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The impact of bookable loading bays on stress levels of freight drivers - A pilot study

Castrellon, J.P.[a*], Sanchez-Diaz, I.[a], Browne, M.[b], Bergstad, C.[c]

[a]*Chalmers University of Technology, Vera Sandberg Allé 8, Gothenburg, 41296, Sweden*
[b]*University of Gothenburg, Vasagatan 1, Gothenburg, 41124, Sweden*
[c]*University of Gothenburg, Haraldsgatan 1, Gothenburg, 41314, Sweden*

Abstract

This study examines how kerbside digitalization affects stress scores among freight delivery crews in urban settings. Stress was assessed using self-reports and physiological indicators, including electrodermal activity, pulse rate, and skin temperature, before and after the introduction of bookable loading bays. Data from 17 monitored trips in London's Borough Market area provided insights into stress triggers, particularly related to searching for parking and loading bay availability. The findings motivated reflections about the potential of digital solutions to address driver working conditions, traffic safety, and conflicts over access to kerbside space.

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Keywords: bookable loading bays; freight drivers; stress; physiological indicators; self-efficacy.

1. Introduction

Driving along a route, searching for parking, and loading or unloading goods creates emotional stress for freight drivers (Prasolenko et al., 2019). Emotions are activated when conflicts arise, e.g., risky driving/walking behaviours from other users, congested roads, lack of space for parking at delivery locations, among others. These emotions cause physical reactions, increasing nervous tension in drivers. This increase in nervous tension is called emotional stress (Prasolenko et al., 2019). Research suggests a connection between emotional stress and risky driving behavior (Arnau-Sabatés et al., 2012). Additionally, poor emotional states can negatively impact drivers' decision-making and reaction times, increasing the likelihood of unsafe driving situations (George & Dane, 2016).

* Corresponding author. Tel.: +46 73-022-2933.
E-mail address: jpcastrellont@gmail.com

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While research on human factors affecting urban traffic safety involving freight operators remains limited (Galal et al., 2024), recent studies highlight stress and fatigue as main contributors to unsafe driving behaviour in already tense environments, leading to collisions, road rage, and traffic incidents (Belzer, 2018; Prasolenko et al., 2019). Beyond traffic safety concerns, there are broader implications for psychosocial aspects, including the impact on drivers' working conditions. In terms of health, high levels of stress lead to hypertension, heart disease, obesity and metabolic syndrome, type II diabetes, and arthritis (Kivimäki M, et al., 2022). Additionally, from the freight companies' perspective, reduced productivity, poor performance, high turnover rates, and increased personnel costs due to sick leaves are also consequences of stress on drivers' health.

Conflicts related to access to kerbside space that induce stress may affect the mental health and overall well-being of those involved. Freight operators face these conflicts in urban environments that have densely populated areas, intense traffic activity and multiple users, all competing for the same limited kerbside space. The struggle to find suitable parking spots often leads to cruising or illegal parking, resulting in cumulative fatigue and stress throughout the drivers' journey (Iacobucci et al., 2022; Mamcarz et al., 2019).

To mitigate these challenges, local authorities implement initiatives aimed at de-conflicting kerbside access. These initiatives involve defining right-of-way rules based on user type and time, coupled with technological solutions to enforce space utilization and coordinate access. For instance, digitalisation in loading bays allows drivers to pre-book on-street spaces for (un)loading operations (Mor et al., 2020). The impacts of this initiative have been quantified in economic, traffic and environmental terms (Castrellon & Sanchez-Diaz, 2024). However, the implications on drivers' health–particularly stress–is an area that needs investigation.

Bookable (un)loading bays can potentially influence the condition of perceived self-efficacy in crew members. The concept of self-efficacy or efficacy beliefs has a foundation in social cognitive theory, and a high degree of self-efficacy can be connected to a range of positive behaviour and outcomes for individuals including stress and their general health and well-being (Bandura, 2001). In this context, self-efficacy refers to confidence in the ability to control navigation in urban areas knowing that resources are available, e.g., kerbside space for parking, and meeting performance targets in delivery operations.

This research aims to estimate the effects of a kerbside digitalization initiative on stress levels among freight drivers. The initiative involves bookable loading spaces, which are made available for freight operators to perform deliveries in central urban areas for up to 90 minutes. By providing these designated spaces, the study assesses the stress scores of drivers and variability in the degree of self-efficacy.

Previous research has shown how skin conductivity and heart rate can estimate driver's stress levels (Healey & Picard, 2005), supporting the design of studies aimed at understanding factors influencing driver stress (Belzer, M. H., 2018). This study extends this analysis by examining emotional stress in the context of kerbside access conditions, specifically evaluating the impact of technological solutions, such as bookable loading bays, when managing access space for freight deliveries.

2. Methodology

The study analysed changes in the stress levels of delivery crew members exposed to experimental and control conditions based on whether they perform freight deliveries using pre-booking systems or not. GRID Smarter Cities, technology operator providing freight kerbside solutions in London, supported the pilot installing five virtual loading bays (VLB) around the Borough Market (Southwark Borough, London).

VLB is a pre-booking system for loading bays in designated areas of the city, allowing drivers to secure a space in advance for loading and unloading activities for up to 90 minutes. The specific loading bays included in this study were determined by GRID in collaboration with Southwark Borough council and the Brewery Logistics Group (BLG), which represents logistics companies operating across the UK. The BLG provided the location of customers requiring freight deliveries in the Borough Market area.

The measurement corresponded to the evaluation of stress levels of freight drivers and other crew members performing deliveries with and without use of the pre-booking system. This evaluation was performed before and after using bookable loading bays for the same area and same delivery crew. The study involved two delivery crews and the transport managers of two companies responsible for operations at the Borough Market. Both delivery crews were

experienced in operating in this area and had participated in previous VLB pilot programs in other boroughs of London. Their participation in the study was voluntary, following GDPR protocols.

Data collection occurred between November 27 and December 28, 2024, with a total of 17 tracked trips. Variations in the number of observations among delivery crews were due to unplanned leave of the participants on specific dates, or technical issues with the wearable devices used to measure physiological signs during operations. Data sources involved self-report by rating scales, physiological signs from the participants and GPS data of the tracked trips provided by the companies.

2.1. Self-reports

Surveys were distributed before and after the driver performed a delivery route. Questionnaires asked crew members about subjective scaling of stressful events and self-efficacy perceptions (Table 1). Assessment on scales from 1 (Totally disagree) to 7 (Totally agree) was made by drivers both before and after the implementation of the VLB.

Table 1. Self-report survey.

Before a delivery routine	After a delivery routine
Q1 “I believe it will be possible to perform (un)loading with the minimum disruption (blockage, space encroachment) to other kerbside users”	Q1 “I was able to perform operations with the minimum disruption (blockage, space encroachment) to other kerbside users”
Q2 “I have the necessary resources available from the local borough, in terms of space for stopping and delivering, to perform (un)loading operations on the kerbside”	Q2 “I had the necessary resources from the local borough, in terms of space for stopping and delivering, for (un)loading on the kerbside”
Q3 “I am confident that traffic regulations related to kerbside use for freight deliveries do not hinder the timely and safe completion of scheduled operations”	Q3 “I felt that traffic regulations related to kerbside use for freight deliveries did not hinder the timely and safe completion of scheduled operations”
Q4 “Overall, it is stressful to think about the upcoming delivery tasks of today due to lack of parking space at some delivery locations”	Q4 “The delivery tasks were stressful due to lack of parking space at some delivery locations”
Q5 “It is likely that PCNs will be issued during today’s operation due to the lack of parking space”	Q5 “Did you get PCNs when delivering?” Yes/No
	Q6 “Did you experience any conflicting situation with any other user related to the kerbside access while parking or searching for parking?” Yes/No

2.2. Physiological indicators

Furthermore, there were measures of physiological processes used as indicators of the external manifestation of the driver’s emotional stress. Galvanic Skin Response methods (GSR) measure changes in the electrical properties of the skin, while the electrocardiogram method (ECG) measures changes in the difference in electrical potentials that occur on the surface of the body due to the activity of the heart. Crew delivery members were provided with a smart wearable to measure these physiological signs. They wore it during the tours before and after VLB implementation, including the base line measurement, i.e., background state.

A background state for each driver was recorded under conditions of no physical activity. The wearable, i.e., Empatica®, collected physiological signs measured while driving along the route, loading and unloading. Physiological indicators were contrasted with geolocation data to identify sources of change in heart activity and electrical and thermal properties of the skin due to, for instance, access to highways, traffic jams, searching for parking, loading/unloading operations, among others.

The combination of surveys and physiological indicators supported validity assessments of the results since occurrence of relevant variations in the physiological signals were addressed via questionaries. Additionally, companies involved in the pilot provided GPS data for each of the tracked journeys making it possible to associate physiological metrics to locations of interest.

2.3. Stress levels estimation

To compute stress levels the authors used the datasets provided by Empatica®, consisting of physiological signals recorded every minute over multiple days, including electrodermal activity (EDA in μS), pulse rate (beats per minute–bpm), and skin temperature (in Celsius degrees–°C), collected during the entire journey from depot to the Borough Market and back. The data was pre-processed as follows:

Normalization: Electrodermal activity and skin temperature signal were scaled between 0 and 1 using min-max normalization.

Time Aggregation: Data was grouped into 10-minute intervals.

Feature extraction - EDA: EDA responses were analysed by identifying phasic peaks, indicative of nervous system activation, i.e., number of peaks N_{EDA}, and Peak amplitude range A_{EDA}. The EDA score was calculated as indicated in Equation (1).

$$EDA_{score} = \frac{N_{EDA} - A_{EDA}}{2} \tag{1}$$

Feature extraction - Skin temperature: Two temperature-based features were extracted, i.e., mean temperature and minimum temperature drop. The Temperature score was computed according to expression (2).

$$TEMP_{score} = \frac{1}{T_{mean}+1} + \frac{1}{|T_{drop}|+1} \tag{2}$$

Feature extraction - Heart Rate Variability (HRV): Since only the pulse rate (beats per minute–bpm) was available instead of raw ECG data, synthetic R-R intervals were estimated following the guidelines of the European Society of Cardiology in which:

$$RR = \frac{60{,}000}{HR} \tag{3}$$

where HR is the pulse rate in bpm. R-R intervals refer to the time between successive R-peaks in an ECG signal, measured in milliseconds (ms). HRV is commonly calculated from these intervals. However, since ECG data is not available, and only pulse rate (bpm) is provided, R-R intervals were approximated synthetically from the pulse rate using the Equation (3).

The HRV score was then calculated as:

$$HRV_{score} = \frac{1}{HRV_{RMSSD}+1} + \frac{1}{HRV_{SDDN}+1} \tag{4}$$

where HRV_{RMSSD} and HRV_{SDDN} correspond to the Root Mean Square of Successive Differences (RMSSD) and Standard Deviation of NN intervals (SDNN), respectively, computed from the synthetic R-R intervals, following Equations (5) and (6).

$$HRV_{RMSSD} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N-1}(RR_{i+1} - RR_i)^2} \tag{5}$$

$$HRV_{SDNN} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(RR_i - \overline{RR})^2} \tag{6}$$

Stress Score Calculation: A composite stress score was computed for each 10-minute interval using a weighted sum of the extracted physiological features:

$$Stress_{score} = \omega_{EDA} EDA_{score} + \omega_{HRV} HRV_{score} + \omega_{TEMP} TEMP_{score} \tag{7}$$

The weights ω_{EDA}, ω_{HRV} and ω_{TEMP} were set based on (Zhang et al., 2022) and incorporated in the model with the values 0.5 (higher importance on EDA responses), 0.3 (moderate importance on HRV), and 0.2 (least impact from temperature changes).

Regarding the perceived self-efficacy levels, survey data were analysed by comparing responses before and after the implementation of the VLB, providing insights about crew members perception on kerbside access when using VLB.

3. Results

Data analysis was conducted in Python 3.11.11 using Google Colab. Fig. 1 presents the physiological metrics of one participant before and after the introduction of the VLB in the study area. Changes in size and colour of the circle markers indicate variations in EDA, pulse rate, and skin temperature, providing a visual representation of intensity levels. This analysis was conducted across all four participants involved in the pilot during the tracked trips.

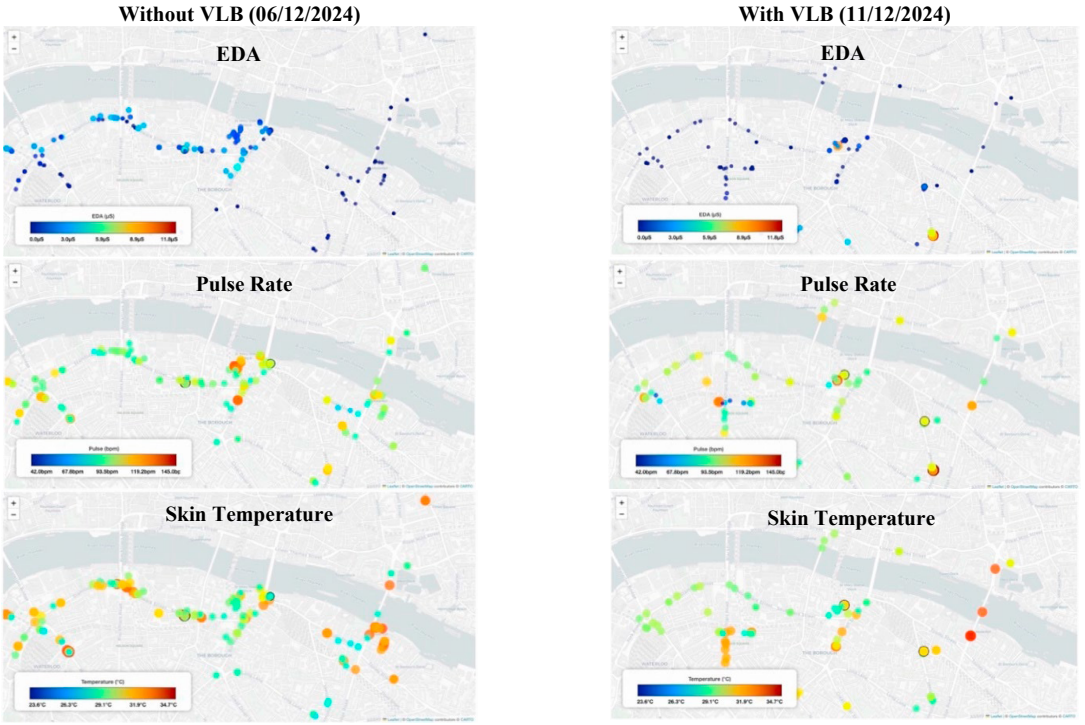

Fig. 1. Physiological signs for Driver 1 before and after the VLB implementation.

Stress levels were calculated based on Equation (7) and shown in Fig. 2. The red box highlights the specific times when the driver approached the Borough Market and made deliveries in that area. For this driver, the medium and high stress levels observed before the VLB implementation were further examined during the debriefing. The lack of available parking spaces in the Winchester Square zone –due to loading bays being blocked by a sewage truck and two other HGVs– forced the driver to cruise for 20 minutes in search of a spot. This led to parking in a restricted area, resulting in a Penalty Charge Notice (PCN).

This conflict over kerbside access illustrates one of the challenges of freight deliveries and the associated stress for drivers. Since metrics were also collected for the copilot, whose stress score was lower than the driver for this specific time window, it motivated the study of each participant's role separately, i.e., driver and copilot, for drawing conclusions based on their specific roles.

Fig. 3 (a) presents stress scores before and after the implementation of the VLB at an aggregate level, displaying the entire journey from the depot to delivery points and back (left), and the specific area of the Borough Market (right).

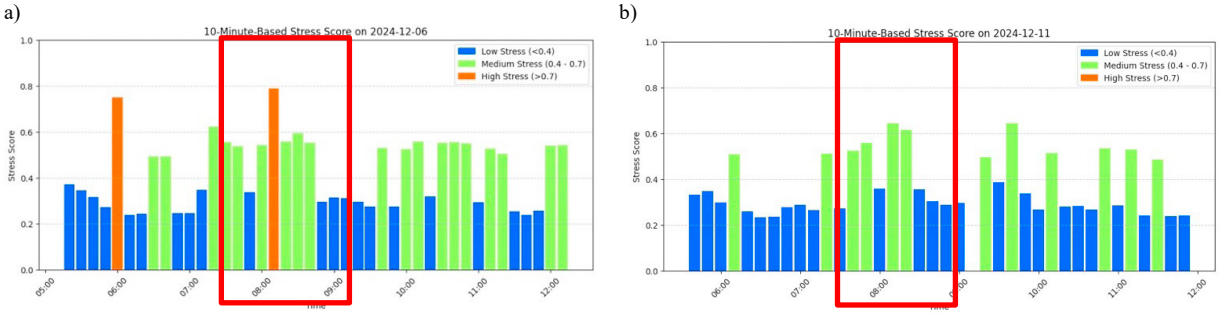

Fig. 2. Stress levels for Driver 1 (a) before VLB and (b) after VLB implementation.

The analysis of stress scores indicated no significant difference related to VLB implementation. However, a significant difference was observed between the background state, i.e., red line measured under relaxed conditions, and the stress score obtained during deliveries, both with and without the VLB, highlighting the relevance of considering stress measures when implementing interventions aimed at improving urban freight.

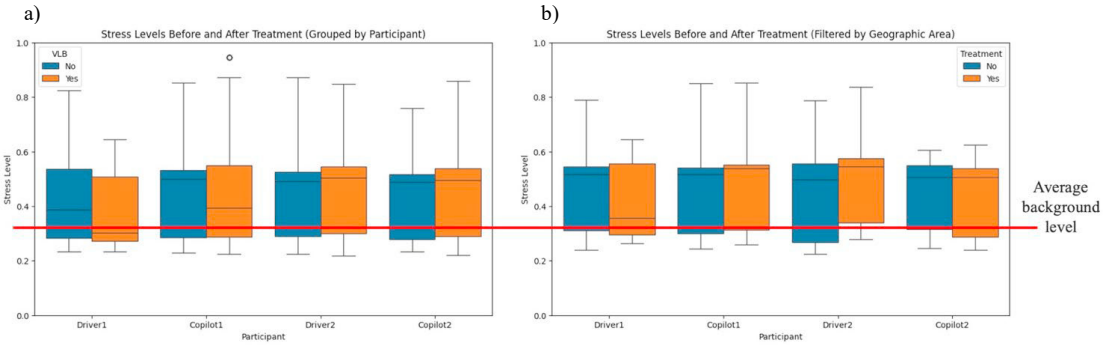

Fig. 3. Stress levels before and after VLB grouped by participant during a) the entire journey; b) at the Borough Market area.

The variance at the participant level was not significant, indicating minimal between-subject variability in stress scores. This suggests that the primary variation in stress scores occurred within individuals rather than between individuals. It implies that both driving and co-piloting tasks resulted in similar stress scores, though they may have been triggered by different situations.

Table 2 presents descriptive statistics of the physiological variables collected from both drivers and copilots with and without the VLB. Standard deviations indicate fluctuation in physiological responses during operations, explained by the different tasks the crew performed during each operation, i.e., driving, parking, (un)loading and delivery. Average stress scores fell between 0.43 and 0.51 across all participants, showing consistency in overall stress exposure during delivery tasks, which is significantly higher than the average background level, i.e., 0.32.

Table 2. Summary of statistics (mean ± std) of physiological scores with and without VLB.

Variable	Driver 1		Copilot 1		Driver 2		Copilot 2	
	No VLB	VLB	No VLB	VLB	No VLB	VLB	No VLB	VLB
EDA score	0.35±0.28	0.3±0.26	0.36±0.29	0.37±0.30	0.34±0.32	0.46±0.35	0.39±0.24	0.35±0.27
Pulse rate score	0.04±0.02	0.03±0.01	0.04±0.03	0.04±0.02	0.06±0.05	0.03±0.02	0.05±0.03	0.03±0.02
Skin temperature score	1.31±0.11	1.35±0.10	1.32±0.10	1.37±0.12	1.18±0.07	1.33±0.13	1.21±0.07	1.26±0.07
Stress score (0-1 scale)	0.45±0.14	0.43±0.14	0.46±0.15	0.47±0.15	0.43±0.16	0.51±0.17	0.45±0.12	0.43±0.14

Seasonal effects are being further analysed, though preliminary insights were obtained from freight volume data during the study period (Fig. 4). The chart indicates differences in parcel volumes between days with and without VLB intervention, represented by lighter and darker bars respectively. Volumes tend to be higher on non-VLB days, suggesting greater workload under standard conditions. This variation is important when interpreting stress measurements, although a full understanding requires consideration of traffic conditions at the delivery site, which directly impact the crews' operational experience.

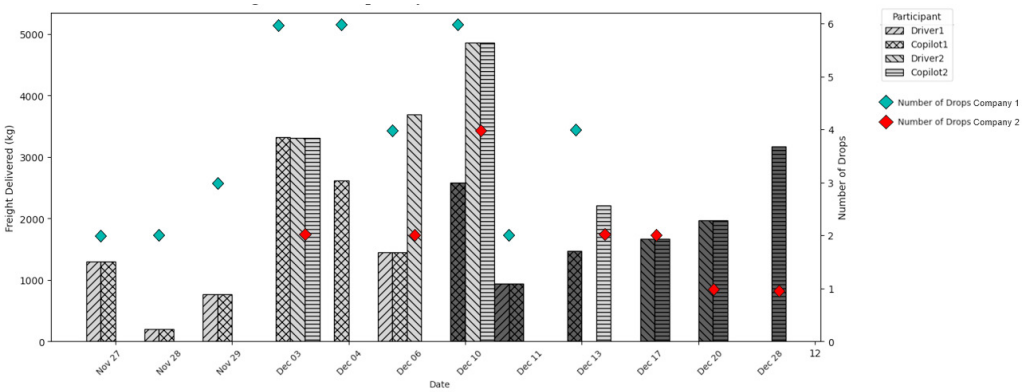

Fig. 4. Freight delivery per day in kg (darker shade = during pilot).

Regarding the self-report results, the comparison of responses before and after VLB implementation showed low variability, indicating limited improvement in the perceived self-efficacy after the pilot intervention. As the pilot covered only a short segment of the route, its effect on self-efficacy was likely constrained by other uncontrolled factors, such as traffic conditions, time pressure, and street layout, identified during debriefs as relevant factors of drivers' sense of control and confidence during operations.

4. Discussion

Given the geographical scope of this study, the analysis considered specific delivery locations and the portion of the trip leading to the designated VLB to assess the targeted intervention at the Borough Market. Conclusions were drawn based on survey responses, as quantitative modelling of effects is ongoing, with data collection on freight demand and traffic flows still in progress. However, the statistical significance of the findings from the survey remains limited due to the sample size, implying cautious interpretation and the need for further data collection to strengthen the analysis.

Although the Borough Market was the primary focus of this study, the availability of GPS data and physiological signs across the entire journey allowed for the identification of factors influencing driver stress in other areas of the city. Variability was observed in locations such as Waterloo, Elephant and Castle, and Tower Bridge, highlighting potential areas for further research. Examining the specific conditions at these sites through interviews with delivery crews and transport managers could offer insights into stress-related factors in freight operations, including the built environment, kerbside access, traffic conditions, interactions with other road users, and high freight demand zones. Additionally, the journey length suggests that conditions throughout the daily trip potentially have an impact on stress levels that outweigh efforts for reducing these levels at relatively small portions of the route. This highlights the need for integrated interventions aimed at reducing stress at critical points along the entire journey.

Pilot results are likely influenced by the timing of data collection, as responses with the VLB were gathered closer to the Christmas period –a peak season for freight activity and increased competition for space due to higher pedestrian, visitor, and private vehicle presence. Thus, while the VLBs did not drastically alter perceptions of self-efficacy in delivery operations during the pilot phase, a prolonged analysis is necessary to assess their impact over different periods, accounting for peak and off-peak variations in the demand for space.

5. Conclusions

This study analysed the stress levels experienced by freight delivery crews in a specific area of London. By analysing self-reported data alongside physiological indicators and GPS data, the study was able to capture shifts in stress scores and provided explanations for these variations. However, certain limitations in the experiment, such as the sample size and external factors affecting stress beyond parking availability, are acknowledged.

A key aspect of the results was the identification of differences in stress scores, which helped pinpoint specific situations related to kerbside access. The study revealed that prolonged searches for parking, uncertainty over kerbside access, peak operational periods and time constraints contributed to heightened stress. By distinguishing these elements, the research offers insights into the pressures faced by freight delivery crews to be considered in the design of urban freight solutions.

Although the statistical limitations of the conclusion, the experiment revealed the usefulness of the data collection implemented in this research for exploring specific conditions to address conflicts in the access to kerbside space. Insights from these analyses could lead to solutions improving traffic safety, and overall, space users' quality of life. Thus, outcomes from the research can better inform the development of right-of-way regulations that mitigate conflicts in the access to kerbside space.

Wider implementation of bookable (un)loading bays, e.g., VLB, along the entire delivery route, can be further explored regarding their influence on conditions of self-efficacy in crew members working conditions. For further research, it is essential to consider broader implications related to traffic safety, driving behaviour and overall work quality. The study pointed to the need for integrated interventions that address not only specific areas but have a wider scope to influence driver well-being. Improving access to designated loading areas, implementing stress-reducing policies, and integrating technological solutions can contribute to a more sustainable and efficient freight system while enhancing the quality of work for delivery crews.

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