



Pandemic impacts on public transport safety and stress perceptions in Nordic cities

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Abstract

COVID-19 has brought severe disruption and demand suppression to mobility, especially to public transport (PT). A key challenge now is to restore trust that PT is safe again. This paper investigates pandemic impacts on PT safety and stress perceptions in three Nordic cities, drawing on 2018 and 2020 survey data analysed in structural equation models. While finding modest pandemic effects on safety and stress perceptions overall, strong heterogeneities exist across gender, age and geographic categories. Women perceive less PT safety and more stress, especially during the pandemic. Older adults reduced PT more during the pandemic and perceived no stress reduction like younger adults. Stockholm travellers feel less safe and more stressed than in Oslo and Bergen, whilst pandemic PT use and perceived safety reductions are least in Bergen. The paper discusses the long-term implications for theory and policy across multiple mobility scenarios accounting for modal change and travel demand uncertainties.



Keywords

Perceived safety; Stress; Public Transport; COVID-19; Pandemic; Mobility Scenarios

1. Introduction

The COVID-19 pandemic has had a major effect on travel in general and on public transport (PT) in particular. In general, travellers have been recommended to cancel or avoid unnecessary travel, work from home, do online shopping and, for school children and students, do distance learning. A recent study (Jenelius & Cebecauer, 2020) showed that the decrease in PT ridership was as much as 40%–60% across regions in Sweden. The observed decrease could not be explained by lower service levels since it was unchanged in most cases, but by a lower number of active PT users. This is also in line with Dingil and Esztergár-Kiss (2021) who showed that PT users have a much higher propensity to change their commute behaviour than car users, motorcycle users, and walkers, respectively. Socioeconomic status did play a role in behavioural change in Stockholm, in that those with the least resources continued travelling with PT to the greatest extent (Almlöf et al., 2021). The negative decrease in PT use observed in Sweden during COVID-19 are in parity with the development in many other countries (Tirachini & Cats, 2020).

To feel safe is a human right and part of the UN Agenda 30 plan for sustainable development. A sustainable transportation system is one that allows the basic access needs of individuals and societies to be met safely (Litman, 2007). Factors related to travel safety perceptions should therefore be carefully considered in planning (Friman et al., 2020). This study aims at providing an increased knowledge about safety perceptions in PT and providing recommendations for re-building PT after COVID-19.

During the COVID-19 pandemic, PT authorities and providers implemented several measures to ensure safe and secure travel for all. Type and number of measures have varied in when, where and how. A general recommendation implemented on and off during multiple waves in many countries, has been to avoid travel by PT whenever possible, in particular during rush hours. Also, a mandatory use of face masks and restrictions in the number of passengers allowed on board vehicles have been in place during various periods of time. Innovative information techniques have been applied to remind travellers to keep physical distance and proper hand hygiene, also the cleaning routines on board the vehicles and in waiting halls have increased. In some regions, there have been an increase in number of departures during rush hours in order to reduce on-board congestion. More informants have been recruited to help travellers to find suitable and less crowded departures.

Despite all measures taken, we have witnessed a huge decrease in travel by PT, which above all, is explained by the general call for restricted travel. However, existing studies also points to other factors that have influenced people's willingness to travel by PT during the pandemic. Socio-demographic, pre-COVID-19 commuting mode choice, walking time from home to the nearest metro station, and indicators of infection risk in private car and PT are some important factors (Kopsidas et al., 2021, Tan and Ma, 2020). While existing work has highlighted some aspects of the pandemic's effects on PT, many aspects are still largely unknown, including the role of perceived safety. Insight into the latter is of critical importance, as the regain of trust and perceived safety has become a, if not the, key issue in making PT attractive again in a post-pandemic society. This is for example illustrated by a study from Gdansk, Poland, which reveals that as many as 25% of PT users have no intention to return to PT unless an appropriate level of safety is guaranteed (Przybylowski et al., 2021).

An analysis and increased understanding of such relationships requires detailed information on PT users' actual travel perceptions during the pandemic. The aim of this paper is to analyse the impacts of COVID-19 on PT use and perceived stress safety in three cities (Stockholm, Oslo and Bergen) before (in 2018) and during the pandemic (in 2020). Based on a unique longitudinal dataset, this paper examines the simultaneous effects of sociodemographic, geographic and temporal (pandemic) predictors and their interactions on, and relationships between: 1) normal frequency of PT use, 2) stress perceived in travel generally, and 3) safety perceived in PT. The paper presents its results in relation to existing literature on these issues, in particular with regard to underlying gender and age inequalities and the relationships between attitudes and travel behaviour. It also discusses PT policy and planning implications to restore the attractiveness, safety and use of PT, while accounting for long-term mobility uncertainties across multiple travel demand and modal change scenarios.

2. Literature review

Safety is defined as the condition of being safe from undergoing or causing hurt, injury or loss. In line with the availability bias (Tversky and Kahneman, 1973), *safety perceptions* are often influenced by what comes to mind when recalling a specific (travel) situation. This was recently confirmed in a European study among PT users (Friman et al., 2020), showing that

recalled satisfaction with the service was associated with perceived safety. Thus, the more satisfied the travellers were with the service (e.g., functionality and comfort) the higher they scored on perceived safety and vice versa. A condition perceived as unsafe is often accompanied by unpleasant emotions, such as fear, anxiety or stress caused by the anticipation or awareness of danger ([Merriam-Webster, n.d.](#)). In this study we investigate both safety and stress perceptions during travel by PT travellers. Even though perceptions of safety and stress may thus be related and found to be correlated, it is important to note that stress may also originate from sources external to safety perception, such as domestic or work-related responsibilities or time pressures.

Earlier research, predating the pandemic, has described where and how people do not feel safe in PT. Common situations in travel, from a user point of view, are related to the individuals perceived risk of being exposed to crashes and injuries, crimes or insults and/or transmissions of infection and diseases. [Currie and others \(2013\)](#) demonstrated that psychological influences, that is “feeling comfortable with people you don’t know on PT,” had the largest individual influence on perceptions of safety. A qualitative study from Edinburgh ([Stradling et al., 2007](#)) highlights the unwanted stress and anxiety observed in less safe situations. Examples are anxiety when travelling at night or while waiting at the bus stop, or when other passengers seem threatening during travel. Some people, even though this study far predates the current COVID-19 pandemic, reported to perceive unwanted anxiety when people sneeze/cough without covering their nose/mouth.

To most people though perceptions of safety have probably gotten an extra dimension after COVID-19 was first introduced to our societies. A study from Brazil by [Lucchesi and others \(2022\)](#) showed that crowded vehicles and crowded stops/stations were considered the most detrimental factor in feeling safe while riding in the COVID-19 outbreak. The high number of users in the vehicles and the need to interact with many different people were users’ primary concerns. A survey-based study from greater Oslo, Norway, one of the case study areas in this study, revealed elevated levels of self-reported anxiousness during the pandemic in areas more reliant on PT as compared to areas less reliant on PT ([Mouratidis, 2022](#)). Reports from other parts of the world show more mixed or contradicting results. A study from Sicily, Italy ([Campisi et al., 2021](#)) detects for example negative associations between fear and commuting by bus locally/regionally and between stress and non-commuting by bus locally during wave two of the pandemic. However, the same study finds opposite associations between fear and non-commuting by bus regionally, and no significant associations between fear, stress and anxiety and other types of bus usages or at other time periods (before the pandemic, or at the first post lockdown phase). A study of Tehran’s bus system before and during COVID-19 showed that perceptions of service quality improved during the pandemic, particularly in relation to comfort (including crowding), safety, reliability, and information ([Esmailpour et al., 2022](#)). A study on the perceived safety of PT in eight cities in China ([Dong et al., 2021](#)) also found that overall satisfaction with PT increased with the reopening of PT systems after a first pandemic wave, but in this study it was specifically related to safety improvements applied during the period that the system was temporally closed.

Understanding the perception of unsafety during pandemic PT travel is particularly important as it has been found to affect travel behaviour of different individuals in different ways, for example in relation to psychological factors such as anxiety levels or risk avoidance. The above reviewed Chinese study by [Dong and others \(2019\)](#) reveals that perceptions of safety are negatively affected by peoples’ levels of anxiety. A study of psychological factors forming COVID-19 safety-related perceptions in Athens, Greece ([Kopsidas et al., 2021](#)), showed that risk-averse travellers tend to avoid PT if they perceive the service as unsafe. The same study also showed that those willing to use face masks when traveling, are less likely to return to PT. Several other recent studies have also demonstrated how risk attitude and fear of infection is associated with changes in travel times, travel mode changes, and travel destinations ([Chan et al., 2020](#), [Borkowski et al., 2021](#)).

Perceptions of stress and safety during pandemic travel may also differ significantly between societal groups. Understanding such potential heterogeneities in pandemic travel outcomes, requires an awareness of underlying structural mobility and societal inequalities predating and enhanced by the pandemic. Socioeconomic variates like gender, age and income have been pivotal in ascertaining how pandemic confinement is experienced ([Caselli et al., 2021](#)). Highly pronounced are the pandemic impacts on the mobility (by PT) of women ([Gauvin et al., 2020](#), [Reisch et al., 2020](#); [Caselli et al., 2021](#)). Rather than a simple result of reduced PT frequencies, change in routes and reduced seating capacities, these have turned out to be tightly knit with societal norms and structural conditions. Because women are more frequently employed in sectors such as the hospitality sector that have fewer home-office opportunities and that have often ceased to operate under the stay-at-home-orders, women have faced greater reductions of working hours, more prevalent incidences of being laid off, and/or stronger

curtailments of their incomes (Alon et al., 2020). Due to women's persisting higher domestic and childcare responsibilities, women have also been hit harder by the closing down of day-care centres, schools and by restricted opportunities to seek help from family members or others. Interwoven with these employment and caregiving challenges, women face pre-existing gendered mobility inequalities, such as a lower access to both private (e.g. car) and smart (e.g. bike/car-sharing, e-scooters) mobility solutions (Gilbert, 2010; Priya Uteng et al., 2020; González-Sánchez et al., 2021); a subsequent higher reliance on the pandemically-restricted and discouraged PT; and gender-specific safety concerns in doing so (González-Sánchez et al., 2021, Alon et al., 2020). The resultant effect on women can be best described as a sumptuous layering of burdens where caregiving and household responsibilities had to be precariously balanced with reduced employment, income and mobility opportunities.

The onset of the pandemic was also accompanied by highly segregated narratives around the topic of ageing. Older adults were rendered more vulnerable due to their unmet basic needs, social isolation and the disruption of health services, increasing sociopsychological risks such as (perceived) loneliness and functional decline (Hall et al., 2021). Results from Seoul, Korea found that the decrease in subway use (as and when the pandemic unfolded) was the most prominent among people aged 65 years and over (Park & Cho, 2021). Vulnerability and risk-exposure vis-à-vis the ability to be mobile got also strongly interlinked with existing inequalities of gender, race/ethnicity, income, and residential segregation, thereby further exposing vulnerable groups of older people to negative consequences of COVID-19 (Monahan et al., 2020, Morley and Vellas, 2020). Studies highlight significant changes in life-space mobility for older adults, particularly outside of the home environment (in the neighbourhood, the town, and beyond), with strong intra-group effects. A study from Brazil finds that older men with higher education and income levels enjoyed more life-space mobility compared to women and those with a lower education and income (Perracini et al., 2021). These developments had strong correlations with the freedom (previously) afforded by use of PT. A study from Hamilton, Canada revealed that older adults who had mobility options to do so (e.g., access to a car) shifted away from PT as soon as after the pandemic was declared, whereas those who did not had to continue using PT despite being fearful, setting both safety and ageism narratives in motion (Ravensbergen & Newbold, 2020). Similar results were reported from Northern Ireland (The Consumer Council, 2021), Iran (Shaer & Haghshenas, 2021) and Germany (Eisenmann et al., 2021), which, irrespective of geo-location, echo that society's affluence or structural conditions supporting ageing and daily mobility of older adults was marred with connotations of ageism, anxiety of using PT, and their avoidance of PT affecting their daily lives, consumption, and production activities.

Our review shows the importance of perceived safety for the use and satisfaction of PT, both in general terms, and more specifically during the special circumstances of the COVID-19 pandemic. It also reveals that the pandemic impacts on everyday life, mobility and mobility experiences show large intersectionality with underlying pre-existing and pandemically reinforced socio-demographic, -cultural and -economic inequalities. Drawing on these existing findings, this study will investigate and compare how COVID-19 impacts perceptions of safety of PT and stress during travel across gender and age groups in three northern European cities. Even though the cities in this study benefit from more egalitarian social welfare systems than some of the existing studies reviewed, they too face structural gender and mobility inequalities that are expected to influence the investigated outcomes.

3. Materials and Methods

3.1. Study areas and COVID-19 impacts

This study is situated in three Nordic cities: Oslo, Bergen and Stockholm. Oslo (pop. 704,000) is the capital and most populous city of Norway, situated southeast in the country. Bergen is Norway's second most populous city (pop. 288,000), situated on the nation's west-coast. Oslo and Bergen are also the two cities in Norway with the highest share of trips by PT (30 and 18 percent respectively, according to 2018-2019 national travel survey data). Stockholm (pop. 980.000) is Sweden's capital situated east in the country. Stockholm (including neighbouring municipalities Solna and Sundbyberg) had a share of 35% of trips by PT in 2019 (Region Stockholm, 2020).

From March 12th, 2020, Oslo and Bergen were subjected to Norwegian national and additional regional lockdown measures imposed to suppress the first wave of COVID-19 cases and secure a functional health care system, including the temporary of closing of schools, colleges, universities, kindergartens, non-essential shops, offices, restaurants, fitness centers, and

cultural venues, and restrictions on cross-municipal and non-essential travel. Even though the PT system remained functional, its use was heavily discouraged to limit infections and preserve capacity for only most essential use like commuting by healthcare workers. As a result, ridership numbers in greater Oslo and greater Bergen were down respectively 40 per cent (Ruter, 2021) and 35 per cent (Skyss, 2021) for the year 2020 compared to 2019. While Norway gradually reopened later in spring and summer, many of the same restrictions, with a notable exception of closures of kindergartens and schools for young children, were re-introduced in autumn to limit the impact of a second wave. Whilst COVID-19 had impacted health and social life in Oslo and Bergen seriously, both cities had relatively low number of cases and death tolls when compared their peers in neighbouring countries, especially Sweden, and the rest of Europe, and were spared from curfews established in many other European cities.

Unlike Norway and most of the rest of Europe, Sweden, and with it, Stockholm, did not introduce a similar suppression strategy to the first pandemic wave. It relied more on a mitigative approach, urging people to practice hand hygiene, keep distance, work from home if possible and limit travel (including by PT) voluntarily, but keeping businesses, restaurants, bars, kindergartens, and schools for children under the age of 16 open. However, at the end of our study period, also Sweden closed down non-essential public workplaces such as gyms and libraries and recommended the use of face masks on PT. Ridership numbers in Stockholm dropped to minus 60 per cent in April and were down between 30 and 50 per cent most other months in 2020 compared to 2019 (Greater Stockholm Local Public Transport, 2021). For a more detailed comparison of pandemic restrictions, outcomes and the backgrounds, principles and functioning of health care systems in Norway and Sweden, see for example Laage-Thomsen and Frandsen (2022).

3.2. Data and sample composition

This study was based on data collected by BEST (Benchmarking European Service of Public Transport) in collaboration with Norstat, a market research company that complies with international quality standards (ISO 26362 and ISO 9001). The PT authorities included are part of the BEST network and participated in the study due to a special interest in benchmarking experiences and use of PT. The data collection consisted of monthly web surveys combined with structured telephone interviews. All procedures were performed in compliance with regulations and institutional guidelines, including appropriate institutional committee approval (C2017/938). The participants were informed about their anonymity, the right to drop out at any time, and gave their consent to participate. Upon completion of the questionnaire, they were offered a small reward (e.g. cinema ticket, lottery ticket, or a charity donation). Data collection in the three northern cities (Bergen, Oslo, and Stockholm) took place medio January to December 2018 (N=3,523) and early May to December 2020 (N=2,718). Collected from the second through the ninth month after the World Health Organisation declared COVID-19 a global pandemic in March 2020, this 2020 data sample will be used to investigate peri-pandemic outcomes against the pre-pandemic 2018 baseline. The spring and autumn/winter parts of this 2020 survey period coincided respectively with the first and second wave of the pandemic.

In the survey, data was collected on sociodemographic background (age and gender), and on the use and perceptions of PT. Unweighted sample statistics for the three cities can be seen in Table 1. As can be seen from the table, the sample composition in terms of age and gender is somewhat different in 2020 as compared to 2018. Notable differences for 2020 as compared to 2018 include less male-dominated samples in Oslo and Stockholm, and younger samples in Bergen and Stockholm. We calculated a weight matrix for all combinations of year, gender and age class (≤ 35 ; 35-64; ≥ 65 years of age). The analyses in the remainder of this paper weight observations according to this matrix. This is important to make sure that we correctly attribute possible outcome differences to the unique conditions of the pandemic (versus the pre-pandemic reference year), and not falsely to a different sample composition.

Table 1. Unweighted sample statistics for each of the three cities in 2018 and 2020

City (Inhabitants in millions)	Oslo (1.3)	Bergen (0.4)	Stockholm (2.3)	All
Descriptive statistics 2018				

City (Inhabitants in millions)	Oslo (1.3)	Bergen (0.4)	Stockholm (2.3)	All
N	566	1781	1176	3523
Women (%)	46.1	45.4	46.9	46.0
Mean age (S.d.)	49.9 (18.1)	55.1 (16.0)	53.5 (18.3)	53.7 (17.3)
≤ 35 years of age (%)	25.3	14.9	21.3	18.7
35-64 years of age (%)	53.0	51.8	48.4	50.9
≥ 65 years of age (%)	21.7	33.2	30.4	30.4
Self-reported normal frequency of PT use:				
daily (%)	31.8	10.5	29.2	20.2
some times a week (%)	27.6	18.1	25.3	22.1
some times a month (%)	26.5	29.5	26.6	28.1
less than once a month (%)	12.2	34.6	15.5	24.6
never (%)	1.9	7.2	3.4	5.1
I feel safe at stations and bus stops (1-5)	4.31	4.36	3.66	4.11
I feel safe onboard busses and trains (1-5)	4.37	4.37	3.88	4.21
I am not afraid of traffic accidents when using public transport (1-5)	4.27	4.22	4.09	4.18
I feel stressed (1) vs calm (7) during travel (1-7)	5.27	5.38	4.79	5.17
Descriptive statistics 2020				
N	425	1358	935	2718
Women (%)	51.5	46.5	51.7	49.1
Mean age (Std)	48.8 (17.9)	49.0 (18.0)	48.9 (19.2)	48.9 (18.4)
≤ 35 years of age (%)	29.2	28.3	31.0	29.4
35-64 years of age (%)	46.4	46.7	41.1	44.7
≥ 65 years of age (%)	24.5	25.0	27.9	25.9
Self-reported normal frequency of PT use:				
daily (%)	25.6	13.0	24.1	18.8
some times a week (%)	30.6	18.6	25.2	22.8
some times a month (%)	25.2	26.3	23.6	25.2
less than once a month (%)	16.0	34.6	23.1	27.7
never (%)	2.6	7.5	4.0	5.5
I feel safe at stations and bus stops (1-5)	4.37	4.38	3.47	4.07
I feel safe onboard busses and trains (1-5)	4.30	4.36	3.70	4.13
I am not afraid of traffic accidents when using public transport (1-5)	4.25	4.19	4.06	4.16
I feel stressed (1) vs calm (7) during travel (1-7)	5.30	5.30	4.81	5.13

3.3. Dependent variable outcomes

As the first of several travel outcomes, respondents were asked about how frequently they typically use PT, measured by five levels (daily, a few times per week, a few times per month, less than monthly, and never). What was a relatively straightforward question in 2018, has been repeated unaltered in the 2020 version of the survey. However, what respondents consider as their “typical” PT frequency in 2020 is somewhat ambiguous, and could refer to a pre-pandemic normal, a new pandemic normal, or a mix of both. Nevertheless, the comparison of answers to this unaltered question gives important insight into the extent to which people on average have started adjusting what they consider their normal use of PT use, but we want to stress the reader to interpret answers to this question cautiously and reflectively.

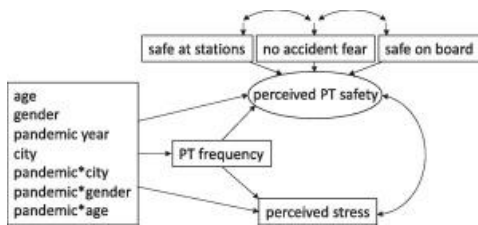
Second, perceived PT safety was measured in 2018 and 2020 with three statements covering perceptions of safety at stations and on bus stops (I feel safe at stations and bus stops), onboard (I feel safe onboard buses and trains), and in relation to accidents (I am not afraid of traffic accidents when using PT), all on a scale ranging from 1 to 5 (1 = do not agree, 5 = fully agree). It is important to note though that without specific indicators that measure perceived safety with regard to getting infected or infecting others, or supplementary information as to what it is that has changed safety concerns at stations, onboard and with regard to accidents, the observed changes in perceived safety cannot be explicitly linked to the pandemic. Rather it is an assumption that these are related to a combination of new biosecurity concerns and changed travel practices under confinement (less travel, less travel by PT, avoiding of rush hour).

Third, perceived stress during travel was measured in the 2018 and the 2020 survey as part of the satisfaction with travel scale (Friman et al., 2013). The respondents were asked to think about their daily travel and then rate their degree of stress on a 7-point scale (“Think about your daily travel. How do you experience your daily travel in general? I feel ...”) with the end points “very stressed, worried, hurried” (1) versus “very relaxed, calm, confident” (7). We inverted the scale so that higher values indicate higher levels of stress. As reflected upon in the literature review, the pandemic may have altered what PT travellers perceive as unsafe and stressful, introducing or reinforcing the role of infection risks in their perceptions, besides pre-existing sources of unsafety and/or stress, such as accidents, crime, insults and time pressure.

3.4. Statistical modelling techniques

The multivariate analyses in this paper are based on Structural Equation Modelling (SEM) through the software package STATA. SEM offers the opportunity to assess the simultaneous effects of sociodemographic, geographic and temporal (pandemic) predictors (and their interactions) on, and relationships between, three key outcomes of relevance in our paper: 1) normal frequency of PT use, 2) stress perceived in travel generally, and 3) safety perceived in PT. Causality between the outcomes is theoretically defined as follows: Perceived stress in travel and perceived safety in PT are reciprocally related. We model their relationship as a correlation, without assuming prior causal direction. We assume both subjective assessments to be affected by PT frequency, i.e., we expect those who normally travel by PT more frequently to have different perceived stress and safety outcomes than those who do so infrequently. Even though we measure one-way causality here, we acknowledge that also these relationships may be bi-directional, i.e., perceived levels of stress and safety may also feedback on the frequency one uses PT.

A second reason for using SEM is that it allows us to integrate in our analysis a factor model for safety perceived in PT, based on three items: 1) perceived safety at stations, 2) perceived safety onboard, and 3) not being afraid of accidents while travelling with PT, each measured on a 5-point Likert scale. Prior to being integrated into SEM, exploratory factor analysis revealed that the three items load well on a single-factor. The scale is reliable revealing good internal consistency with a Cronbach’s Alpha of .819. We allowed for correlated residuals between the items “perceived accident safety” and “perceived safety at stations” and between “perceived accident safety” and “perceived safety onboard”. By doing so, we account for that unexplained variance between the items may be correlated (Cole et al., 2007) and improve model fit. Figure 1 visualises the final structure of the SEM analysis that forms the basis for our results. Besides the model depicted in Figure 1, we also ran and briefly discuss a model without interaction effects for testing model sensitivity.



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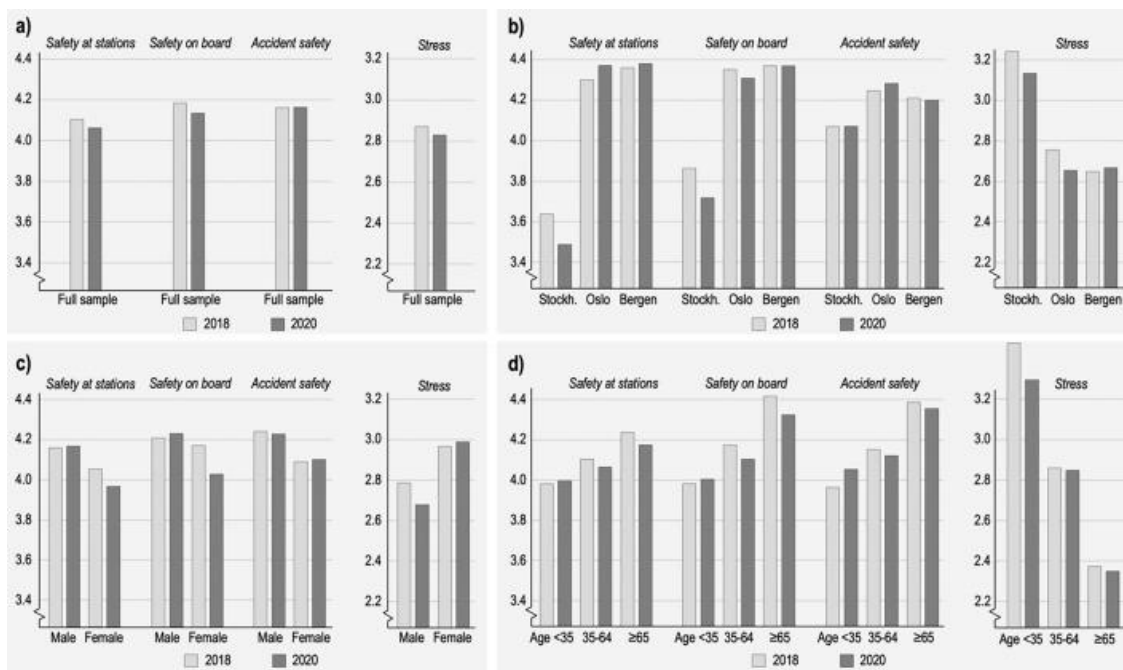
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Figure 1. Visualisation of structural equation model structure

4. Results and discussion

4.1. Descriptive results and reflections

Figure 2 shows levels of pre- and peri-pandemic perceptions of safety during PT travel and stress during travel. All numbers are weighted to account age and gender differences between the pre- and peri-pandemic survey samples (see section 3.1). The reported trends are based on descriptive bivariate relationships between perceived stress and safety outcomes and the different population segments and pandemic phases. Whether or not these depicted trends yield any statistical significance will be examined in paragraph 4.2.



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Figure 2. a-d: Pre- and peri-pandemic perceptions of PT safety and stress during travel overall (a), by city (b), by gender (c) and by age (d).

Survey respondents report somewhat lower levels of safety onboard PT and at stations during the pandemic year 2020 as compared to the pre-pandemic 2018 baseline, whereas perceived accident safety appears unaffected (Figure 2a). These

findings make sense, given that former two may be more directly affected by the pandemic (e.g. fear of infection, discomfort of crowding, visibility of facial masks) than the latter. On the other hand, levels of stress appear somewhat smaller during the pandemic. This may be related to the reduced intensity of travel overall, as well as to the possibility that travel during the pandemic consists for a smaller part of the time-pressured work-related travel at busier and more stressful peak-hour periods of day (Figure 2a).

It is important to note though, that these general trends hide a lot of uneven outcomes for different demographic groups and geographies. Figure 2b reveals that PT travellers in Stockholm perceive substantially lower levels of safety and substantially higher levels of stress than those in the two Norwegian cities in our study. Moreover, the drops in perceived safety in Stockholm got reinforced during pandemic. The drop in perceived safety on board and at stations during the pandemic, appears to originate predominantly in Stockholm and less so in the other two cities. The generally lower levels of perceived safety in Stockholm confirm previous analyses from 2007-2011 (BEST report 2011) which may reflect the higher crime statistic (crimes per 100,000 inhabitants 2016-2018 >80 in Sweden compared to <20 in Norway; Eurostat official statistics) and the higher population in Stockholm versus Oslo (Table 1). On the plus side, Stockholm travellers in our survey do perceive some relieve of travel-related stress during the pandemic as compared to before, even though their levels of stress remain high in absolute terms when compared to the Norwegian cities.

Besides these regional differences, our results show striking intersectionality with gender (Figure 2c). When looked at the average scores across gender, only male respondents perceive the earlier-described reduction in stress during the pandemic. Women's levels of stress do actually slightly increase. This is in accordance to the unfolding of a double taxation for women described in our literature review: i) being more impeded in their mobility than men because of unemployment or reduced employment; and ii) having fewer opportunities than men to transfer to home office and/or away from PT (González-Sánchez et al., 2021). Also, the earlier observed drop in average levels of perceived safety on board PT vehicles and at stations, appears to borne in its entirety by women, whilst men perceive if anything slightly higher levels of safety. Episodes of empty PT due to reduced seating capacities and a general drop in PT usage was perceived as being determinants of perceived insecurity around the world (Godhamgaonkar et al., 2021).

Although not as strong as for gender, the perceptions of safety and stress also show intersectionality with age. Young people in our sample perceive lower levels of safety of PT and higher levels of stress during travel than middle and especially older age groups do, especially from before the pandemic. Possible explanations may be that young people have to travel more for work/study purposes (especially when compared to the oldest segment of the population), more during peak hour, and that they are more time-pressured to combine jobs or study with the possible presence of young children in their households (Perracini et al., 2021). When looked at pandemic impacts however, it appears that younger age groups perceive some improvement of their situation (slightly higher perceived safety and slightly lower stress), possibly because the pandemic reduced their necessity to travel generally or travel during peak hours. In contrast, middle and older aged groups observe no such relieve in stress during the pandemic, and even some declines in perceived PT safety. It has in fact been continuously highlighted at a global scale that older adults were most severely and negatively affected by reduced mobility opportunities on PT. There were also strong variations in this group determined by access to independent car use. Older women, and older adults with low income and education were found to be negatively affected in most cases (Park and Cho, 2021, Monahan et al., 2020, Morley and Vellas, 2020).

4.2. Multivariate results discussed

Table 2 presents our final multivariate SEM results regarding the effects of sociodemographic, geographic and temporal (pandemic) predictors and their interactions on frequency of PT use (column on the left), on stress perceived in travel generally (centre column), and on our construct of perceived safety in PT (column on the right). Before running this final model, two alternative SEM analyses had also been run: a model without interaction terms of the pandemic year with age, gender and region, and a model where perceived safety at stations, perceived safety on board and perceived accident safety were analysed as separate indicators instead of as part of a construct. The paper presents only the final model, but we discuss also a couple of results from the two alternative model configurations. From top to bottom, Table 2 presents the factor loadings in our perceived PT safety measurement model, non-standardised regression coefficients of our predictors (direct effects), significant interaction effects, and the relationships between the dependent variables. The model is well-fitted with

an RMSEA value of .049, a CFI value of 0.973, and an explained overall variance (full model R_2) of 32.6 %. Individual dependent variable explained variance is 15.0 % for PT-frequency, 10.0 % for perceived stress in travel, and 16.2 % for perceived safety in PT.

Table 2. Multivariate results

	Structural Equation Model (N=6,241)								
	PT frequency			Perceived stress in travel			Perceived safety in PT		
<i>Measurement model factor loadings</i>									
Perceived safety at stations							1		
Perceived safety onboard							0,869	41,92	***
Perceived accident safety							0,46	59,35	***
<i>Independent variable regression coefficients</i>									
Female	0,204	5,50	***	0,121	2,48	*	-0,046	-1,44	
Age	-0,015	-14,16	***	-0,025	-17,41	***	0,006	7,78	***
Oslo (ref=Stockholm)	0,127	3,01	**	-0,525	-9,44	***	0,706	18,95	***
Bergen (ref=Stockholm)	-0,672	-17,02	***	-0,531	-12,72	***	0,707	19,94	***
Pandemic year 2020 (ref=2018) ^a	0,022	0,23		-0,386	-3,35	***	-0,041	-1,02	
<i>Significant interaction effects</i>									
Pandemic*Female	-0,194	-3,44	***	0,148	2,00	*	-0,118	-2,46	*
Pandemic*Age	-0,003	-2,10	*	0,005	2,30	*	omitted	b	
Pandemic*Bergen	0,183	3,26	***	omitted	b		0,147	3,21	***
<i>Relationships between dependent variables</i>									
Effect of PT frequency on...				-0,031	-1,84		0,008	0,76	
Correlation perceived stress in travel with...							-0,377	-20,33	***
Constant	4,320	64,20	***	-3,452	-30,83	***			
Dependent variable R_2	.150			.100			.162		
Overall model fit:	$Chi^2(df) = 1,094(20)***$ Model $R_2 = .326$ RMSEA = .049 CFI = .973								

Significance: * $p \leq .1$; ** $p \leq .05$; *** $p \leq .01$

a We also ran a model without interaction effects. In this non-interaction model the pandemic year has a significant negative effect on PT frequency.

b Non-significant interaction effects have been omitted from the model

In alignment with our descriptive results, [Table 2](#) confirms that COVID-19 has reduced levels of stress during travel, which could be ascribed to a higher share of people who did not necessarily have to travel, were travelling less during peak hours, were travelling under less crowded conditions, or had switched to individual modes (walking, cycling, car). Our multivariate findings also indicate that COVID-19 has a negative effect on what respondents describe as their “normal” frequency of PT

use¹ (in the model without interactions; non-significant in the final model in [Table 2](#)). We have found no significant effect of COVID-19 year on perceived safety in PT when looked at these outcomes in general terms – neither in our final model presented in [Table 2](#), nor in an alternative model where safety at stations, on board and regarding accidents were measured as separate indicators. However, clear social and regional differences are observed, see below.

In line with our literature review (e.g. [Shaer & Haghshenas, 2021](#); [Caselli et al., 2021](#)), we find that the general trends hide strong uneven impacts along the lines of gender and age. The interaction effects in [Table 2](#) highlight that COVID-19 does specifically reduce reported normal PT use for women and older age groups. Adding additional information to the descriptive results, it was found that those who use PT more often perceive less stress when travelling (no effect on perceived safety), and women use PT more frequently compared to men, but reduced PT more relative to men under COVID-19. Women perceive more stress and less safety generally, and even more stress and less safety during the pandemic. Older age groups use PT less frequent in general and even less under COVID-19 in particular compared to younger groups. Although older age groups feel safer in PT and less stressed in travel generally, they do feel more stressed under COVID-19 specifically. These findings correspond to the main findings emerging from literature review and it seems that even in societies like Sweden and Norway where there is a consistent focus on gender equality and strategic policy framing on Active Ageing, women and older adults suffered from an interlocking of forced mobility (physical presence required at workplaces, mandatory car responsibilities etc.), restricted mobility (ageism narratives and anxiety in being in public spaces, including public transport) or fear-based mobility.

Besides intersectionality of pandemic impacts with age and gender, we also observe strong regional differences. Stress perceptions are lower and safety perceptions higher in Oslo and especially in Bergen, when compared to Stockholm. Reported normal PT use is generally highest in Oslo, followed by Stockholm, and least in Bergen. However, Bergen seems to be less impacted by the pandemic compared to the Oslo and Stockholm, with PT frequencies and levels of perceived safety holding up better than in the other two cities.

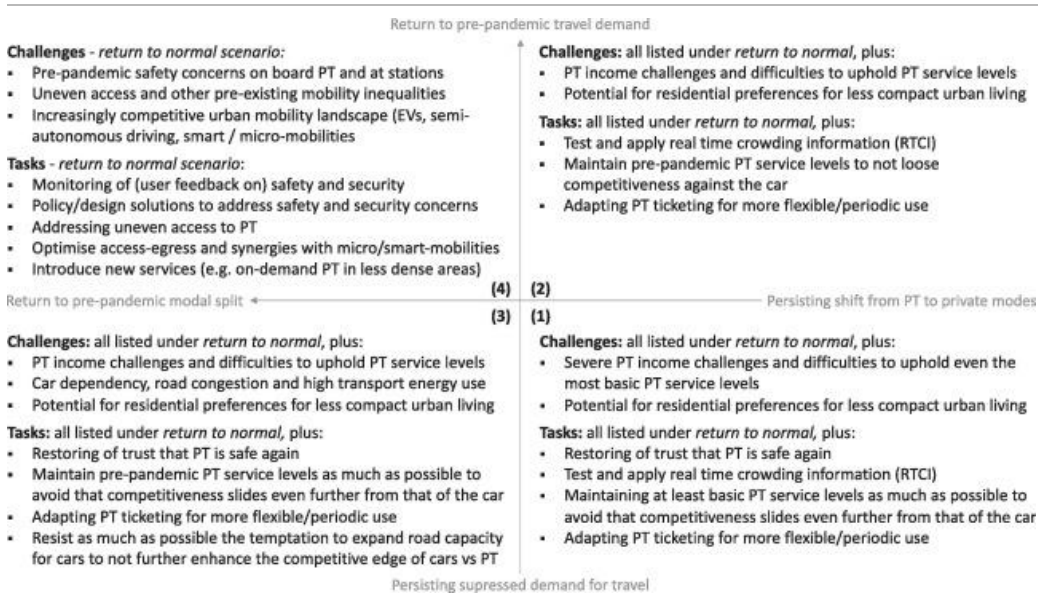
4.3. Discussion

The COVID-19 pandemic and its subsequent phases of lockdown and confinement have brought severe disruption and suppression of demand to daily mobility around the world. Whilst short term pandemic impacts have challenged the use, functioning and financing of all transport mode systems, post-pandemic continuations of such challenges are particularly visible and expected for the public transport (PT). On top of long-term travel demand uncertainties for all transport modes with the rapid rise of digital substitutes from working to shopping to leisure, PT have faced extensive periods of discouragement to use PT by the authorities and unique challenges related to crowding and the restore of trust and perceived safety ([Kopsidas et al., 2021](#), [Tan and Ma, 2020](#), [Tirachini and Cats, 2020](#)) that take time to recover ([Przybylowski et al., 2021](#)) and have only gradually and partially done so. Yet, time is a luxury many financially-crippled PT systems, as well as cities that critically hinge on these systems in their transitions away from fossil fuels and car dependency, can hardly afford. Knowledge on how the pandemic has impacted travel-related attitudes for different demographics and geographies, and what it takes to restore perceived safety and trust in PT, is therefore urgently required.

In this paper we examined the interrelations between the pandemic, PT ridership, and attitudinal factors with regard to perceived PT safety and stress during travel. It is clear that these attitudinal changes are far more marginal than the changes in actual externally-measured PT ridership changes in Oslo (minus 40 % year over year for 2020), Bergen (minus 35 % year over year for 2020) and Stockholm (minus 30-60 % for different months in 2020 as compared to 2019). PT ridership appears to have dropped first and foremost as a result of authorities' clear discouragement to use PT, whilst the more marginal changes in attitudes rather have followed as a result of changing behaviour. This is in line with studies on the reciprocal relationship between attitudinal changes and behavioural changes ([McCarthy et al., 2021](#); [De Vos, 2022](#)), which indicate that behavioural changes not necessarily always come as a result of attitudinal changes, but also vice versa. Nevertheless, we have observed some important changes in safety and stress perceptions during the pandemic year 2020 as compared to 2018, especially for demographic and regional subsamples of our data, that bear significance for behavioural change: perhaps not so much for the initial PT ridership drops and immediate partial rebounds, but more so for the mid to longer term stages of the gradual return to normal. Especially the finding that women, unlike men, have observed no reduction in stress and a

higher increase in perceived safety on board and at stations, exemplifies that returning to normal may be a bumpier ride for some than for others.

Figure 3 sketches out some main policy and planning implications of, and beyond, our findings, to restore the attractiveness, safety and use of PT, while accounting for long-term mobility uncertainties that different PT systems may face across four mobility scenarios. The figure draws and expands on ongoing work on pandemic learnings and sustainable mobility goal achievement impacts drawing on stakeholder interviews with urban and transport planners in Oslo and Bergen (Böcker and Tennøy, 2021). Scenario 1, 2 and 3 are characterised by a post-pandemic prolonging of situations that many PT systems are currently facing, where PT ridership is suppressed by a shift from public to private modes (scenario 2), a suppressed demand for physical travel altogether (scenario 3), or both (scenario 1). A major policy and planning task in all three scenarios will be to restore trust that PT is safe again: a shared responsibility that lies with all authorities that have conveyed the message to avoid PT during the pandemic. Part of this is managing the potentially heightened discomfort that people may feel with regard to crowdedness after the pandemic. Real time crowding information (RTCI) at stations and in travel apps may help PT travellers to prepare for and anticipate to this (Drabicki et al., 2021), for example by guiding them how to choose or skip departures or strategically position themselves on platforms.



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Figure 3. Long-term post-pandemic mobility scenarios and the challenges and tasks for PT

However, restoring and improving the attractiveness of PT should not be limited to addressing only new issues that have popped up during the pandemic. Regardless of whether the future holds a return to pre-pandemic modal splits and travel demand (scenario 4) or one of the aforementioned alternative scenarios, there are important *pre-existing* PT safety, security and inequality issues that need to be addressed. In line with earlier studies (e.g. Friman et al., 2020, Abenoza et al., 2019, Dong et al., 2021) we find that: i) PT travellers perceive varying degrees of unsafety at stations, onboard and in relation to the risk of accidents; ii) that perceptions of safety are correlated with satisfaction with travel dimensions like stress perception; and iii) that some societal groups (e.g. women) and geographies (Stockholm in our study) suffer more negative outcomes than others. It is thus important that policy measures recognise, and are sensitive to, the heterogeneous PT needs/outcomes and underlying mobility inequalities (for example in terms of access) of different societal groups in different geographical contexts. Besides improving safety and security, there are other measures to boost PT's attractiveness in a post-pandemic society. These include: i) the upholding of PT service frequencies as much as possible and not succumbing to the building of more roads to absorb a transitory increase in car traffic²; ii) introducing new on-demand PT services in less dense areas; iii)

optimising synergies with micro-/smart mobility solutions for access-egress; and iv) adapting ticketing schemes to cater for a more flexible and occasional need to use PT.

To better guide authorities and PT providers in navigating post-pandemic challenges and improving the long-term safety and attractiveness of PT systems, a supporting knowledge base should be developed by academics in close collaboration with practitioners. First, future studies should follow up with examinations of attitudinal and travel behavioural changes during later stages of the return to normal. Second, studies may want to capture perceptions of safety and stress beyond the broad categories (accident-, station- and onboard safety, and general stress/calmness levels) measured in this study, as well as other relevant travel-related attitudes missing in this study. Studies may want to also deeper examine the reasons for feeling unsafe, insecure or stressed, and pay particular attention to issues of unsafety perceived by women or marginalised groups, including sexual harassment and discrimination. Third, studies may want to link safety and stress perceptions to measures of PT frequency of use that are more precise than the somewhat ambiguous measure of “normal PT frequency” used in this study. Fourth, the fact that our study reveals substantial variation between relatively similar Nordic cities, reveals an important need to compare our findings with other areas outside of the Nordic context, including with cities in the global south, where issues of safety and security in PT may be far more abundant, uneven and multidimensional, while being less measured, recognized, acknowledged and addressed (Porter et al., 2021).

5. Conclusion

This paper investigates pandemic impacts on public transport (PT) travellers’ safety and stress perceptions in three Nordic cities, comparing 2020 (N=2,718) to 2018 (N=3,523) surveys. We find little pandemic effect *overall* on perceptions of safety, stress (actually some reduction here) and what respondents describe as their “normal” frequency of PT use, yet these general trends hide important *socio-spatial heterogeneities*. Women travel more by PT than men, but feel less safe and more stressed doing so – both of which reinforced during the pandemic. Older adults faced larger drops in PT during the pandemic, and none of the benefits in stress reduction perceived by younger adults. Regional comparisons reveal that travellers in Stockholm feel less safe and more stressed compared to those in Oslo and Bergen, whilst Bergen appears to hold up somewhat better in terms of perceived safety and reported drops in PT during the pandemic. Post-pandemic challenges and tasks include the restoring of trust that PT is safe again; handling the discomfort of crowding; addressing besides post- also pre-pandemic safety concerns; adapting PT ticketing to more flexible/periodic use; upholding PT frequencies and expanding on-demand services; and all of the above with full recognition of underlying heterogeneous mobility needs, outcomes and inequalities.

CRedit authorship contribution statement

Lars Böcker: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **Lars E. Olsson:** Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Funding acquisition. **Tanu Priya Uteng:** Investigation, Resources, Writing – original draft. **Margareta Friman:** Conceptualization, Resources, Writing – original draft, Funding acquisition.

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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- ¹ See section 3.2 for a reflection on the meaning and limitations of this variable
- ² Combined PT divestment and car infrastructure investment, even if presumed on transitory basis, bears a serious risk of entering a negative spiral of diminishing PT quality that could further slide its competitiveness relative to the car, with potentially strong and lasting ramifications for transitions towards sustainable, attractive and healthy cities.

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