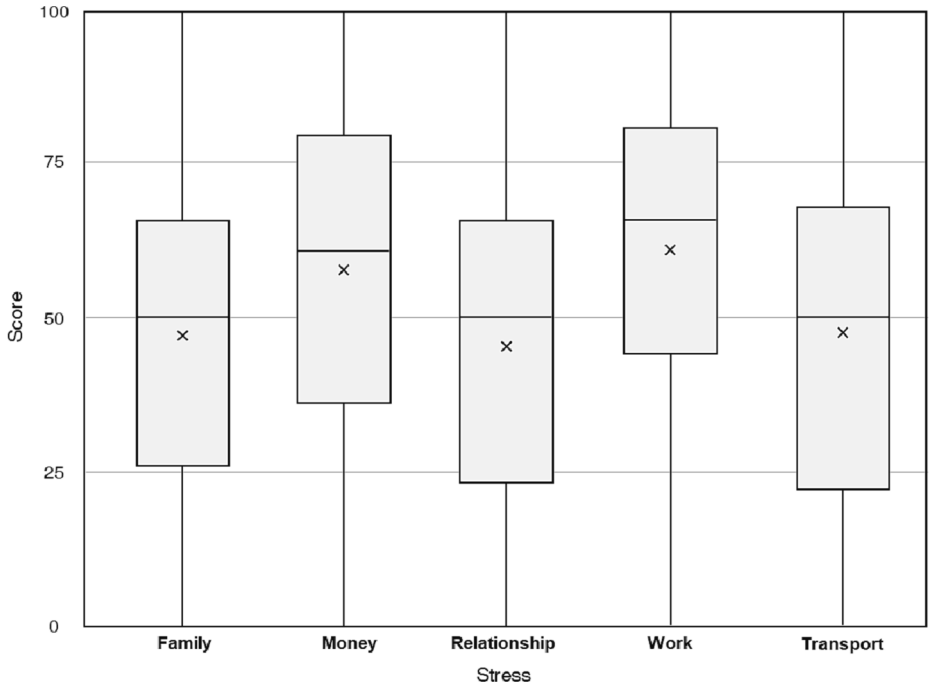


Fig. 4. Boxplots of personal and transport stress Note: The bottom, middle and upper lines of each grey bar represent the lower quartile (25th percentile), median, and the upper quartile (75th percentile) of the stress level respectively. The cross marks indicate the mean values.

Fig. 5. Encounters of potential environmental stressors during rail commutes.

Fig. 5 illustrates the distribution of encounters with the 35 potential environmental stressors during rail commutes. When examining stressor items with a score of 3 or above (i.e. often, frequently or always), over 70% of the respondents indicated that they encountered compartment-level crowding without available seats (C1 and C2), followed by crowding and a lack of seats at both stations (A8 and A9) and interchanges (B1 and B4) (47.8–60.1%), suggesting that crowding is pervasive not only in the train compartment but also throughout the entire MTR journey. Notably, commuters also reported frequent encounters of a lack of Wi-Fi at the train compartment (C5) (59.7%), uncomfortable temperature (C6) (59.2%), noisy environment (C7) (43.6%), and a lack of toilets and charging facilities at major interchange (B5 and B6) (36.8–40.0%). Furthermore, 25.6% of respondents reported a score of 3 or above in feeling nervous of being infected by COVID-19 or an infectious disease during the commute journeys.

4.2. Rail-specific environmental stressors

The response items of 35 MTR environmental stressors have a Cronbach's Alpha of 0.9 and a Kaiser-Meyer Olkin (KMO) value of 0.95, which indicates that the samples are internally consistent and sufficiently factorable. The Principal Axis Factor (PAF) with a Varimax orthogonal rotation of environmental stressors generates seven components of Eigen value>1. Table 2 summarizes the results of the factor analysis (loadings<0.3 are excluded of better presentation). Overall, the factor analysis explains 66.1% of variances. Component 1 captures crowding-related stressors, which are concerned with over-crowding situations (and without seats) at MTR stations, interchanges, and train compartments. Component 2 is largely a station-based factor composed of poor hygiene, hostile staff attitudes, as well as poor ticketing and navigation. Component 3 consists of time-related stressors especially unreliable MTR services, excessive waiting, and the lack of responsive actions upon disruptions. Component 4 is specifically related to the lack of ancillary facilities in stations, such as toilets, charging points and Wi-Fi. Component 5 illustrates discomfort in train compartments including

Table 2
Rotated factor loadings of 35 environmental stressors during rail commutes.

Stressors*	Components/Factors						
	1	2	3	4	5	6	7
A1						0.83	
A2						0.74	
A3	0.49	0.32				0.35	
A4							0.79
A5		0.67					0.33
A6	0.41	0.51					
A7	0.60	0.45					
A8	0.74	0.35					
A9	0.71						
A10		0.65					
A11		0.66	0.34				
A12		0.69					
A13		0.34		0.71			
A14				0.64			0.37
B1	0.75						
B2		0.38		0.31		0.54	
B3			0.33	0.36		0.45	
B4	0.66			0.40			
B5				0.71			
B6				0.77			
C1	0.70				0.40		
C2	0.77				0.41		
C3		0.53	0.32		0.48		
C4	0.32	0.38			0.55		
C5				0.40	0.58		0.36
C6	0.48				0.56		
C7	0.44		0.31		0.51		
C8			0.41		0.42		
C9		0.41	0.49		0.32		
C10		0.37			0.46		
D1			0.76				
D2	0.47		0.56				
D3			0.75				
D4			0.74				
D5		0.30	0.67				

* For details about the stressors, refer to Fig. 5. Note: Varimax with Kaiser Normalization is used for rotation. Shaded cells indicate that the item obtains a factor loading>0.5 in the respective component. They are used in the calculation of the average factor scores.

noisy environment, uncomfortable temperature, and the lack of complimentary Wi-Fi. Component 6 is about the lack of clear signage and information boards. Component 7 is primarily about the lack of platform screen door, reflecting on the safety dimension. Table 3 indicates the basic descriptive statistics, reliability, and validity of each component. Overall, all factors achieve good levels of internal consistency (i.e. Cronbach's Alpha > 0.7) and validity (i.e. KMO > 0.7).

4.3. Relationship between perceived transport stress and transport stressors

Table 4 illustrates the results of the multiple linear regression model of transport stress of rail commutes. Overall, the people-environment model achieves an R^2 of 0.50 without any multi-collinearity issues. When compared with the baseline model that only considers travel parameters and socio-economic attributes, the explanatory power of the people-environment model has significantly improved in terms of the R^2, indicating that personal and environmental stressors are highly relevant in explaining

Table 3
Descriptive statistics, reliability and validity of each component.

	Descriptive statistics					Reliability	Validity
CT	Items	Mean	Sd.	Sk.	Kur.	Cronbach's Alpha	KMO
1	7	3.07	1.16	−0.20	−0.74	0.90	0.85
2	6	1.26	0.89	0.97	0.63	0.86	0.88
3	5	1.83	1.06	0.71	0.24	0.88	0.88
4	4	2.07	1.22	0.32	−0.49	0.81	0.69
5	4	2.62	1.14	−0.03	−0.59	0.75	0.76
6	3	1.32	0.88	0.76	1.01	0.80	0.70

CT = component; Sk. = skewness; Kur. = Kurtosis.

transport stress. In the subsequent analysis, we focus on the results of the people-environment model. For travel impedance, as expected, rail commuters tend to experience a higher level of transport stress when travel time is longer ($\beta = 0.27$, $p < 0.00$) and more transfers are required ($\beta = 1.33$, $p < 0.00$). Travel time plays an important role in explaining transport stress (Evans and Wener, 2006; Wener et al., 2003).

For the socio-economic attributes, age ($\beta = 0.12$, $p < 0.00$) and male ($\beta = 4.98$, $p < 0.00$) are positively associated with transport stress. In addition, commuters of higher household income ($\beta = -0.03$, $p < 0.00$) and being a professional ($\beta = -2.04$, $p < 0.00$) generally have a lower level of transport stress. More importantly, sole-income earners ($\beta = 6.84$, $p < 0.00$) and those with reported health issues ($\beta = 0.78$, $p < 0.00$) generally feel more stressed in rail commutes. For stress levels in other life domains, work stress is positively related to transport stress and exhibits the highest association ($\beta = 0.25$, $p < 0.00$), followed by family stress ($\beta = 0.17$, $p < 0.00$) and relationship stress ($\beta = 0.11$, $p < 0.00$). Aligning with Novaco et al. (1990), transport stress is not solely attributable to the travel experience but also related to the stressors in other life domains.

Six out of seven environmental stressors/factors of rail commutes are positively associated with transport stress. Among all, inaccurate time information, excessive waiting and delays (CT3) displays the strongest relationship with transport stress ($\beta = 3.05$, $p < 0.00$). Crowding at MTR stations, interchanges, and compartments (CT1) is the second most significant contributor of transport stress ($\beta = 2.55$, $p < 0.00$). In addition, poor station environment, including poor hygiene, hostile staff attitudes and poor navigation (CT2) ($\beta = 2.33$, $p < 0.00$), and uncomfortable environment in train compartments (i.e. temperature and noise) (CT5) ($\beta = 2.30$, $p < 0.00$) are notably the significant environmental stressors. Moreover, a lack of protection facilities (i.e. platform screen doors) (CT7) ($\beta = 0.17$, $p < 0.00$), as well as ancillary facilities such as toilets and Wi-Fi (CT4) ($\beta = 0.12$, $p < 0.00$), are positively associated with transport stress. Yet, there is a negative relationship of unclear signage (CT6) and transport stress ($\beta = -2.65$, $p < 0.00$). Perhaps the stations of unclear signage with multiple exits and navigation routes are usually more convenient and accessible (i.e. locating in urban cores and CBD), and commuters are usually familiar with their routes for their daily commutes. Finally, rail commuters who felt anxious of being infected by COVID-19 during rail commutes tend to feel more stressed ($\beta = 3.76$, $p < 0.00$). Notably, its impact on transport stress can be comparable to that of travel time and some major rail-specific environmental stressors.

Table 4
A multiple linear regression model of transport stress of MTR commutes.

	Baseline model			People-environment model		
	Coef.	**Sd.**	**VIF**	**Coef.**	**Sd.**	**VIF**
Intercept	18.88** [0.30]			−21.02** [0.25]		
Travel parameters						
Travel time (min)	0.31** [0.00]	0.17	1.26	0.27** [0.00]	0.15	1.30
Number of transfers	2.07** [0.04]	0.08	1.25	1.33** [0.03]	0.05	1.37
Socio-economic characteristics						
Gender (1 = Male)	3.16** [0.07]	0.06	1.04	4.98** [0.05]	0.09	1.08
Age	0.06** [0.00]	0.03	1.07	0.12** [0.00]	0.05	1.17
Household income ('000 HKD)	0.00** [0.00]	0.00	1.05	−0.03** [0.00]	−0.03	1.11
Working hours	1.35** [0.03]	0.06	1.05	0.03 [0.02]	0.00	1.09
Professional [1] (1 = Yes)	−3.31** [0.07]	−0.06	1.02	−2.04** [0.05]	−0.04	1.12
Sole income earner (1 = Yes)	8.71** [0.08]	0.14	1.04	6.84** [0.06]	0.11	1.10
Reported health issues (1 = Yes)	9.26** [0.13]	0.09	1.02	0.78** [0.10]	0.01	1.12
Personal stressors in other life domains						
Family stress				0.17** [0.00]	0.16	2.25
Money stress				−0.04** [0.00]	−0.04	2.56
Relationship stress				0.11** [0.00]	0.11	2.11
Work stress				0.25** [0.00]	0.25	1.97
Environmental stressors of rail commutes						
Crowding (CT1)				2.55** [0.04]	0.11	2.59
Poor station environment (CT2)				2.33** [0.05]	0.08	3.38
Service delays and lack of responsive plans (CT3)				3.05** [0.04]	0.12	2.79
A lack of ancillary facilities (CT4)				0.12** [0.03]	0.01	1.82
Uncomfortable compartments (CT5)				2.18** [0.03]	0.09	2.52
Unclear signage (CT6)				−2.65** [0.04]	−0.09	2.30
A lack of platform screen doors (CT7)				0.17** [0.02]	0.01	1.32
Feeling anxious of being infected by COVID-19				3.76** [0.02]	0.20	1.54
R-squared	0.09			0.50		
Std. error	25.64			19.03		

[1] Professional includes Professional and Finance, and Education and Health. ** $p < 0.00$; values in the bracket denote the standard error.

5. Discussion

The above results highlight that personal, environmental and travel-related stressors can contribute to perceived transport stress. Based on the findings, if a commuter (with a median level of travel parameters, socio-economic characteristics and personal stressors among the samples) reduces the intensity of encountering all rail-specific environmental stressors from "always" (i.e. score 5) to "sometimes" (i.e. score 2), the transport stress can be reduced by 28.2%. A further reduction of the frequency of being anxious of being infected by COVID-19 during MTR commutes from "always" to "sometimes" can also reduce transport stress by 13.7%. The findings highlight that some mode-specific interventions on transit environment, as well as non-pharmaceutical interventions on controlling the spread of pandemic on public transport, might reduce transport stress and promote sustainable public transport.

Among the seven rail-specific environmental stressors, inaccurate time information and service delays (CT3) are the most significant stressor in rail commutes. Similar to other studies (Mann and Abraham, 2006; Rezapour and Ferraro, 2021), the control of getting to work on time and fulfilling obligations without delay is a critical dimension of rail transport. In Hong Kong, despite an over 99.9% of the punctuality performance by MTRC (MTRC, 2022), some severe disruptions caused by weather events, signal failures and social movements (Loo and Leung, 2017; Chan et al., 2022) over the past few years without prompt announcements might make passengers stressed as they got stuck in traffic. Our study suggests that rail commuters strongly prefer timely and proactive actions upon disruptions of MTR services, where around 45% and 39% of respondents indicated that responsive plans and prompt public announcement upon significant delays were the top two prioritized measures that could improve their transit experience. This aligns with Grisé and El-Geneidy (2018) that effective communication with customers regarding service disruptions is as essential as service reliability. An accurate passengers' information system is essential to reduce the negative feelings upon disruptions (Rezapour and Ferraro, 2021).

Consistent with other studies across various large cities, crowding is also a dominant factor of transport stress and it lowers subjective well-being (Cox et al., 2006; Evans and Wener, 2006; Kumagai et al., 2021; Mohan and Kulkarni, 2022). Our study further supplements that stressful transit experience can arise from crowding in different parts of the commuting journey, including train compartments, station areas (concourses and platforms), and major interchanges. Furthermore, undesirable station environment, including poor hygiene conditions and navigation design, can increase transport stress. This requires further investigation as only a few studies have looked into the impacts of microscopic environment (including in-vehicle and station design) on people's affective experience and stress levels. Cox et al. (2006), for instance, suggest that coach design such as appropriate spacing, choice of seat and point of entry and exit can reduce discomfort. While the reduction of commuting time and crowding might not be easily achieved, some improvement measures of enhancing station and compartment environment, offering more ancillary facilities, and having better responsive plans upon disruptions are some feasible strategies to alleviate transport stress in the near future.

Our study also reveals that apart from time-related measures, enhancing the comfort on train compartments (i.e. the provision of Wi-Fi, suitable thermal comfort, more hygiene environment, and reduced noise level) and station-based measures (i.e. better ventilation, more escalators and installation of toilets) are top strategies (with 20.5% – 36.6% indicating those as highest priorities). Providing ancillary facilities such as complimentary Wi-Fi on train compartments is also advisable. This allows passengers to "multitask" that might reduce boredom and other negative feelings (Choi et al., 2021; Gatersleben and Uzzell, 2007). Essentially, thermal comfort in public transport, as well as acceptable noise level, can improve transit experiences (Cox et al., 2006, Liu et al., 2016). Overall, a better design of service environment including seat availability, spaciousness, ventilation, lighting, cleanliness, spatial layout, can largely enhance travel comfort (Li, 2003), but further studies need to examine to what extent various improvement strategies can reduce the stressful experience of commuters.

Finally, our findings indicate that commuters who feel anxious of being infected by the COVID-19 more often have a higher transport stress level. Recent empirical evidence suggests that public transport has suffered from a rapid drop in patronage since the pandemic (Jenelius and Cebecauer, 2020; Molloy et al., 2021; Tirachini and Cats, 2020); and people's perceptions towards public transport has become more negative (i.e. anxious and fear) because the risk of being infected by a highly contagious disease in the public transport system is perceived to be much higher than that on private modes (Gutiérrez et al., 2021; Zafri et al., 2022). In compact cities, fear and anxiety of exposed risks in public transport as a media for disease spread (Dong et al., 2021; Loo et al., 2021; May et al., 2021) can escalate the level of perceived transport stress. To relieve the transport stress under COVID-19, our survey asked respondents to rank the top five desirable measures that improve their transit experience under COVID-19. The findings suggest that respondents strongly preferred measures that enhanced the hygienic standards both in train compartments and at metro stations (78% indicating it in the top five ranks), followed by better ventilation (59.6%) and a compulsory requirement on mask-wearing during travel (53.2%), instead of social distancing measures or temperature inspection by staff (15%) that might lengthen travel time and reduce travel efficiency. This conflict has been discussed in Tirachini and Cats (2020). Moreover, with these measures implemented, the confidence of respondents in using public transport increased significantly from 29.5% (before the improvement) to 75.9% (after the improvement), suggesting that the anxiety can be ameliorated with corresponding measures.

6. Conclusion

This study investigates the perceived transport stress of rail commuters in Hong Kong and identifies the significant personal and environmental stressors. Overall, our findings highlight the importance of examining transport stress from a people-centric approach. It also pinpoints that commuters' daily encounters of the stressors in the transit environment need to be examined along their entire commute journeys (versus within the train compartments or on platforms only). There are three major contributions. Firstly, this study develops a people-environment framework to evaluate the association of a comprehensive set of factors and transport stress. Our

findings highlight that transport stress is a multifaceted concept that the affective experiences in both transport and non-transport domains can interact with transport stress. Secondly, this study unveils various important rail-specific environmental stressors and personal stressors that have seldom been examined in previous studies. Apart from the common attributes of in-vehicle crowding and service unpredictability, other environmental stressors include poor station environment, the lack of responsive plans upon disruptions, uncomfortable compartment environment and insufficient platform screen doors. Though work stress and money stress are the highest among the survey respondents, transport stress is also notable and comparable to the levels of family stress and relationship stress. Also, poor health status and being a sole-income earner are positively associated with transport stress. These findings suggest that the relationship between transport stress and personal characteristics in other life domains can be interwoven. Thirdly, our study also examines the impacts of COVID-19 pandemic on perceived transport stress. The findings support that the anxiety of disease spread at a highly contagious public space of public transit environment can transform to a higher level of stress. Nonetheless, specific strategies of improving the rail transit environment (e.g. station-based or other micromanagement measures) and addressing the public health concerns during the pandemic (e.g. frequent sanitization) can be conducive to a less stressful travel experience.

There are several limitations. Firstly, the online surveys may not capture the older and underprivileged population segments. Also, the survey was conducted during the end of the 4th wave of COVID-19 in Hong Kong (and under work-from-home arrangement) which might not capture some population segments. Secondly, since the patronage of the MTR has dropped during the pandemic, the findings in this study may overestimate the importance of some COVID-19 related stressors (including hygiene and fear of infection) in transport stress and underestimate the magnitude of crowding in transport stress due to lower patronage. Nonetheless, this study sheds important insights on transit planning and management. Further studies can examine and identify the environmental stressors of different modes and multimodal journeys. The relationship among stressors and stress responses can also be further scrutinised. Finally, the effectiveness of specific improvement measures or policy interventions on transport stress can be further investigated. Identifying the potential environmental stressors for improvement requires a thorough understanding of how one perceives the environment along the entire travel journeys and its relationship with actual stress levels.

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Lombardi and Ciceri, 2021; Wener et al., 2005.

CRediT authorship contribution statement

Ka Ho Tsoi: Data curation, Formal analysis, Methodology, Validation, Visualization, Writing – original draft. **Becky P.Y. Loo:** Conceptualization, Funding acquisition, Investigation, Methodology, Supervision, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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