ANALYZING SAFE EPIDEMIC DISTANCING IN PUBLIC TRANSPORT BUSES: A SIMULATION STUDY ON PASSENGER FLOW

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Abstract

During the COVID-19 pandemic, public transport played a crucial role in maintaining essential services while ensuring the safety of both passengers and staff. As the world gradually resumes operations, the impact of the pandemic is expected to persist for some time. Existing studies focus on virus transmission in vehicles, with limited knowledge about post-pandemic passenger flow, safety, and satisfaction. This paper presents a model of passenger movement in public transport, considering factors like boarding times, movement within stops, and the impact of crowding and delays. To reduce transmission at bus stops, we developed a simulation-based passenger flow model using PTV Vissim. The program was used to simulate passenger exchange scenarios, using data collected from real data. The goal was to create a model that minimizes the risk of infection. By understanding passenger flow and interactions with the public transport system, effective measures can be implemented to mitigate the spread of COVID-19 and other infectious diseases.

Keywords:

Pandemic; Simulation; Risk infection; Public transport; Passenger.

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1. Introduction

The passenger exchange process, particularly during times of epidemic risk when public transport rules are evolving, influences the safety and efficiency of journeys, encompassing boarding and disembarking. Amid the pandemic, public transportation operators faced increased demands from passengers for comfort, more frequent services, safety measures, and changes in travel habits (Kłos-Adamkiewicz and Gutowski, 2022; Liu et al., 2022; Thomas, Jana and Bandyopadhyay, 2022). In response to the pandemic, some individuals chose personal vehicles over shared transport to reduce potential exposure (Chen et al., 2022). During the second wave of the COVID-19 pandemic in Poland, the probability of SARS-CoV-2 infection through the use of public transport was estimated to be around 0.05% (Burdzik and Speybroeck, 2023). Government entities should swiftly provide accurate information to mitigate the pandemic's adverse consequences, protect the well-being of both passengers and operators, and counteract the spread of misinformation (Zhang, 2020).

The public transportation crisis arose from passengers' concerns about overcrowded conditions (Cartenì, Di Francesco and Martino, 2021). Implementing preventive measures such as temperature checks, mask usage, and good hand hygiene can help reduce virus transmission in the realm of public transportation (Zhou et al., 2021). Wearing masks reduced the overall particle count released into the bus by an average of 50% or more depending on mask quality and reduced the dispersion distance by several feet (Edwards *et al*., 2021). Consequently, many individuals were hesitant to use transportation services during the pandemic (Sevi and Shook, 2022). A comprehensive assessment of the epidemic risk in the transportation sector must consider various factors, including the duration of potential exposure, the number of individuals exposed, and the consequences of infection (Burdzik, 2023). This entails addressing challenges and fostering economic development (Slaughter, A.-M., 2020). The exchange of passengers is intrinsically tied to the start and end of a journey, which encompasses the boarding and disembarking of public transport.

1.1. Analysis of passenger Movement in Public Transportation during the COVID-19 Pandemic

Passenger Flow is the fluctuating count of passengers aboard a bus, influenced by factors like time and location. It results in shifts in passenger numbers for buses across different time periods and locations as passengers board and disembark at each stop (Zhang et al., 2017). The higher the respiratory rate of an infected person, the greater the risk. Consequently, the risk of infection is higher during longer exposure times in public transportation, particularly during long-distance travel (Park and Kim, 2021). The efficient development of the public transport system and the identification of ideal station locations are crucial for meeting user requirements in strategic planning (Asadi Bagloee and Ceder, 2011). When designing a network that optimizes user connectivity, accessibility, and convenience, careful consideration and thorough planning are essential (Shrivastava and O'Mahony, 2009).

Vital for containing the transmission of COVID-19 is the employment of social distancing and self-quarantine techniques (Davalbhakta et al., 2020). Our research primarily focuses on the development of intelligent applications to mitigate the consequences of pandemics (D. B. Taylor, 2020; Khuroo et al., 2020). Utilizing call data records (CDRs) for monitoring COVID-19 patients can play a crucial role in halting the virus's spread by providing valuable insights into the movement patterns of infected individuals, effectively aiding in curbing transmission (Nisar et al., 2021; S. Nisar, M. A. Zuhaib, A. Ulasyar, 2021).

In the efficient monitoring of individuals diagnosed with COVID-19, the technique of contact tracing proves invaluable (Ong et al., 2020). Several mobile applications have been suggested, such as the Smittestop contact tracing app created by the Danish Health Authority to monitor and restrict the transmission of COVID-19 within Denmark (Martin et al., 2020). The Serbian government has introduced an application, known as VirusRadar, designed to aid in monitoring and curtailing the transmission of COVID-19 within the country (Herendy, 2020). The Italian government has introduced Immuni, a contact tracing app designed to assist in monitoring and curtailing the transmission of COVID-19 within Italy (Berardi et al., 2020). Safety measures, including social distancing, organized passenger queues, and streamlined boarding and payment methods will reduced the transmission of the virus (Burdzik, Chema and Celiński, 2023).

1.2. Examination of Physical Distancing during a Pandemic

The capacity of prospective travelers to tolerate risk plays a significant role in influencing their decision to embark on a journey (Chen, Xia and He, 2020). Social distancing, as a preventive measure, hinders close interpersonal contact, reducing the risk of virus-laden respiratory droplets transmission, primarily through human breath (Sun and Zhai, 2020). Sitting in the same row on public transport as an infected person significantly increases the risk of getting infected compared to sitting in different rows (Hu *et al*., 2021). Social distancing is a recommended solution by the World Health Organization to minimize the spread of COVID-19 in public places

(Rezaei and Azarmi, 2020). It is essential to maintain social distance not only in outdoor settings but also in indoor environments, particularly in transportation modes, to protect against COVID-19 (Burdzik, 2022).

Factors such as age, gender, and educational background can affect an individual's perception of comfort and breathability (Shafaghi et al., 2020). Computational fluid dynamics models indicate that the virus can travel significant distances when a person sneezes or coughs, which has been studied extensively ('How far droplets can move in indoor environments – revisiting the Wells evaporation–falling curve', 2007).

Respiratory droplets carrying infectious agents can be conveyed and deposited onto the mucous membranes of individuals positioned in the airflow's trajectory, a phenomenon that is common in various modes of transportation (Lu et al., 2020). In complex environments, ventilation systems and thermally induced forces from human activities can lead to intricate air patterns and the formation of recirculatory air flows (Li et al., 2022). When traveling, passengers should prioritize their health and safety by carrying masks, personal protective equipment, and hand sanitizer, and wearing masks in crowded areas like passenger terminals and public transport to reduce infection risks (Shen *et al.*, 2020).

2. Materials and Methods

Simulation software "PTV Vissim" was used to model passenger exchange, known for its realistic passenger flow on public transport. Simulations were conducted for a specific transit line and stop using data from the Metropolitan Transport Authority (ZTM), which is essential for understanding passenger flow dynamics tied to journey beginnings and endings, especially during times of changing public transport rules, affected by factors like vehicle occupancy and timing of passenger actions.

2.1. Simulation development

The simulation model, constructed with data and executed using Vissim software, aimed to detect potential problems related to passenger exchange within the transportation system. The primary goal was to devise effective solutions by simulating various scenarios. Specifically, the simulation focused online A, investigating the passenger exchange dynamics at different bus stops. This process involved observing and analyzing the simulation outcomes to gain insights into passenger behavior and facilitate the development of targeted solutions.

PTV Vissim software serves the purpose of precisely pinpointing the location of a designated transportation stop, referred to as „line X,Y and Z" on a map. The figure displayed below provides a satellite map view of this selected stop within the program, visually conveying its exact location. This software's functionality allows for the precise mapping of this specific stop. The subsequent figure, depicted below, further illustrates this stop through a satellite map view, all within the PTV Vissim program.

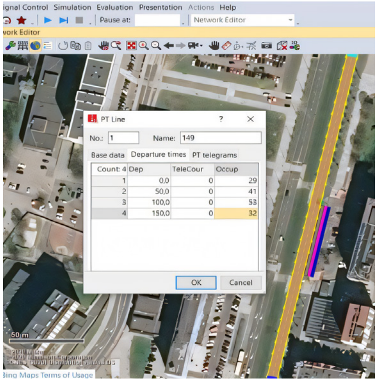
Essentially, this statement outlines a specific phase within a comprehensive procedure wherein the software is utilized to accurately determine and depict the exact geographic coordinates of the specified transportation stop. The accompanying illustration plays a vital role in clarifying the precise location of this stop within the entire transportation framework, supporting users in their transportation system planning, analysis, and decision-making processes.

Fig. 1. The position of the line X, Y and Z stop, visible on the PTV Vissim map.

In PTV Vissim, a comprehensive simulation relies on specific parameters that are pivotal for accurately replicating real-world public transport scenarios and passenger movements. These parameters encompass the „Link" for road network mapping, crucial for realistic traffic flow simulation, „Public transport stops/boarding volume" to pinpoint passenger boarding and alighting spots, „Public transport line/public transport line stops" for accurate route and schedule representation, „Areas" to identify diverse zones and distribute passenger demand, „Pedestrian inputs" for marking pedestrian entry points, and „Pedestrian routes" to model passenger pathways. Together, these parameters allow for a precise depiction of passenger flow, offering insights into optimizing public transport efficiency and safety, particularly in epidemic scenarios. Additionally, the map visually displays specific transportation routes through the designated link object, and subsequent steps involve the identification of suitable bus stops, passenger additions, bus stop platform creation, and route adjustments, providing a comprehensive overview of the simulation process.

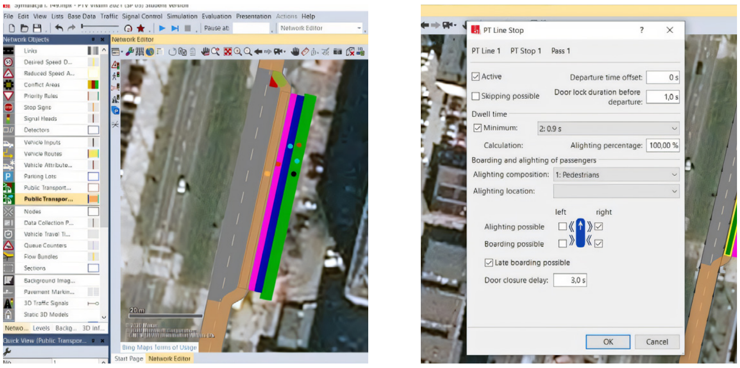
The following steps in the process included the identification of an appropriate bus stop, the addition of passengers to the bus using the „boarding passengers" tab, the creation of a bus stop platform through the „add lay-by stop" function, the addition of an area object to the platform to serve as a part of the road's edge, and the subsequent establishment of a waiting area for public transport passengers. Within the transport line parameters, fundamental data was specified, and a bus was chosen with a speed of 30 km/h. Both lanes were designated as the designated transport line route. Departure times of 0, 50, 100, and 150 were selected for the public transport vehicle's departure in relation to the simulation's start. The count of passengers boarding the vehicle (occupancy) was determined and recorded. Lastly, the transport line was relocated to the designated bus stop line, and the route was adjusted accordingly. A visual representation of this process is available in the accompanying figure.

Fig. 2. The transportation route and its path through the bus platform were identified and established, as shown.



After pinpointing the bus platform, the next stage includes establishing a passenger entry point. This serves as a designated path (depicted in green) guiding passengers towards the stop. Pedestrian inputs (indicated by black circles) are designated on the sidewalk to generate simulated passengers. Additionally, pedestrian routes (depicted by orange and blue circles) are outlined, outlining the specific paths pedestrians follow in their movement.

Fig. 3. Shows the procedure for including a passenger zone and defining the locations for passenger generation and setting up settings for a stop.



Subsequently, the configuration for the stop was arranged, and the stop was activated, complete with the specification of essential parameters and door settings to facilitate passenger boarding and alighting.

3. An outcome of the simulation

A substantial passenger volume creates an environment of congestion that escalates the risk of COVID-19 transmission. This heightened risk is primarily attributed to the fact that COVID-19 predominantly spreads through respiratory droplets emitted when an infected individual speaks, coughs, or sneezes. When individuals are closely packed and not wearing protective masks, the probability of transmission significantly increases. To reduce this transmission this simulation has been done. Following the initiation of simulations at this particular bus stop, the outcomes were meticulously recorded and will be visually presented via print screenshots. One of the modifications aims to resolve a passenger exchange issue that manifests online A during the simulation. The line specifies the existence of three bus stops, namely, bus stop X, bus stop Y, and bus stop Z.

Fig. 4. PTV Vissim map displaying the bus stops along Line X, Y and Z.

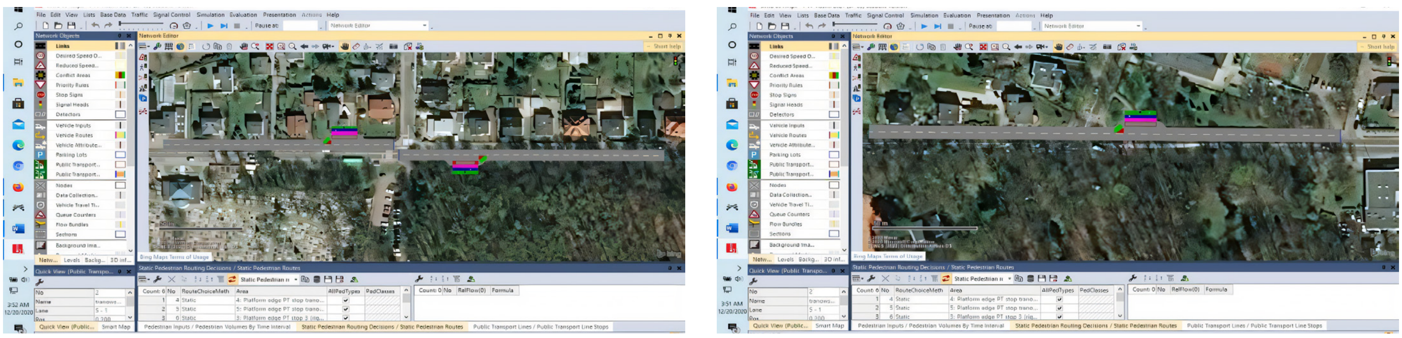


Fig. 5. 3d A simulation illustrating a well-organized passenger flow with a 2-meter separation.

The public transport line's departure schedule is established using data provided by the metropolitan transport authority. In this scenario, each bus stop is serviced by four buses. To mitigate concerns related to excessive passenger occupancy and chaotic boarding, adjustments were introduced. These adaptations featured the incorporation of queues with a 2-meter gap to facilitate orderly passenger boarding and disembarkation. Distinct queue configurations were utilized, depending on whether passengers were regular commuters or wheelchair users. These modifications are visually represented in a 3D diagram, setting them apart from previous diagrams (such as those for Line A) through the inclusion of spacing distances and queue distinctions based on passenger types.

The ultimate step encompassed initiating the simulation following the implementation of modifications aimed at addressing issues related to high occupancy, disorderly passenger entry, and congestion at bus stops. These alterations included enforcing a 2-meter passenger distance and organizing queues for a systematic passenger exchange process. The objective was to monitor passenger movement as they board the vehicle and assess the efficacy of these adjustments.

Furthermore, the research delved into program-related challenges and potential remedies, including the implementation of a 2-meter spacing between passengers and the establishment of passenger queues to ensure a well-organized exchange process. Additionally, considerations were given to the number of doors and the payment methods for boarding and alighting passengers. The availability of more doors leads to reduced boarding and alighting times, which aids in streamlining passenger flow, alleviating congestion, and minimizing passenger interactions. Overall, our research is dedicated to enhancing the safety and efficiency of passenger transportation, especially during epidemics, by taking into account multiple variables affecting passenger movement and implementing effective solutions.

4. Conclusion

Transportation technologies have assumed a pivotal role in the management of public transport systems amidst the pandemic. The utilization of real-time data and predictive analytics has empowered the adaptation of service levels and routes in response to evolving demand, thereby enhancing operational efficiency. The focus of this research paper revolves around tackling these challenges by delving into the enhancement of passenger flow and the integration of technology in public transport, with a paramount emphasis on safeguarding the well-being and health of both passengers and personnel. Hazard assessment that was conducted for the transportation system, which involved estimating the number of SARS-COV-2 particles that could be expelled through respiratory activities like talking, coughing, and sneezing. This was done in an unventilated indoor environment, with the subsequent inhalation of these particles by one or more individuals in the same space. The assessment also considered the possibility of transmission of SARS-COV-2 through aerosols outside the 2-meter social distance.

The smooth operation of transportation systems relies heavily on the movement of passengers, and a critical aspect of this is the dwell time of public transport vehicles. Dwell time refers to the duration a vehicle remains stationary for passenger boarding and alighting. It's greatly influenced by the number of passengers and their boarding speed. When dwell times are extended, it can lead to overcrowding at stops, disrupt the passenger flow, and create disorder within the public transport system. An important variable affecting dwell time is the number of doors on the vehicle, as having more doors accelerates passenger flow and reduces the time spent during service. In analyzing passenger boarding and alighting times, it's imperative to consider potential delays experienced by passengers with disabilities, who may need extra time. Prioritizing individuals with disabilities and elderly passengers during boarding and alighting procedures helps minimize physical contact among passengers. The presence of multiple doors on a vehicle significantly decreases the time required for passengers to board and alight, thus facilitating an organized passenger flow, lessening overcrowding, and reducing passenger interactions. The impact of COVID-19 on passenger flow and task completion time is intricate and varies depending on factors such as the specific measures in place, the level of compliance with these measures, and the risk profile of the community.

Our research strives to improve the safety and efficiency of passenger transportation, particularly during epidemics. This is achieved by addressing a multitude of factors that influence passenger movement and introducing effective solutions. These measures include maintaining physical distance between passengers and establishing orderly passenger queues. Furthermore, temperature checks have been introduced as screening measures, which might have an impact on passenger waiting times. The success of these efforts in mitigating the impact of COVID-19 on passenger flow and task completion time depends on a range of factors, including the effectiveness of the implemented measures, the level of compliance with these measures, and the risk level within the community.

In conclusion, the models discussed in the article should place a strong emphasis on incorporating passenger queues as a fundamental strategy to ensure a meticulously organized passenger exchange process. By doing so, we can effectively manage and control overcrowding at transportation stops, thereby reducing the risk of COVID-19 transmission. This approach recognizes the importance of maintaining physical distancing, especially in high-traffic areas, to mitigate the spread of the virus. Implementing well-organized passenger queues not only contributes to public safety but also enhances the overall efficiency and effectiveness of the transportation system, ultimately leading to a more seamless and secure passenger experience during these challenging times.

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