https://doi.org/10.34074/rere.00303

Article

ADOPTION OF ARTIFICIAL INTELLIGENCE-BASED SYSTEMS IN DEVELOPMENT OF PUBLIC TRANSPORTATION SYSTEM IN AUCKLAND

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ABSTRACT

The concept of smart cities has gained significant momentum with rapid advancements in Artificial Intelligence-based automation. Public mobility is a crucial component of modern cities, and its development significantly impacts the level of smartness of a city. The application of Artificial Intelligence to the public transportation industry necessitates a continuous reassessment of the factors influencing the design, development, and implementation of the public transportation infrastructure. This investigation aims to explore these factors, their implications for an effective transportation system in Auckland, New Zealand and the significant results that adopting Artificial Intelligence would bring to the system. It includes the integration of an Intelligent Transportation System, an Artificial Intelligence-based real-time data collecting system, and fully automated driverless vehicles that are connected to the Intelligent Transportation System.

Keywords: public transportation, infrastructure for public transportation, intelligent transportation systems, network connectivity, travel time analysis

INTRODUCTION

Smart cities are characterised by their commitment to sustainability and efficiency, utilising innovative technologies to elevate the quality of life for their residents. Smart transportation is a critical component of smart cities, and it involves the use of data analytics to optimise the movement of people and goods within a city (Macke et al., 2018). In Auckland, smart public transportation (PT) systems have been proposed as a way of improving the city's transportation network (Munjal et al., 2020)

Smart PT signifies the use of advanced technologies to promote the efficiency and safety of the PT systems. Smart PT systems use progressive technologies such as the Internet of Things (IoT), Artificial Intelligence (AI) and Big Data Analytics to optimise the flow of traffic, reduce congestion, and provide passengers with real-time information on routes, schedules and delays. Such systems also incorporate other advanced technologies such as autonomous vehicles, electric buses, and intelligent traffic management systems (Costa & Duran-Faundez, 2018).

Auckland Transport is a council-controlled corporation engaged with Auckland's transport services, including roads, public transport, cycling, and walking (Auckland Transport, 2022). Auckland Transport's key priorities are to reduce congestion, improve safety, and increase accessibility and sustainability (Radio New Zealand, 2022; Auckland Transport, 2022). Issues that negatively impact the linkage between Auckland's transportation system and smart PT systems include limited coverage of AI-based smart technology implementation and challenges in data integration and utilisation (Wolken et al., 2018).

The objective of this investigation is to understand the current state of PT in Auckland and what are the potential AI-based solutions to optimise the existing system.

LITERATURE REVIEW

As one of the fastest-growing cities in New Zealand, Auckland's PT system has faced challenges in accommodating increasing demand, addressing congestion, and providing reliable and efficient services. In the process of this literature review, it was discovered three distinct domains of issues concerning the Auckland PT system.

- Insufficient Infrastructure: Auckland's PT system requires significant investment in infrastructure to meet the increasing demand for services including upgrading existing infrastructure, constructing new bus stations, and developing integrated transport hubs (Auckland Rapid Transit Baseline, 2021)
- Poor Network Connectivity: Auckland's PT network lacks seamless connectivity between different modes of transportation, leading to reduced accessibility and convenience for users. This includes inadequate connections between buses, trains, and ferries, and limited access to key destinations (Jacobson, 2018)
- Driver Shortage: Auckland's PT system is facing a shortage of bus drivers, which impacts the reliability and efficiency of services (Scott, 2023)

Critical Evaluation of Public Transportation in Auckland

In modern infrastructure, a properly functioning PT system holds the utmost significance. Evaluating a PT system necessitates a thorough assessment of influencing factors such as reliability, efficiency, and safety (Atombo & Dzigbordi Wemegah, 2021). The PT system in Auckland is a notable feature of the city's urban infrastructure (Arora, 2023). Arora stated that it is comprised of multiple modes of transportation, including buses, trains, and ferries, which provide people with an array of options to navigate the urban landscape. The AT HOP card system is an addition to the PT system, which enables passengers to conveniently pay for fares and transfer between modes of transportation (Arora, 2023). Auckland Transport has been proactive in its efforts to improve the reliability and frequency of services, utilising initiatives such as bus priority lanes and rail electrification as well as providing real-time features such as real-time bus and train arrival information through the Auckland Transport website and app (Hyde & Smith, 2017). As Chowdhury et al. (2018) stated, the Auckland City Rail Link, a substantial infrastructure project currently under construction, is expected to significantly enhance the efficiency and capacity of the public mobility system.

However, the quality of PT services has been the subject of complaints, with delays, cancellations, and overcrowding being common issues (Horsnell, 2023). A lack of integration between different modes of transportation has also been noted (Jacobson, 2018). There are concerns regarding accessibility, particularly for those residing in areas with limited PT options or those with mobility issues. Furthermore, some suburbs and rural areas are underserved by the PT system, with limited access available (Imran & Pearce, 2015). On the other hand, Campbell, (2023) identified the shortage of bus drivers in Auckland which has emerged as a persistent issue in recent years.

Overall, Imran and Pearce (2015) stated that while the PT system in Auckland has various strengths, it is evident that there is scope for improvement. They also identified that addressing issues such as reliability, accessibility, and coverage will be vital for the system to cater effectively to the needs of Auckland residents, sustain growth, and promote the city's sustainability (Imran & Pearce, 2015).

The Issues

According to the report published by Fleming (2019),)Auckland has the world's eleventh worst PT, based on scores in accessibility, reliability, and affordability. Hence, this section will be followed by detailing the identified issues in relation to insufficient infrastructure, poor connectivity, and the bus driver shortage.

– Insufficient Infrastructure

The contemporary issue of traffic congestion and air pollution caused by urban expansion and increased transportation usage has garnered significant attention from scholars and policymakers alike. Private vehicles, in particular, have been identified as a major contributor to traffic congestion and air pollution in urban areas worldwide (Lu et al., 2021).

Cilliers (2023) quoted that "residents that rely on public transport are forced to endure atrocious trip lengths and infrequent services" and also emphasised the necessity of PT development especially in Westgate, Auckland. Williams (2022) reported a striking rise in traffic congestion in Auckland, which is believed to be primarily driven by population changes in the region. Furthermore, it was also noted that the likelihood of an individual driving to work and the length of their commute increases with distance from Auckland city centre. The author quoted that a report published in April 2022 by an Auckland Transport spokesperson indicated that only 26% of morning trips to Downtown Auckland were made using PT, compared to 67% using private transportation such as their own vehicle (Williams, 2022).

In addition to the environmental and logistical consequences of traffic congestion, Wild et al. (2021) have identified the negative psychological impacts on drivers. Their study at the University of Auckland revealed that residents in Auckland are excessively reliant on their vehicles, which has led to increased stress and anxiety among drivers. The authors represented the findings of a study in an urban planning programme at the University of Auckland, that argued addressing this issue will require a shift in New Zealand's socio-cultural values that have historically placed a high value on private vehicle ownership (Wild et al., 2021).

Given the above information, it is evident that the efficient expansion of the PT infrastructure is critical to addressing the transportation challenges facing Auckland. However, the infrastructure needs of PT systems can be complex and require careful planning and resource allocation (Williams, 2022).

– Poor Network Connectivity

Ceder (2009) argued that insufficient connectivity can be a deterrent to passengers utilising public transit network connectivity refers to the degree to which different modes of PT, such as buses, trains, and subways, are integrated and connected. To consider this issue, they proposed a methodology for measuring the performance of mass mobility connectivity in Auckland. Their research found that the PT network in Auckland generally performs at a medium level in terms of overall connectivity. However, certain areas exhibit lower connectivity to employment centres and universities. Ceder (2009) suggest the use of a connectivity index to evaluate the number of potential journeys that can be made within a certain travel time threshold, while also considering the frequency and reliability of services.

Chowdhury et al. (2018) asserted that integrating different modes of PT, such as buses, trains, and trams, can lead to a seamless and efficient network that allows users to move from one mode to another without the need for additional tickets or transfers between different transport providers. Nevertheless, they declared coordinating and integrating different transport modes can be challenging, particularly in terms of ensuring that they are all running on time and that they are connected in a way that is convenient for users. For instance, if a bus arrives late at a train station, it may cause users to miss their connecting train, leading to frustration and inconvenience. It is important to ensure equitable access to integrated PT systems, including accessibility for users with different mobility needs. For example, disabled individuals may require additional accessibility features such as ramps or lifts to navigate the system (Chowdhury et al., 2018).

– Bus Driver Shortage

Campbell (2023) reported New Zealand's largest cities were having difficulty in managing the bus driver shortage, which is making passengers impatient and late for work. Furthermore, cancelled buses, three years of impending rail closures, and staff shortages on ferries are all contributing to the weakening of Auckland's PT system.

Chandiran et al. (2023) mentioned that the bus driver shortage can result in several issues, such as delays and cancellations, overworked drivers, increased costs, safety concerns, and decreased morale. The shortage can disrupt PT services, leading to inconvenience and disruptions for users specially students and their parents who are taking them to schools. Overworked drivers can compromise safety, increase the risk of accidents, and is a cause of fatigue and burnout due to the need to take on extra routes. Chandiran et al. (2023) showed how higher transportation costs leads companies to invest in new technology or equipment to improve efficiency and reduce the need for drivers.

In light of the above, it is apparent that Auckland's PT system is hampered by a cycle of interconnected problems. Increased use of private vehicles as a result of inadequate infrastructure creates traffic congestion and ineffectiveness of PT due to the weak network connectivity increasing people's reliance on their private vehicle. On the other hand, the lack of bus drivers raises the need for alternate modes of transportation. In order to increase the overall effectiveness, dependability, and accessibility of PT in Auckland, it is imperative to address each of these problems in detail.

DISCUSSION

Urban mobility planning is a comprehensive process that involves analysing transportation demand, identifying gaps and inefficiencies in existing systems, developing policies and plans, and implementing and monitoring transportation systems in urban areas (Ceder, 2021). It is a multifaceted and dynamic process that requires collaboration and coordination among various stakeholders to create sustainable, efficient, and equitable transportation systems that can address the complex social, economic, and environmental challenges faced by cities. The process utilises various tools, techniques, and methodologies to inform decision-making and ensure the planning process is inclusive, participatory and transparent (Ceder, 2021). However, according to Nieuwenhuijsen (2020) urban transport planning involves consideration of various actionable factors depending on the context of the planning activity such as urban planning, business planning, strategic planning, etc. that may interact with each other in complex ways, and planners must consider them carefully to develop effective plans.

Gao & Zhu (2022) determined that the effectiveness of PT hinges on various city attributes that necessitate careful consideration during the design and implementation of PT systems. Considering these factors, more efficient, accessible, and dependable PT systems that cater to the needs of all users, regardless of their geographic location or socio-economic status can be developed (Gao & Zhu, 2022).

On the other hand, the concept of AI-based automation has led to the development of powerful technology in various fields able to carry out operations like sensing, thinking, and decision-making that ordinarily need human intellect (Kar et al., 2019). Kar sated that the AI branch of machine learning is concerned with developing algorithms and statistical models that can learn from data and improve over time. Therefore, Ang et al. (2022) suggested upgrading the urban mobility planning of the cities is of great importance to adopt data analytics and machine learning in processing and interpreting large volumes of transportation-related data, such as traffic patterns, travel behaviour, and road conditions.

Recently, smart cities have been utilising Deep Learning (DL); a machine learning method to extract complex features based on artificial neural networks and Internet of Things (IoT) data analytics to support the development of smart cities Atitallah et al. (2020). For instance, DL and IoT big data analytics can be used to analyse traffic patterns and optimise traffic flow, reducing congestion and emissions (Heidari et al., 2022). Reis Da Silva (2023) examined how big data analytics would enhance PT efficiency in the city of Natal, Rio Grande do Norte (RN), Brazil. The same author published the applicable outcomes that could significantly enhance the efficiency of PT in the target city by implementing big data analytics solutions including DL and IoT (Reis Da Silva, 2023). However, there are several challenges associated with the use of DL and IoT big data analytics in smart cities (Reis De Silva, 2023). These include concerns around data privacy and security, the need for more interpretable and explainable DL models, and the development of more efficient and scalable DL algorithms. According to Atitallah et al. (2020), big data analytics based on DL and IoT have enormous potential to aid in the creation of smart cities and enhance residents' quality of life in several ways including improvements to the PT system. However, further research and innovation are needed to overcome the current challenges and fully realise the benefits of these technologies.

Nevertheless, there are challenges associated with implementing emerging technologies in smart transportation systems. According to Ang et al. (2022), firstly, data privacy and security are crucial issues that need to be addressed. Smart transportation systems rely heavily on collecting, processing, and analysing large amounts of data, including personal and sensitive information about individuals. Hence, it is crucial to make sure that data is gathered and utilised properly and that the proper steps are taken to preserve people's security and privacy. Secondly, the implementation of smart transportation systems requires collaboration between different stakeholders, including government agencies, the private sector, and citizens. The authors also state that, as smart transportation systems involve multiple components and systems, such as traffic management, PT, and vehicle technology, collaboration between different stakeholders is necessary to ensure that these systems work together seamlessly and that they meet the needs and expectations of all stakeholders.

Data Analytics and Artificial Intelligence for Public Transportation Infrastructure Expansion

As discussed in previous sections, the enhancement of the PT infrastructure network constitutes a crucial aspect of urban mobility planning, which can be effectively optimised through the utilisation of AI and data analytics (Ang et al., 2022). The adoption of data analytics methodologies enables PT agencies to acquire and process large volumes of data, thereby gaining invaluable insights that can facilitate informed decision-making regarding infrastructure design, optimisation, and maintenance (Ang et al., 2022). Zou et al. (2014), stated that several key areas can be measured and analysed, such as user flow, traffic patterns, travel time analysis, user behaviour analysis, and environmental factors in the design phase of PT infrastructure.

The utilisation of big data analytics allows the prediction of demand, optimisation of routes and schedules, and enhancement of service quality through the analysis of user flow data. This data assists PT agencies in identifying high-demand routes and allocating resources, such as additional vehicles or increased service frequency, to meet user needs (Welch & Widita, 2019). Furthermore, such insights can aid in the optimisation of transportation layouts to better align with user preferences and requirements (Abduljabbar et al., 2019).

The Massachusetts Bay Transportation Authority in Boston, United States of America, uses data analytics to monitor user flow in realtime, allowing the agency to optimise service frequency and capacity based on actual demand (Chen & Zegras, 2016). Public Transportation agencies use travel time analysis to evaluate PT performance and pinpoint areas for improvement (Ang et al., 2022). By gathering data on travel times and comparing them to expected times, PT agencies can identify and prioritise routes with frequent delays or bottlenecks, thus improving service reliability and reducing travel times (von Mörner, 2017). Das et al. (2017) explained that infrastructure improvements like road widening or signal optimisation can help alleviate congestion and reduce travel times, and using data analytics to identify areas where these improvements would have the greatest impact can help PT agencies efficiently allocate resources and provide better PT services to the users.

The New York City Department of Transportation, United States of America, uses travel time data to evaluate the performance of bus services and identify areas for improvement, such as bus lane prioritisation and signal optimisation (Yazici et al., 2012). Liu et al. (2021), claimed the importance of user behaviour analysis for understanding the required PT infrastructure. They noted the analysis help agencies identify improvement areas and meet the needs of their users. Finally, the analysis of environmental data, such as weather patterns, natural disasters and topography of an area can improve the resilience, effectiveness, and responsiveness of PT infrastructure (Liu et al., 2021).

In summary, the application of data analytics can provide valuable insights for PT agencies to make informed decisions about infrastructure design, optimisation, and maintenance, thereby optimising their operations and improving user experience in PT systems. Investment in data analytics methodologies is the recommendation of this study to address the insufficient PT network issue in Auckland. The recommended approach involves the collection and analysis of data on user flow, traffic patterns, travel time, user behaviour, and environmental factors to gain insights and facilitate informed decision-making in PT infrastructure design, optimisation, and maintenance. Despite the potential benefits of data analytics, concerns exist over data privacy and security, and the possibility of biases in data collection and analysis. Additionally, cost and feasibility issues may pose barriers for some transportation agencies.

Data Analytics and Artificial Intelligence for Network Connectivity

Transfer synchronisation plays a crucial role in providing the best possible travel experience for users by coordinating the arrival and departure times of linked services (Ibarra-Rojas & Rios-Solis, 2012). Gkiotsalitis et al. (2023) have emphasised that real-time control, a critical phase of transfer synchronisation, involves making timely adjustments to the timing of services based on real-time data such as user demand, delays, and disruptions. Their predictive models and optimisation algorithms to determine the best course of action and resulted successful implementation of real-time control for transfer synchronisation. These models require accurate and timely data, reliable communication systems, and effective coordination among stakeholders such as transport operators, traffic managers, and users.

Sumalee & Ho (2018) examined the combination of AI with technological advances like the IoT, which has the potential to transform PT systems. One of the key functions of AI in this domain is the development of Intelligent Transportation Systems (ITS), which can optimise PT networks by analysing real-time data on user demand, traffic conditions, and route schedules. This optimisation can reduce wait times and enhance operational efficiency by allowing for the optimisation of the routes and schedules of PT. Furthermore, the integration of emerging technologies can enable a more connected and intelligent PT system, facilitating real-time monitoring and control of traffic flow, as well as predictive maintenance of vehicles and infrastructure. Notably, explored ITS how can facilitate the development of smart cities, where PT is seamlessly integrated with other aspects of urban life, such as energy management and public safety. However, they observed that the implementation of ITS also presents significant challenges, including data privacy and security, the digital divide, and ethical implications (Sumalee & Ho, 2018).

This study endorses the realisation of the full potential of ITS requires collaborative efforts between industry, government, and academia, as well as investment in research and development. Ultimately, the investigation offers insightful information on the potential of cutting-edge technology to improve PT infrastructure.

The interconnection of rising technologies such as AI, big data analytics and IoT in the development of ITS are effective strategies for enhancing the optimisation of PT networks. Given the increasing importance of transfer synchronisation in PT operations and the potential benefits of the integration of emerging technologies in the development of ITS, findings of this investigation indicate and highly recommended policymakers in the PT industry to practice the application of real-time control in Auckland PT.

Data Analytics and Artificial Intelligence for the Bus Driver Shortage

The use of AI in PT automation has expanded the idea of driverless vehicles in PT systems. Artificial Intelligence-powered driverless vehicles, such as buses or trains, can navigate and make decisions without human intervention, and optimise routes based on real-time data on user demand and traffic conditions (Caballero Galeote et al., 2023). Artificial Intelligence algorithms can also analyse data on traffic patterns and predict congestion or other road hazards that may affect PT, enabling PT agencies to adjust routes and schedules in realtime. Bharadiya, (2023) reported that AI can be used to monitor the health of PT vehicles and predict when maintenance is required. By analysing data from sensors and diagnostic systems, AI algorithms can identify potential issues and schedule maintenance before a breakdown occurs, thereby reducing downtime and improve the overall reliability of PT services (Bharadiya, 2023).

Nikitas et al. (2021) explored the potential effects of driverless vehicles on employment in the urban PT industry and identified three potential scenarios: job creation, job displacement, or a mix of both. They suggested that the impact of driverless vehicles on employment will rely on a number of variables, including the rate of adoption, the type of vehicles utilised, and the state of the labour market. While there is a lack of consensus in the literature on the topic, the authors proposed policy recommendations, such as investing in skills and training programmes for employees, developing new business models for the PT sector, and implementing policies that support job creation and the growth of new industries. They stressed the need for proactive policy-making to ensure that the benefits of driverless vehicles are maximised while minimising potential negative consequences (Nikitas et al. 2021).

The EZ10 shuttle is a driverless vehicle that transfers users and has been undergoing testing on a medical university campus in Toulouse, France since early 2021 (Bateman, 2021). It is the first driverless vehicle in Europe to be authorised to operate on a public road in mixed traffic without a human attendant, and operates at Level 4 autonomy, making it the most intelligent driverless shuttle provider in the market. In contrast, Tesla's Full Driving Feature Car is classified as a Level 2 Society of Automotive Engineers (SAE) vehicle, which requires human supervision to some degree. The comparison highlights the EZ10 shuttle's technological advancements and potential for significant changes in the PT industry (Bateman, 2021).

Consequently, this investigation recommends further research on the potential impact of AI-powered driverless vehicles on employment, job creation and job displacement in the urban PT sector, particularly in the context of the scenarios identified in the Nikitas et al. (2021) study. It is important to consider the various factors that can affect the impact of driverless vehicles on employment, such as the speed of adoption, the type of vehicles used, and the labour market conditions. This investigation may help to develop strategies to maximise the benefits of driverless vehicles while minimising potential negative consequences. Additionally, investing in skills and training programmes for PT employees and developing new business models for the PT sector could help mitigate any negative effects on employment and support job creation and the growth of new industries. This could involve retraining PT drivers and other PT employees to work in areas such as vehicle maintenance, data analysis, software development and customer service (Nikitas et al. 2021).

CONCLUSIONS AND RECOMMENDATIONS

Based on the information provided, it is recommended that PT agencies in Auckland invest in data analytics methodologies to optimise the design, maintenance, and performance of PT infrastructure networks as a solution to address the insufficient PT network issues. The use of data analytics can provide PT agencies with valuable insights to make informed decisions about infrastructure design, optimisation, and maintenance. This would involve the collection and analysis of data on user flow, traffic patterns, travel time, user behaviour, and environmental factors to gain insights that could facilitate informed decision-making.

Correspondingly, the development of ITS can benefit from the incorporation of cutting-edge technologies like AI, big data, and IoT, which could improve the optimisation of PT networks through the analysis of real-time data. This article discusses information on the integration of emerging technologies in the development of ITS providing valuable insights into the application of real-time control and emerging technologies in increasing the operational quality of public transportation. It is recommended that scholars, practitioners, and policymakers in the PT industry consider this investigation to inform their decision-making and strategies.

Finally, another important development that could be used to improve the public transportation levels of Auckland PT users is the use of driverless vehicles. These vehicles are fully automated and connected to a real-time database, enabling them to make the best decision dependent on time and cost. This technology can further enhance the efficiency of PT systems by reducing the need for bus or train drivers, minimising human error, and allowing for more effective route planning and scheduling.

There is also a need for further research on the potential impact of AI-powered driverless vehicles on employment in the urban PT sector. This should focus on the three scenarios identified in the present study namely job creation, job displacement, or a mix of both. Various factors can affect the impact of driverless vehicles on employment, such as the speed of adoption, the type of vehicles used, and the labour market conditions. It is recommended that policymakers use the results of this investigation to develop strategies that maximise the benefits of driverless vehicles while minimising potential negative consequences. It is suggested that policymakers invest in skills and training programmes for PT employees and develop new business models for the PT sector to mitigate any negative effects on employment and support job creation and the growth of new industries. This could involve retraining bus and train drivers and other PT employees to work in areas such as vehicle maintenance, data analysis, and software development. Additionally, new business models might also be established to open new job prospects in sectors like fleet management and customer service.

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