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Evaluating the Impact of Improvement of Wayfinding at a Train Station: Agent-based Simulation Study

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Abstract

Major commuter railway stations tend to face issues with wayfinding, including ease of use & clarity. In peak times, users stopped at wayfinding signs & boards can cause congestion at key points on the concourse and on the platform. As a result, passenger satisfaction is negatively affected, and both occasional and regular users have their experience degraded. This study thus aims to improve passenger satisfaction in the passenger experience from when they first enter the station, until they board their train. This is achieved by moving wayfinding away from high-flow areas of the concourse and platform, and improving signage by making signage easier to read from a distance, simplify the network map to make it easier to understand where a train is going, and have dynamic displays. The proposed system causes the amount of time passengers spend at wayfinding to be reduced, as well as moving stationary and slow-moving passengers away from high-flow areas.

An agent-based simulation model is used to model dynamic behaviours of heterogeneous passengers along a platform as a proof of concept. This paper develops an agent-based model which enables the testing of various hypothetical scenarios, representing different positioning of wayfinding screens on the concourse & platform. The input parameters (passenger volumes and distribution of passengers along the concourse) for the simulation are prepared based on historical smart card data. The results from the simulation suggest that moving service points can ease congestion at key choke points, such as near escalators and in the middle of the concourse. Additionally, feedback on the passenger experience was obtained by an online survey to gain an understanding of the passenger experience and how it could be improved. The survey results are also used to extend the conceptual simulation model to reflect actual operations and passenger flow.

1. Introduction

Wayfinding is a crucial part of engineering design, as it determines how easily people can navigate around in a certain environment, as well as the impact that an individual person can have on the passengers around them, particularly during peak times. Wayfinding is formally defined as the use of sensory cues from the external environment (Farr, 2012). Poor wayfinding creates barriers to the effective usage of an environment, and this in turn has significant impacts on passenger flow through that space, which causes congestion (Wilson et al., 2007).

According to Kim et al. (2014), a station's layout also has an impact on station wayfinding. As it is difficult to quantify 'good' and 'bad' wayfinding, and no two stations are exactly alike in layout and usage, it is difficult to find a general solution to wayfinding issues. There has been little research conducted on the impact of wayfinding on passenger flow and passengers'

experience and overall satisfaction. While there are plenty of resources looking at wayfinding for passengers during emergency evacuations, or the qualitative impact of wayfinding on accessibility, there has been little inquiry into the impact of non-emergency wayfinding on passenger flow at railway stations.

This paper thus seeks to analyse the impact of wayfinding on passenger flow through the concourse and platform at Brisbane Central Station. The adopted approach of this research involves developing a pedestrian and railway simulation model for crowd analysis and scenario testing. This approach also includes a qualitative survey-based study to aid with understanding and identifying specific wayfinding problem areas at the station and what qualitative changes could be made.

Our results show that a major criticism of wayfinding is that it is unclear and lacking (i.e. there is a lack of maps, and the large bank of information screens results in an unnecessary abundance of information). From the simulation modelling, it is found that by moving wayfinding away from choke points, or by improving wayfinding, congestion is to be eased in trouble spots, such as in front of escalators and along key flow corridors.

The structure of this paper is as follows: First, we conduct literature review and start with providing background information for case study area at Brisbane Central Station in Australia. After discussing passenger flow data analysis based on smart card and manual observations, we explain about survey which is to be undertaken to adequately evaluate the relevance of this study to Central Station users. We then discuss about simulation modelling with three different scenarios while comparing between the current situation and possible improvements at Central Station. Afterwards, the results of the survey are discussed in detail with regard to wayfinding issues. We close the paper by briefly suggesting directions for future research and by proving a summarising conclusion.

2. Literature Review

The quality of passenger service provided by Brisbane Central Station is directly related to the station's level of service and ease of wayfinding for its users. To better facilitate passenger journeys and better accommodate both frequent and infrequent passengers at the station, available wayfinding facilities must be examined to isolate points of conflict or passenger confusion to ultimately improve the ease of passenger wayfinding.

Improvement of passenger wayfinding facilities ultimately results in an increase in the station's level of service capabilities and consequently an improvement in the quality of passengers' journeys. Better journeys encourage ridership, which leads to reduced road congestion and a more efficient transport network (Debrezion et al., 2008). An improvement in the ease of passenger wayfinding will result in a more 'socially-justifiable' decision-making process for passenger prioritising rail/public transportation over personal transport methodologies (Givoni & Rietveld, 2007).

Wayfinding is characterised by the ease of communication between the station facilities and the patrons using them (Apelt et al., 2007). The ease of wayfinding is dependent on the interfacing between the users' sensory inputs and the structuring of the station layout and facilities. In terms of passenger interfacing, Apelt et al. (2007) indicate that sensory inputs can be compartmentalised into auditory, visual, tactile and olfactory mediums. Successful wayfinding systems aim to target patrons' auditory, visual and tactile sensory inputs.

The work of Kim et al. (2014) determined that passengers' level of satisfaction and decision—making process to enter a platform using a particular entrance or to board/alight a specific train carriage is directly related to their individual journey circumstances. Passenger Information Systems (PIS) are also a consideration for the reduction of congestion caused by wayfinding complications from both frequent and infrequent users (Kim et al., 2014). PIS aim to provide frequent and rapid updates of train services, their schedules and their associated

platforms. This aims to reduce the confusion that passengers may experience when identifying the platform number of their respective train service from more traditional, static information screens.

Another consideration of passenger wayfinding revolves around the individual passenger's decision to alight or board a train at a certain position along the platform. A study by Chakour et al. (2013) concluded that passenger decision-making for boarding/alighting positions can be dictated by a multitude of factors such as parking availability, walking distances, station facilities, design (both at the boarding and alighting ends of the journey) and passenger crowding. Although these considerations in their entirety are beyond the scope of this study, summarised observations of passenger crowding at platform locations are included in successive passenger-flow simulations.

Regarding physical environmental factors, a study conducted by Kim et al. (2007) concluded that the familiarity that a patron has the layout of a particular station has a direct impact on their ease of wayfinding. Structural elements such as entrances/exits, elevators, escalators, transfer gates and platforms are all defined as points of interest within a station environment, with the station's layout dictating the journey passengers need to take to navigate from point-to-point (Apelt et al., 2007). Ease of wayfinding and ease of station navigation is also heavily influenced by crowding factors and the presence of individuals criss-crossing or not moving in a streamlined manner (Apelt et al., 2007).

Crowding in a confined space, is a key factor when examining the level of service of a station and has a large amount of leverage over passenger satisfaction levels and ease of wayfinding (Klumpenhouwer & Wirasinghe, 2016). Impacts of crowding can be exemplified in the form of passenger stress and anxiety as a result of limited mobility and increased noise within a station or train carriage environment, ultimately reducing the individual passenger's level of satisfaction with their journey. Increased level of passenger stress levels can also initiate inhibited cognitive processing abilities and increased feelings of personal invasion, both factors leading to a reduction in the passenger's ability to locate and interpret wayfinding information (Klumpenhouwer & Wirasinghe, 2016).

3. Background: Case Study Area

This paper conducts a case study while considering the passenger experience at Central Station in Brisbane, Queensland, Australia from when the passenger comes through the go card gates until they exit the train, or vice versa for arriving passengers.

The Brisbane Central Station consists of six platforms on three islands. Each platform island consists of two sets of stairs and escalators and one elevator. There are six sets of go Card (smart card for public transport in Brisbane) gates at Central Station, three are located at the concourse and three are located at the platforms as shown in Figure 1

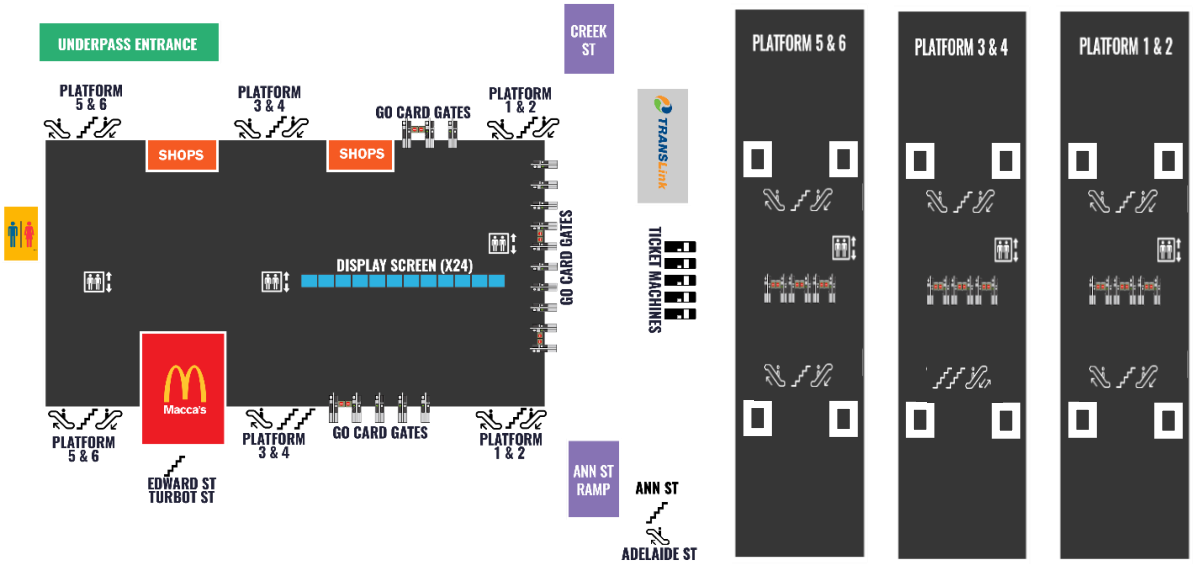
The first part of our work involves go card data extraction and analysis. This is required to produce a figure on overall passenger flows and see how the station is used. This information is relevant as it allows for the analysis of the number of passengers passing through the station in a 30-minute period, as well as the number of passengers using each island platform. This information is sourced by finding the lines servicing each platform. The analysis of go card data also allows us to find the busiest periods at the station.

Manual counts are also required, mainly to fill in the gaps where go card data is unable to complete the picture for passenger flows. For example, go card data does not say what gate a passenger uses, or what escalator or entrance they use. Counts were conducted for various flow points for 15 minute periods in the AM & PM peaks respectively.

Surveys are also conducted as part of our research work, and include information such as wayfinding service times, problems encountered by passengers at the station, as well as potential suggestions for improvement from passengers. From this data, a simulation model

using AnyLogic is created. Simulation modelling and analysis is discussed in detail in Sections 6 and 7.

Figure 1: Layout of concourse and platform islands at Central Station (Not to Scale).



4. Passenger Data Analysis

4.1. Passenger Flows

The actual number of passengers using Central Station is needed to understand the passenger flows at the station and the demand of each island platform. Smart card (i.e., go card in Brisbane) data for February 2016 provided by TransLink. Due to the large amount of data (more than 12 million sets of individual data) contained within the go card data, a data analysis tool written in C++ programming language was implemented. Go card data provided by TransLink contain information on all individual go card tap-on and tap-off transactions within the public transport network. Information recorded in go card data includes, operators of the specific transport mode, operation date, go card ID, tap-on and tap-off time and IDs of alighting and boarding stops. For this study, majority of the go card data is filtered out, leaving only rail data with Central Station as the origin and destination.

In Figures 2 and 3, there are seven different color lines, each color represents a day in a week, each line style represents each week of the month. The two plots indicate two distinct peak times on weekdays: a morning peak between 7:00 and 9:00 and an afternoon peak between 16:00 and 18:00. There are more passengers alighting but less boarding at Central Station during the morning peak, and more passengers boarding but less alighting during the afternoon peak. All weekdays passengers count follow the same pattern, however, Fridays (dark blue lines) has a noticeably lower passengers count. The usage of Central Station on Saturdays and Sundays (represented by purple lines) is significantly lower compare to other days of the week.

Figure 2: Number of alighting passengers at Central Station in February 2016.

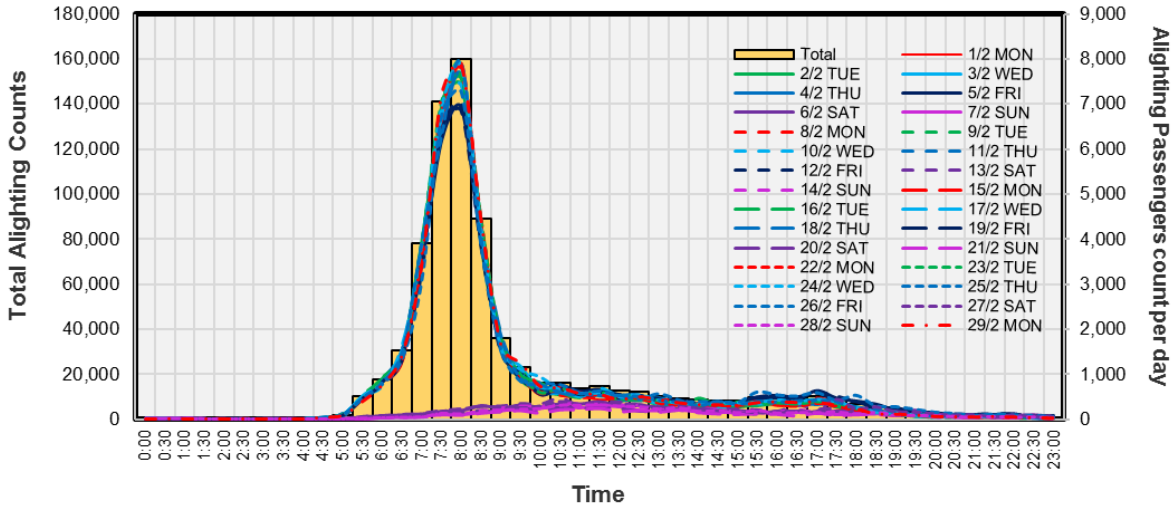


Figure 3: Number of boarding passengers at Central Station in February 2016.

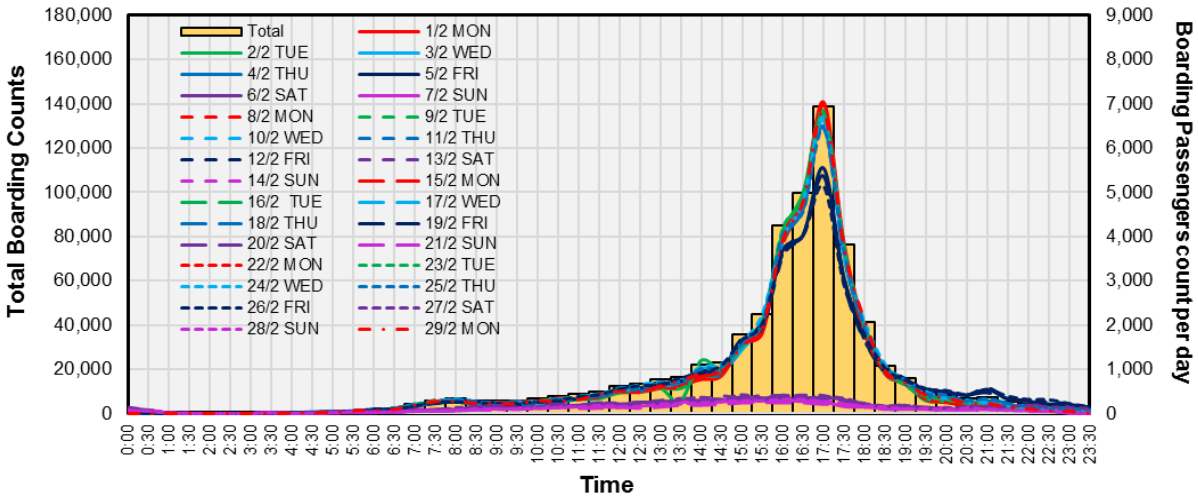


Table 1: Boarding and Alighting passengers count in February 2016.

Day	Day of the week	No. of Boarding Passengers	No. of Alighting Passengers	Fraction of Weekday Passengers in relation to Total Passengers
1	Monday	34654	35284	1.8%
2	Tuesday	34738	35314	1.7%
3	Wednesday	35029	35668	1.8%
4	Thursday	34834	35362	1.5%
5	Friday	34190	35776	4.6%
6	Saturday	6866	6802	
7	Sunday	5086	4944	
8	Monday	34519	35231	2.1%
9	Tuesday	35687	36390	2.0%
10	Wednesday	35494	36050	1.6%
11	Thursday	35281	36013	2.1%
12	Friday	33936	35518	4.7%
13	Saturday	7871	8020	
14	Sunday	6267	5874	

Day	Day of the week	No. of Boarding Passengers	No. of Alighting Passengers	Fraction of Weekday Passengers in relation to Total Passengers
15	Monday	34644	35344	2.0%
16	Tuesday	35462	36344	2.5%
17	Wednesday	35699	36605	2.5%
18	Thursday	35405	36238	2.4%
19	Friday	33982	35873	5.6%
20	Saturday	6935	5374	
21	Sunday	4758	3728	
22	Monday	35388	35674	0.8%
23	Tuesday	36259	36964	1.9%
24	Wednesday	36690	37363	1.8%
25	Thursday	35939	36810	2.4%
26	Friday	34160	36353	6.4%
27	Saturday	7550	7676	
28	Sunday	5531	5347	
29	Monday	35402	36244	2.4%

4.2. Passenger Island Proportions

There are 6 train lines in the Queensland railway network. Passengers who tapped-on or -off at Central Station were sorted by lines per their destination or origin stations depending on if they were travelling from or to Central Station. Subsequently, the passengers filtered by line can be sorted into which platforms they used base on trains schedule and timetable at Central Station. It is important to note that the passengers who used stations with multiple lines that go to Central Station were not identified into any lines and platforms due to the limitation of go card data and the program. Instead, the passengers were allocated to the platforms according to the passengers count ratio between them as shown in Figure 4. It is because the passenger's distribution at peak times are of the highest interest, passengers count at each platform at peak times were analysed.

Figure 4: Proportions of (A) Alighting and (B) Boarding passengers at Each Island at AM and PM Peak.

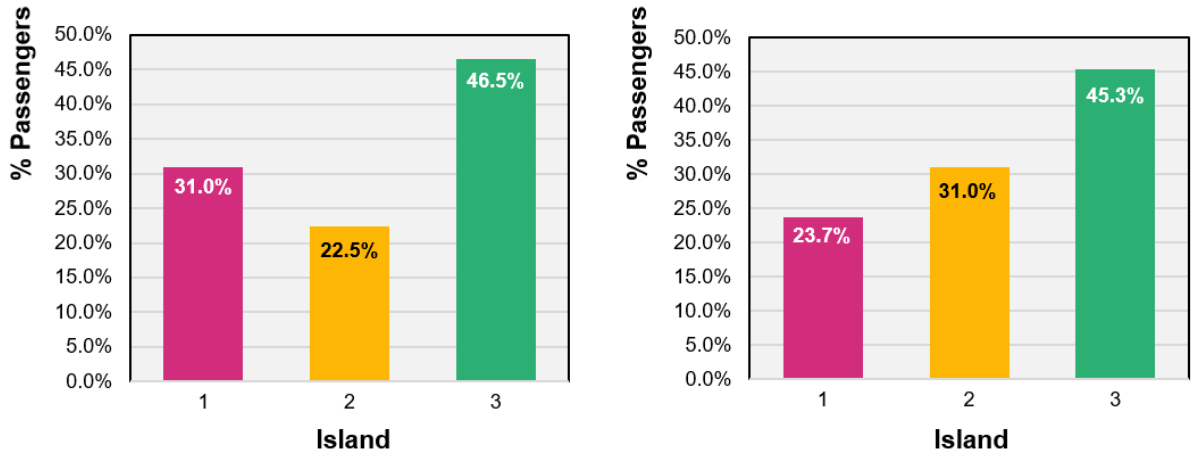


Figure 4 shows that Island 3, consisting platforms 5 and 6, has the largest proportion of passengers at both the AM and PM peak. Island 1, consisting platforms 1 and 2, has the second largest proportion of passengers at the AM peak but smallest proportion of passengers at the PM peak. Island 2, consisting platform 3 and 4, has the smallest proportion at the AM peak but second largest proportion at the PM peak. Referring to Figure 1, platforms 5 and 6

are the two platforms furthest away from the entrances in the concourse meaning, it increases the potential and likelihood of these passengers encountering points of conflicts as they proceed from platforms 5 and 6 to exit or from entrances to platforms.

4.3. Manual Passenger Counts

In order to find the number of passengers using each set of escalators and set of go card gates, manual passenger counts were conducted. This assisted in achieving a more detailed understanding of passenger flow within the station. Manual passenger counts were conducted at Central Station on two occasions, in the PM peak (16:15 – 18:00) on 17th May 2017 and in the AM peak (07:45 – 09:00) on 18th May 2017. These counts are included as Tables 5 & 6 in Appendix A.

Passengers were counted at each go card gate group, as well as at each entrance to the platforms, for a 15-minute period during the morning and afternoon peak periods.

Due to time limitations, the number of trains arriving and departing at Central Station were used as an indicator of peak times at Central Station, however, this turned out to be inaccurate. On site data collection was done before confirmation on peak times from go card data could be obtained, thus the AM peak data collection did not cover the entirety of the AM peak. Also, due to limited available man-power, the number of passengers going through entrances and access points to the platforms could not be counted at the same time, making the counts less reliable because number of passengers going to or leaving Central Station varies between each 15 minute period.

The only reasonable observations that can be drawn are that:

- South go card gates is used the most at PM peak for boarding passengers.
- South go card gates and main go card gates are used evenly (around 40% each) in the AM peak
- The number of people using lifts is insignificant (<1%) compared to overall passenger flow

Other trends that we noticed, but would require further data to confirm include:

- More passengers appear to use the northern entrance of Platforms 3&4 compared to the southern entrance
- Flow is roughly even between escalators for Platforms 1&2 and 5&6 in the peak direction.

If this exercise was repeated, passenger counts across the various access points would be done simultaneously, as well as over a longer period, in order to better understand passenger flows.

5. Survey

It was necessary to undertake a qualitative analysis to adequately evaluate the relevance of this study to Central Station users. Firstly, it was necessary to identify whether Central Station users recognised wayfinding as a problem which affected their overall journey and satisfaction of the venue. Following this, it was imperative to identify key problem areas which caused inconveniences or navigation difficulties for passengers to adequately define the problem.

5.1. Survey Set-Up and Distribution

A Survey was deemed to be the most effective method to collect this information. It was distributed widely over transport and general Brisbane lifestyle forums, and also within personal communication channels of the research team.

The questions posed are shown in Table 2 below.

Table 2: Survey Questions.

Question No.	Category	Question Type	Question
1			Gender
2			Age
3			Occupation
4			Main mode of transport
5			How frequently do you use Brisbane Central Station?
6		Multiple Choice	Have you ever had navigation issues at Central Station?
7		Free Response	Where and why did you have navigation issues?
8		Multiple Choice	How long do you think it took you to figure out where to go?
9		Multiple Response	How did you manage to figure out where to go?
10		Free Response	Do you have any comments/suggestions for improving navigation at Central Station?

It is worth noting that in the case of Question 7, survey takers were also given the option to share any issues they may have had with other rail stations in Brisbane, as this could bring any large scale, network-related wayfinding issues to light.

6. Simulation Model

A simulation model was created using AnyLogic™ to investigate the effect of changing wayfinding parameters and locations upon congestion at the station. The first part of building the model involved creating a 2D floorplan model in the software. As an exact floorplan of the station could not be, persona observations and photographs were used, along with dimensions of the trains and platforms to construct an adequate estimate of the platform space. This included train width, train length, escalator width and length, and the width of a standard & disabled go card date.

Platform 5 & 6 was modelled in the simulation, because the go card data indicated that it was the busiest platform. Furthermore, the principles used to improve flow on that island platform could then be extrapolated to the other island platforms at Central if proved successful.

Once the model was built, it was necessary to find the proportions of passengers using each group of go card gates, each platform, and each platform entrance, as mentioned in the section on data collection. This information turned out to be very important, because personal on-site observations indicated that the area with the most go card gates (Bank 1) had a much smaller passenger flow than Bank 2, despite Bank 1 being larger than Bank 2. In addition, a disproportionate number of passengers used Entry 1 to Platform 3&4 over Entry 2.

This process was undertaken for both departing & arriving passengers in both AM and PM peak. As arriving passengers can often interfere with passenger flow, it was important to account for both, even though the wayfinding needs of arriving passengers were not considered in the creation of the model. Finally, wayfinding service times and usage of wayfinding was considered. Due to restrictions in site access, assumptions were made on service time and the total proportion of people using wayfinding - 5% for both concourse and platform.

For the platform, a triangular service time was assumed, starting at 10 seconds and ending at 90 seconds, with a maximum at 45 seconds. For the concourse, a triangular service time distribution was assumed, starting at 30 seconds and ending at 300 seconds, with a maximum

at 90 seconds. For the reduced service times on the concourse, there was an assumption made that all three of the concourse service times were reduced by 50%.

Once all the data and model dimensions were collected, a logic flow for departing passengers was established as shown in Figure 5. The logic flow for arriving passengers was simpler. Passengers would disembark from randomly allocated doors of each train, before proceeding to the nearest platform exit, before arriving in the concourse and immediately preceding to the go card gates, where they exited the model.

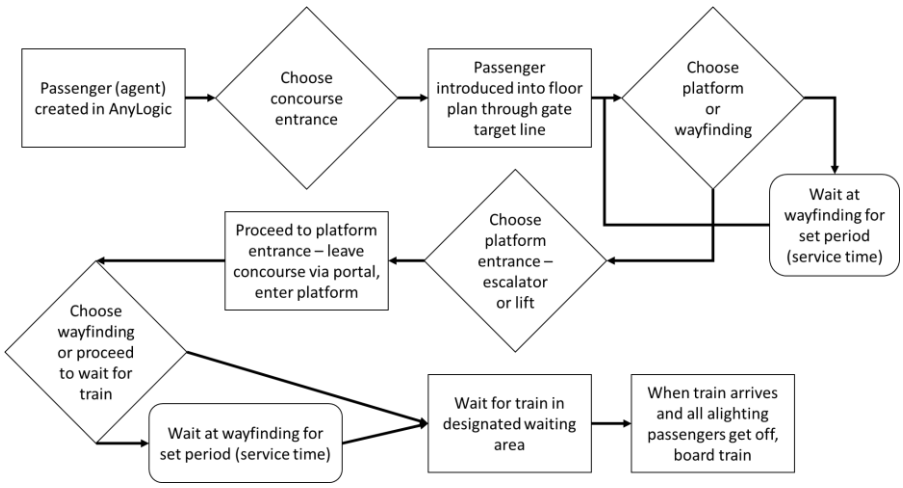
With all required data obtained and logic flow established for passengers, the final stage of the model could be built – the train and the process to board & alight passengers. This involved coding using Java to ensure that passengers only arrived on the platform when a train arrived at the platform, and only boarded while there was a train at the platform. In addition to this, each door was given a waiting area.

Three key assumptions were made in creating this model:

- There are no issues with passengers boarding the train – no carriage overcrowding or 'door-hopping' to find space
- That passengers spread themselves out evenly along the platform, and depending on their entrance, only go to a set amount of entrances
- That all passengers board the first train to arrive

Following this, analytics such as positioning of flow counters and heat maps were included.

Figure 5: Logic Flow followed by Agents (Departing Passengers).



7. Results: Simulation Model

The quantitative analysis was conducted by using AnyLogic simulation software to model the station both in its current form, with the following improvement scenarios:

1. Moving the information panels on the poles next to the escalator to poles further away from the escalators
2. Improving the information screens on the concourse such that service time is reduced
3. Moving the information screens away from the high-flow area of the concourse to an area of lower flow

The results from each simulation are best expressed graphically. In order to ensure easy comparison between the current situation and possible improvements, a simulation of the current scenario at Central Station was first run, with this current scenario displayed beside each simulated improvement.

Firstly, Figure 6 shows that moving wayfinding signage away from the escalator choke points causes a minor decrease in passenger density. It is notable that the reduction for the Exit 1 (on the left) is more significant compared to Exit 2 (on the right). This is likely due to the geometry of the platform. The wayfinding signage is located on narrow columns at Exit 1, meaning any congregation of people around these signs starts to immediately impact passenger flow coming from the stairs. By comparison, there are quite thick columns around Exit 2, meaning that passengers just passing through are 'funnelled' between the two columns. In effect, the choke point is caused by the columns, with the wayfinding having minimal impact on flow. In addition to this effect, more people use exit 1 to enter the platform than Exit 2, because there are both stairs and an escalator, compared to just an escalator.

Subsequently, Figure 7 shows that an improvement in the quality of signage and passengers' ability to find where to go. The density of passengers decreases, because the people who are trying to find their way around the station are no longer obstructing passenger flow by spending an extended amount of time at the wayfinding service point.

Finally, Figure 8 shows that a shift in the wayfinding stopping points reduces congestion. This is because passengers seeking wayfinding information are no longer interfering with passengers in the main area of flow. However, because the service times have not been improved, and passengers seeking wayfinding are funnelled into a reduced area, this does cause an increase in passenger density around the wayfinding.

On the whole, it observed that all three measures produce a reduction in passenger density. However, when comparing Options 1 and 3, it can be seen that Option 1 is the most desirable. For Option 2, the reductions are not as significant.

Figure 6: Improvement 1 – Wayfinding Moved Away from Escalators.

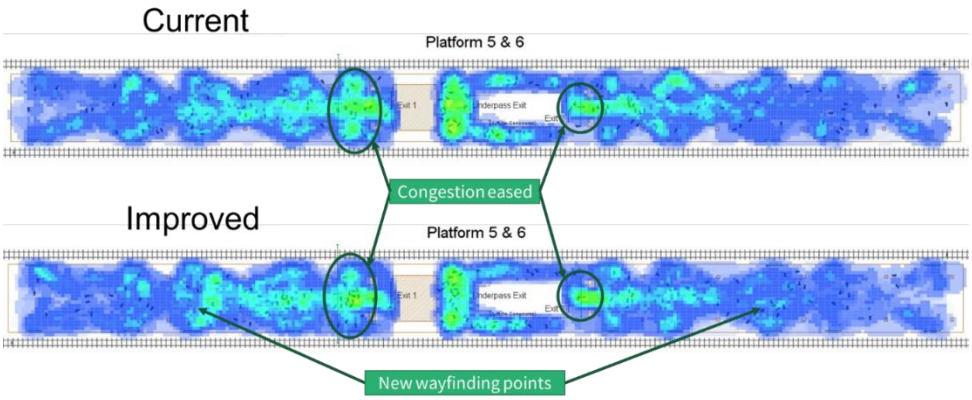


Figure 7: Improvement 2 – Reduction in Service Time.

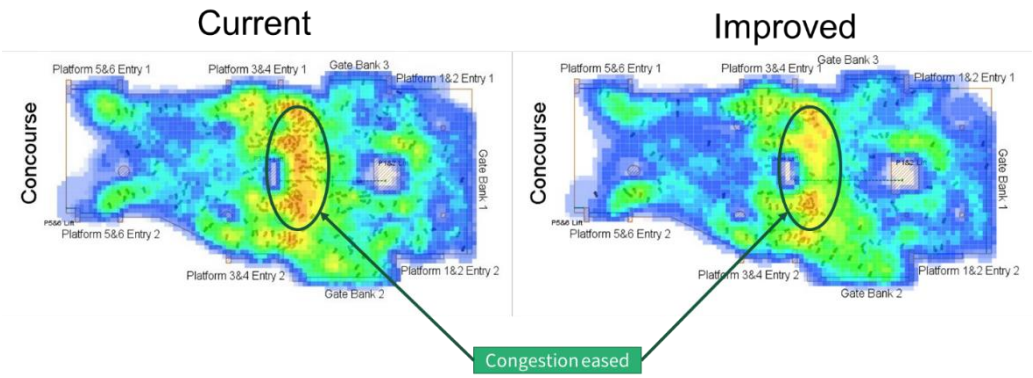
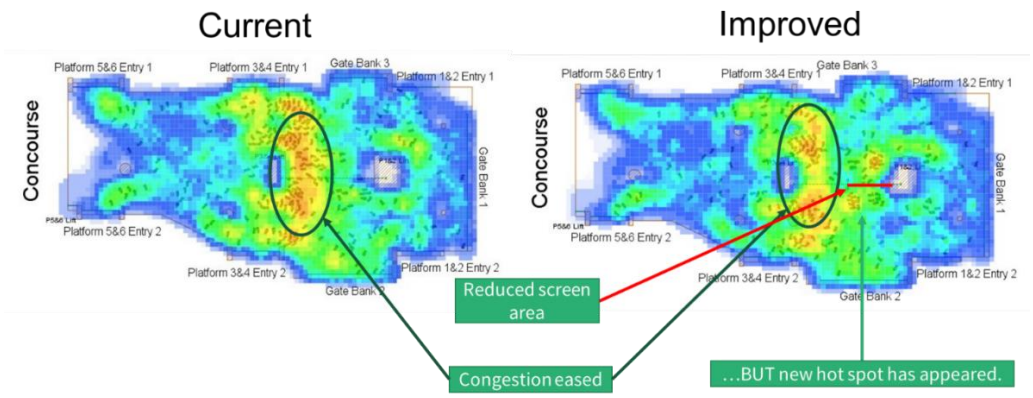


Figure 8: Improvement 3 – Concourse Wayfinding Moved.

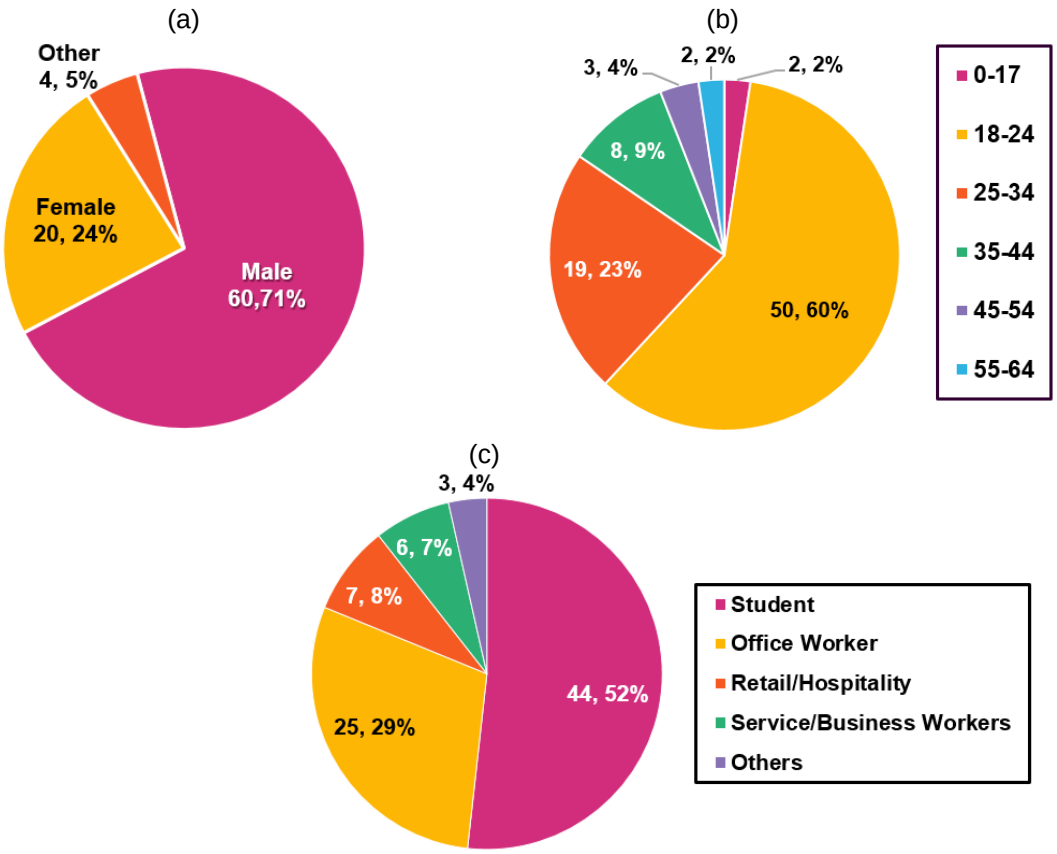


8. Results – Wayfinding Issues

8.1. Study Demographics

The demographics of survey-takers are summarised in Figure 9. The demographics are largely skewed towards males. Students and office workers make up 81% of overall occupations and the majority of survey takers are from the age ranges of 18-24 and 25-34.

Figure 9: (a) Gender of Survey; (b) Age of Survey-Takers; (c) Occupations of Survey-Takers.



The demographics of the survey may have a slight influence on the results obtained. Individuals with ages above 35 years old were very underrepresented as shown in Figure 9(b), although they are most likely to use Central Station to commute and constitute the majority of

office workers in the Brisbane CBD. Individuals with ages above 55 years old or individuals with disabilities, luggage or children may have had more difficulty navigating the station; however, there was no representation of such individuals and there were no survey questions to filter out any such physical incapacities.

Due to lack of clearance at Brisbane Central Station, the survey was only able to be distributed online and through personal connections of the creator; therefore, this limited the demographic that could be reached. Furthermore, one of the two major stakeholders – new passengers and tourists – could not be targeted at all.

8.2. Prevalence of Wayfinding Issues

The second category of the survey (containing Questions 4-6) focused upon the responders' main mode of transport, frequency of visiting or using Central Station and whether they have had any navigation issues at Central Station. The responses from these three questions were analysed individually to understand the survey population. Subsequently, Questions 4 and 5 were related to Question 6 to check for correlations between the two datasets.

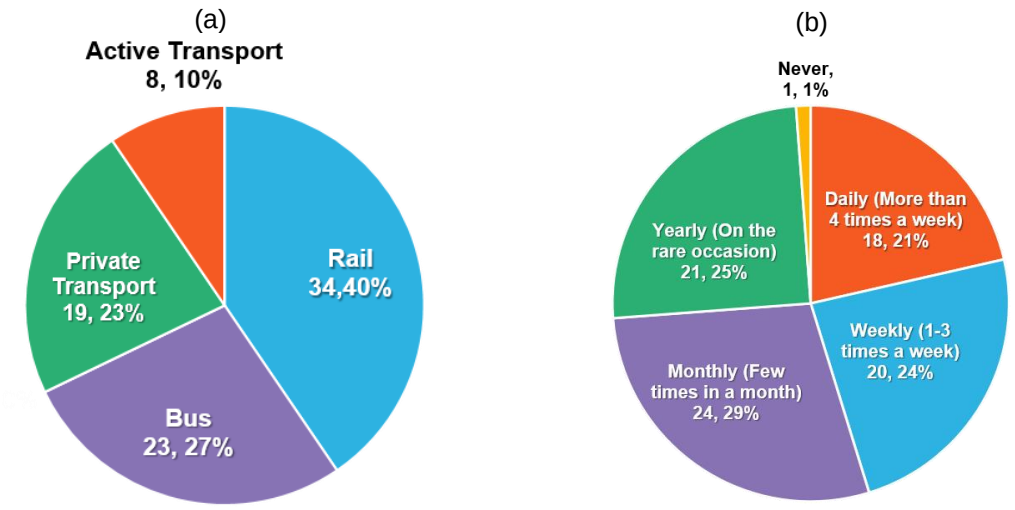
The analysis of these Questions 4-6 aimed to achieve the following:

1. Understand whether wayfinding is considered to be an issue at Central
2. Evaluate whether wayfinding issues are more prevalent for non-rail users or infrequent Central Station users

8.2.1. Overall Transport Mode Preference and Central Station Usage Frequency

The distribution of main transport types is shown in Figure 10(a) while the frequency of usage is shown in Figure 10(b). It is observed that 40% of the responders were rail-users; however, there is an even distribution amongst the other transport types. Furthermore, 99% have used Central Station before, which emphasises the fact that wayfinding issues have the potential to affect a large proportion of commuters who travel through the city.

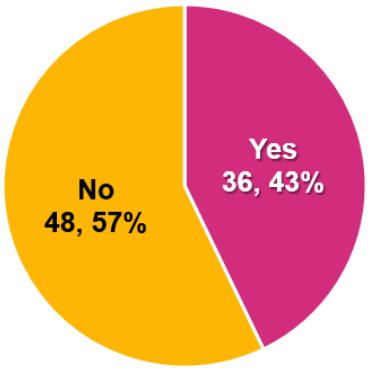
Figure 10: (a) Main Modes of Transport (Q4); (b) Frequency of Central Station Usage (Q5).



8.2.2. Existence of Navigation Issues

The proportion of individuals who have or have not had navigation issues is shown in Figure 11. The data shows that 43% of responders claimed that they have experienced navigation issues at Central Station while 57% have not had any issues.

Figure 11: Navigation Issues (Q6).

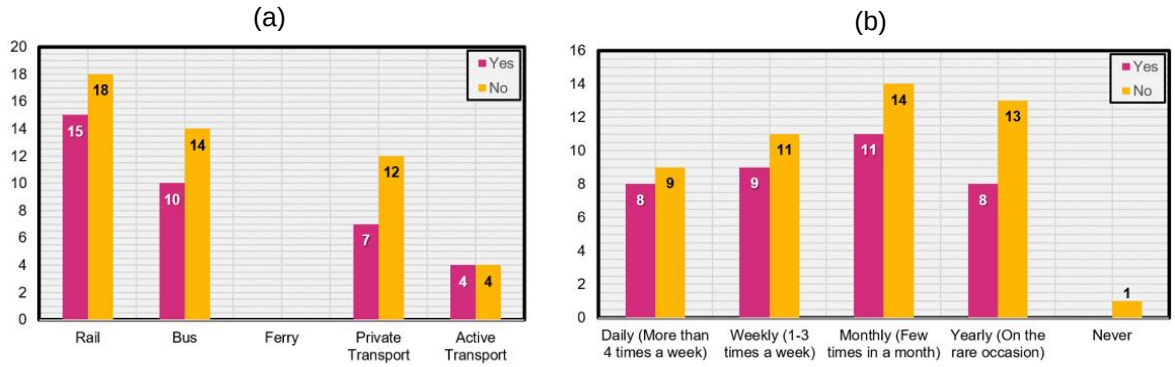


The proportion of individuals who answered 'yes' is close to half of all responders. This is significant because the presence of a large number of confused or lost individuals has the ability to disrupt the flow of passengers who are entering or navigating throughout the entrances, concourse, platforms and areas outside the concourse. This may cause large issues during peak hour, as passengers going against the crowd or blocking members of the crowd reduce the level of service of the station which may lead to congestion, physical inconveniences and passenger dissatisfaction.

8.2.3. Correlation of Navigation Issues with Inexperience

The prevalence of wayfinding issues with relation to passenger experience with: (A) the rail network; and (B) Central Station, are depicted in 12(a) and Figure 12(b) respectively.

Figure 12: (a) Wayfinding Issues in relation to Transport Modes; (b) Wayfinding Issues in relation to Frequency of Central Station Usage



The key observation from both figures is that there is very little correlation between venue and transport experience levels and wayfinding. In both figures, there were a larger number of passengers who did not have wayfinding issues for all categories; however, there were very small differences between those who answered 'yes' and 'no' for Question 6.

As shown in Figure 12(b), wayfinding issues are experienced by 45% of rail users experience at Central Station, which suggests that navigation issues extend beyond identifying the correct service and platform. Furthermore, it also suggests that Central Station may have a difficult layout and inadequate navigation facilities – which make the situation difficult for individuals who use other transport modes. This figure stays within 40-50% for bus and active transport users. However, only 24% of private transport users experienced wayfinding issues. It is worth observing that rail and bus are time-based transport systems, compared with private transport which allows a larger amount of flexibility for individuals. Regular users of private transport may only use the rail network during times of leisure; therefore, they may not feel a sense of urgency when navigating around Central Station. The lack of urgency may influence the

mindset of travellers, as they have more time to observe all wayfinding facilities and make decisions about their travel path.

Figure 12(a) shows that individuals who use Central Station infrequently had a larger tendency to answer 'no' to Question 6 – this is shown by a decreasing proportion of 'yes' answers with decreasing frequency. Out of the passengers who used Central Station daily, weekly and monthly, 44-47% indicated that they have had wayfinding issues. This illustrates that there is no correlation between experience and the prevalence of navigation issues. Furthermore, it confirms that there is an urgent need for improvement in the wayfinding infrastructure, as such a large proportion appear to be dissatisfied. Therefore, these analyses confirm that the study is justified and its outcome is beneficial to a large proportion of people.

8.3. Wayfinding Issues

8.3.1. Problem Areas

The key problem areas identified by manually categorising the word response under the following key terms:

- Passenger Information Systems (PIS)
- Display Screens
- Signage
- Navigation; and,
- Accessibility.

The responses were then further categorised in sub-labels which were tagged to each of the key problem areas. The tags were related to specific issues shared by survey-takers in Question 7. A summary of all the data is shown in Table 3.

Table 3: Key Problems and Sub-Categories of Survey Wayfinding Issues (Q7).

Key Problems	Sub-categories	Relevant Issues
	1.1. Platform Changes	1.1.1. Last minute platform changes 1.1.2. Communication is ineffective in informing passengers well in advance of any changes 1.1.3. Renovation works are causing regular platform changes 1.1.4. Navigating to the correct service in a timely fashion is difficult due to last minute changes
	1.2. Network/Station City Maps	1.2.1. Finding relevant train network and platform is difficult due to lack of large network maps 1.2.2. Navigating into the city from Central station is difficult due to lack of city maps
	1.3. Finding Platforms/Relevant Train Network	1.3.1 See 1.2.1. above 1.3.2 Information systems are lacking, due to: • Inadequate signage • Confusing screens and train lines • Confusing station and concourse layout
	2.1. Visibility	2.1.1. Information on display screens is difficult to see and read due to: • Font choices • Text colour choices • Text size being too small
	2.2. Overstimulation	2.2.1. Information on display screens is abundant and difficult to process in a short time 2.2.2. Too many screens
	2.3. Positioning	2.3.1. Columns are blocking the long-distance view of screens 2.3.2. Diagonal configuration of screens make it difficult to see information from a distance 2.3.3. Reading screens is difficult while moving

Key Problems	Sub-categories	Relevant Issues
3. Signage	3.1. Low visibility	3.1.1. Platform numbers are difficult to see when navigating the concourse 3.1.2. Signs are too small to notice 3.1.3. Exit signs are not adequate and cause confusion when leaving the station
	3.2. Lack of signage	3.2.1. Amenities (e.g. toilets) are hard to find due to insufficient signage 3.2.2. Navigating from station to exits and then into the CBD is difficult due to limited signage
	4.1. Finding Entrances/Exits	4.1.1. Finding stairs connecting the platform to concourse and exits (underpass) is difficult 4.1.2. Finding a way out of the station is difficult for newcomers
	4.2. Finding Platform/Concourse	4.2.1. Finding the entrance to a platform 4.2.2. Finding the relevant elevator for a platform 4.2.3. Reaching platform from tunnel
	4.3. Underpass	4.3.1. Navigating through the underpass to the correct platform is difficult 4.3.2. Navigating from the platform to the correct exit (i.e. Adelaide St or ANZAC Square)
	4.4. City	4.4.1. No visual cues are there to guide passengers after leaving the station; therefore, they cannot figure out the CBD's street layout 4.4.2. See 1.2 4.4.3. Orientating oneself with respect to the surrounding area is difficult after exiting the ticket gates
	5.1. Congestion	5.1.1. A large of flow of passengers is confusing for individuals and may alter their original direction of movement 5.1.2. Positioning of screens in the middle of the concourses causes congestion due to a large number of stationary passengers looking at screens 5.1.3. Moving down stairs/escalators and looking for platform is difficult during peak hour
	5.2. Time	5.2.1. Underpass closed later in the evening makes it difficult to navigate into the station
	5.3. Intuitiveness	5.3.1. Layout is unintuitive 5.3.2. Sharp turns cause passengers to go to wrong platforms

The relevant issues for each sub-category in Table 3, are usually a combination of the sub-categories. It is worth noting that the issues of congestion caused by wayfinding or stationary passengers may have a large impact on physically impaired passengers or individuals who are carrying luggage and minding children. Therefore, this poses a health and safety risks.

Many responders felt that the lack of simple wayfinding options such as large network maps and city maps would improve the process. There are network maps outside the concourse and on the columns of platforms; however, these are inconvenient locations which do not facilitate quick decision-making from passengers. The issues of navigating into the CBD from Central Station and vice versa would be a large difficulty for tourists and new passengers, based on the responses.

8.3.2. Prevalence of Problem Areas

It was observed that 10 of the responders who claimed that they did not have any wayfinding issues, still shared points which may cause issues for others. Therefore, the overall values and proportions do not align directly with the number of responders who answered 'no' to Question 6. The prevalence of key problem areas can be seen in Figure 13. Furthermore, the prevalence of each sub-category can be seen in Figure 14.

Figure 13: Prevalence of Problem Areas at Central Station.

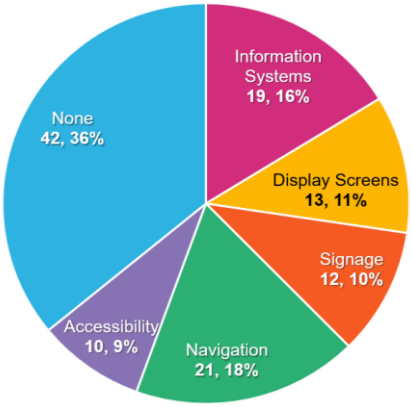
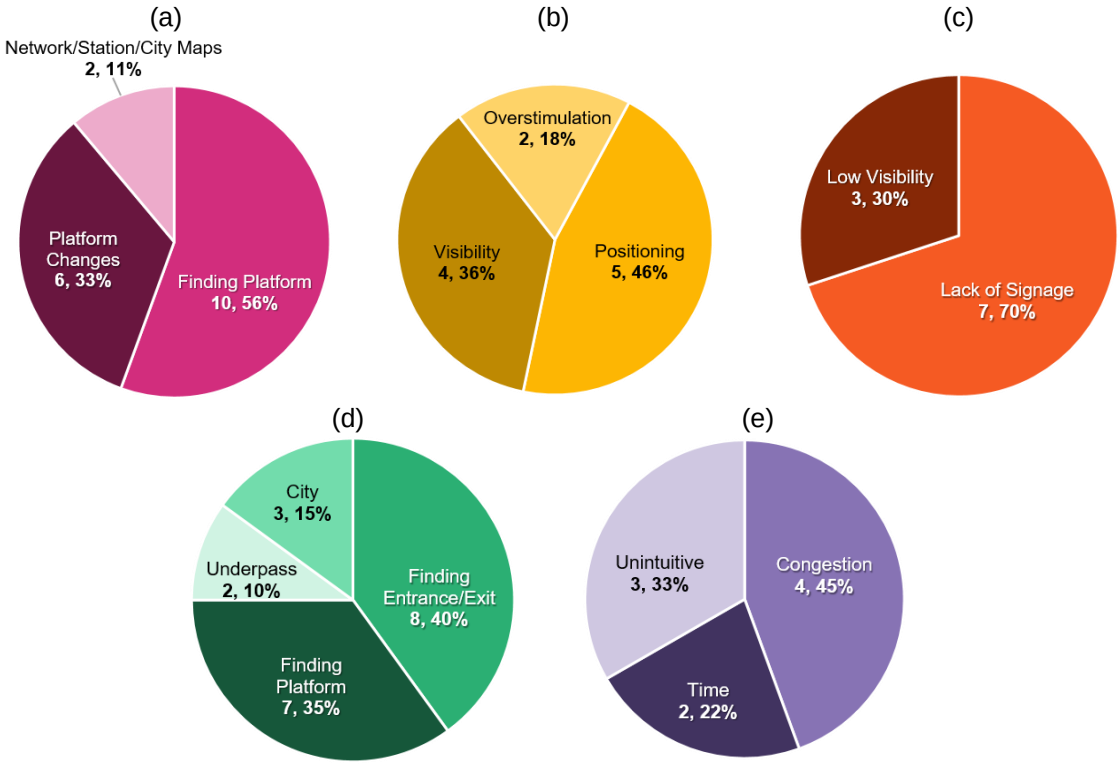


Figure 14: Prevalence of Sub-Categories of Problems: (a) Passenger Information Systems; (b) Display Screens; (c) Signage; (d) Navigation; and, (e) Accessibility.



It is observed that there is an even distribution between the five key problem areas, with navigation and information systems accounting for 18% and 16% respectively (a total of 34% of responses). This indicates that there is a need for improved communication systems in the station, and reduction in the dependency of the display screens for all information. There were no mentions of the Translink mobile phone app, and its use at the station; therefore, it can be assumed that the app is not the primary source of information for the responders. This means that a better communication system must be implemented at the station itself, to ensure that all platform changes and events are relayed to passengers to make the wayfinding decision making process faster.

8.4. Survey Recommendations

The final question (Question 10) of the survey allowed its takers to share recommendations for improving navigation at Central Station. The responses fell under the same key areas identified in Table 3 of Section 148.3.1. The recommendations are summarised in Table 4.

Table 4: Recommendations from Survey.

Key Problems	Relevant Issues
1. Passenger Information Systems	1. Having large and eye-catching city and network maps inside and outside the station at convenient locations 2. Showing landmarks on a large city map so that passengers can orientate themselves and know how to get to their destination 3. Using clearer descriptions of train destinations when announcing (i.e. 'this is a southbound training stopping all stations' instead of 'stopping all stations to destination') 4. Automated announcements for the train instead of manual ones 5. Providing up-to-date station information for mobile phone users (potentially through the Translink app)
	1. Replacing the static digital signage at platform entrances with dynamic signage which shows trains currently on the platform or trains due to arrive soon 2. Flashing alerts on digital signage and PIS displays when a train has arrived at the platform
	1. More signage to indicate entry and exit options for passengers (including small stairwells and the underpass) 2. Including signage above platforms which also shows the trains which normally go to that platform 3. Signage to city landmarks
4. Accessibility	1. Improving the separation of passenger flows through: • Separate stairwells for incoming and outgoing passengers • Walking lines 2. Opening underpass to 24/7 access

9. Conclusions & Future Work

Obtaining proportions of both arriving and departing passengers flowing through each go card gate entrance, each pair of platforms and each set of escalators meant that our simulation model was a very accurate representation of the station and a strength in the design of our model.

Another strength in our model was the accuracy with which the model recreated the Central station environs. This model looks at both the concourse and the busiest platform, and could easily be expanded to allow the analysis of the other island platforms as well. This not only allowed for the thorough analysis of the task at hand.

However, if the study were repeated, we would look to collect multiple days of data so as to get a more accurate representation of the number of passengers using each entrance, as well as using longer sample periods. For example, collecting data over a one-hour period rather than over a 15-minute period.

A weakness in our model was our inability to obtain data in terms of the percentage of people using wayfinding, as well as statistics in terms of how long a passenger takes to find the information they require at a wayfinding point. If given the opportunity to repeat the study, we would look to collect data on how many passengers stop at wayfinding, as well as statistics on the number of passengers requiring assistance from station staff.

A final weakness in the model was the way passengers were taken between the concourse and platforms. An exit/entry logic flow was used, rather than AnyLogic's inbuilt stairs/escalator

function. Again, due to restrictions in data collection as well as the availability of technical data, this study was precluded from including such detail.

Our survey also featured strengths and weaknesses. The survey was highly detailed, covered all the necessary information required and provided a lot of useful data. Weaknesses in the survey included a limited sample population and a lack of interaction with target demographics, such as tourists and the elderly. If the survey data were to be collected again, improvements such as longer survey times, as well as site visits to collect data from passengers at the station, would all be considered.

A potential area for further study would be the wayfinding needs of arriving passengers. A comment made by several passengers in our study was that wayfinding for arriving passengers was confusing. A future study into wayfinding for arriving passengers may look at how to improve the clarity of signage, as well as the positioning of any locality maps at the station. Such a case study at Central could be expanded to other stations across Brisbane, or comparisons made with other major stations in Australia or around the world.

Another potential area for study would be to go down the path of looking at the quality of wayfinding. A future study could look into what makes good wayfinding, how a network can be designed so it is easy to get around and so forth. Finally, further study could conducted into the positioning of wayfinding at station. As was discussed in the third simulation, moving wayfinding away from high flow areas improves overall amenity. However, wayfinding situated in hard-to-find areas may actually work against the purpose of having signage, making it more difficult for passengers to find their way around and resulting in passenger walking aimlessly and causing flow reductions.

This study briefly touched on this by moving the wayfinding points away from the escalators (see Figure 6), but there are numerous human factors to consider when it comes to finding signage & information at stations.

10. Acknowledgements

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11. References

Apelt, Ron; Crawford, John; Hogan, Dennis. (2007). Wayfinding Design Guidleines. *CRC Construction Innovation*, 1 - 68.

Chakour, V., & Eluru, N. (2013). Analyzing commuter train user behaviour: a decision framwrok for access mode and station choice. *Transportation (2014) 41*, 211 - 228.

Debrezion, G., Pels, E., & Rietveld, P. (2008). Modelling the joint access mode and railway statioon choice. *Transport Research Part E*, 270 - 283.

Farr, A. (2012). Wayfinding: A simple concept, a complex process. *Transport Reviews, Vol 32, Issue 6*, 715 - 743.

Givoni, M., & Rietveld, P. (2007). The access journey to the railway station and its role in passengers satisifaction with rail travel. *Transport Polciy 14 (2007)*, 357 - 365.

Kim, H., Kwon, S., Kook Wu, S., & Sohn, K. (2014). Why do passengers choose a specific car of a metro train during the morning peak? *Transportation Research Part A*, 249 - 258.

Klumpenhouwer, W., & Wirasinghe, S. (2016). Cost-of-crowding model for light rail train and platform length. *Public Transport (2016) 8*, 85 - 101.

Wilson, J., Norris, B., Clarke, T., & Mills, A. (2007). *People and Rail Systems - Human Factors at the Heart of the Railway.* London: Ashgate Publishing.

12. Appendix

Table 5: 17-May-2017 PM Peak Manual data collection data.

Date	Start Time	End Time	# Trains	Description	Boarding	Alighting
5/17/2017 (WED)	16:15	16:29	17	Main Go Card Gates	296	98
	16:15	16:29		Go Card Gate North	280	15
	16:15	16:29		P5&6 North	484	107
	16:15	16:29		P3&4 North	284	49
	16:15	16:29		P1&2 North	154	38
	16:30	16:44	15	Main Go Card Gates	370	69
	16:30	16:44		Go Card Gate North	437	10
	16:30	16:44		P5&6 North	653	37
	16:30	16:44		P3&4 North	332	46
	16:30	16:44		P1&2 North	398	63
	16:45	16:59	14	Go Card Gate South	1057	96
	16:45	16:59		Elevators	20	10
	17:00	17:14	16	P5&6 South	645	31
	17:00	17:14		P3&4 South	216	27
	17:00	17:14		P1&2 South	297	38
	17:00	17:14		P5&6 Underpass	578	9
	17:00	17:14		P3&4 Underpass	341	6
	17:00	17:14		P1&2 Underpass	254	10
	17:15	17:29	15	P5&6 South	323	56
	17:15	17:29		P3&4 South	179	20
	17:15	17:29		P1&2 South	214	40
	17:15	17:29		P5&6 Underpass	429	13
	17:15	17:29		P3&4 Underpass	336	3
	17:15	17:29		P1&2 Underpass	434	24
	17:30	17:44	12			
	17:45	17:59	14	Go Card Gate South	809	36
	17:45	17:59		Elevators	8	1

Table 6: 18-May-2017 AM Peak Manual data collection data.

Date	Start Time	End Time	# Trains	Description	Boarding	Alighting
5/18/2017(THU)	7:45	7:59	21	Main Go Card Entrance	16	1206
	7:45	7:59		Go Card Gate South	38	1217
	7:45	7:59		Go Card Gate North	15	585
	7:45	7:59		P5&6 North	60	991
	7:45	7:59		P3&4 North	34	505
	7:45	7:59		P1&2 North	61	240
	8:00	8:14	16	Main Go Card Entrance	13	1326
	8:00	8:14		Go Card Gate South	47	1136
	8:00	8:14		Go Card Gate North	14	503
	8:00	8:14		P5&6 North	103	715
	8:00	8:14		P3&4 North	55	1050
	8:00	8:14		P1&2 North	127	664
	8:15	8:29	17	P5&6 South	0	596
	8:15	8:29		P3&4 South	10	129
	8:15	8:29		P1&2 South	11	431
	8:15	8:29		P5&6 Underpass	2	630
	8:15	8:29		P3&4 Underpass	3	212
	8:15	8:29		P1&2 Underpass	4	497
	8:30	8:44	11	Elevators	13	19
	8:45	8:59	16	P5&6 South	0	396
	8:45	8:59		P3&4 South	10	126
	8:45	8:59		P1&2 South	24	246
	8:45	8:59		P5&6 Underpass	5	355
	8:45	8:59		P3&4 Underpass	1	103
	8:45	8:59		P1&2 Underpass	0	224