New Travel with SMRT-Q:
Innovation towards Smart Transport

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1 Introduction

1.1 Background

Singapore is moving forward in becoming a Smart Nation, to improve the lives of citizen, building stronger communities and making way for opportunities by harnessing technology. This proposal focuses on smart mobility and transport, which is one of its initiatives in pursuing a Smart Nation.

1.2 Problem Statement

Singapore's Prime Minister, Lee Hsien Loong, declared the intention for Singapore to be a Car-lite country. However, Singapore has limited land to accommodate the large traffic figures so the Government started implementing various regulations such as Certificate of Entitlement (COE). In an ideal situation, all the methods should allow the number of vehicles on the road to be reduced while not affecting the efficiency and productivity of individuals who needs transport. However, there are still challenges that people face.

One of the challenges is in the efficiency of public transport and delivering positive commuter's experience. Singapore has 3 main public transports: the Mass Rapid Transit (MRT) & Light Rail Transit (LRT); public buses by SMRT, SBS, Tower Transit and Go-bus; and the Taxis. The most commonly used transport is the MRT.

Due to the rising population and the curbing of private vehicle ownership, there has been an increase in MRT commuters which caused both SMRT and the commuters to face the problem of congestion in trains and on the MRT platforms, due to the heavy human traffic, during peak hours. Currently, the congestion-easing measures carried out by SMRT are increasing the frequencies of the train intervals, and the deployment of staffs to guide the human traffic flow on the platforms. These initiatives are costly in the long run and apparently, are inefficient in alleviating the problem.

Therefore, there is a need to create an Information System (IS) that can strategically complement the current initiatives by leveraging information technology (IT) to offer a better travelling experience for the commuters. We will do this by providing better advisory of emptier carriages and open more doors for future SMART initiatives in transport and mobility. These efforts would provide opportunities in managing the crowd congestion in trains and on platforms, and points out the weaknesses of the co-existing efforts that can be improved, based on organizational learning on commuters' activities and behaviours.

1.3 Methodology

The information for this proposal will be obtained through research and also thorough analysis of data from surveys, interviews and observations etc. The data will be used to help shape the Information System that integrates and delivers meaningful information for users in taking the MRT.

1.4 Scope of the Report

The report introduces the problems faced, the background of SMRT and its current IS. Based on the hypotheses, research will be carried out to propose an add-on prototype IS designed to conduct and improve all the initiatives taken and take it to a more strategic application of Information Technology (IT).

2 Singapore Mass Rapid Transit Pte Ltd (SMRT)

2.1 Background of Organization

SMRT Corporation LTD (SMRT) is a land transport provider in Singapore whose core businesses involves train operations, and providing bus, taxis and automotive services. They also venture into retail, media & marketing business, property & retail management. Overall, SMRT does Public Transport and Non-Public Transport Operations. (SMRT, n.d.)

SMRT faces various problems in its main public transport operations from major train breakdowns, managing large human traffic on train platforms to commuters' relationship management. Thus, SMRT has come up with many initiatives such as providing free bus services in event of breakdowns, free rides during pre- and post- peak hours and deploying staff as marshals on station platforms.

2.2 Train Capacity

As of October 2016, there are 5 main MRT lines: North-South Line, East-West Line, North-East Line, Circle Line, and Downtown Line. Each MRT line has different trains which holds different capacities that cater for the commuters.

For the Circle Line and Downtown Line, the train has 3 cabins in total. At its maximum capacity, each train can carry up to 931 passengers. ("Circle Line | Projects | Public Transport | Land Transport Authority", 2016)
As for the North-South and East-West line, the train has 6 cabins. At its average capacity, each train can carry up to 1920 passengers. ("Siemens C651", 2016)

Table 1 (shown in Appendix A) is a representation of the statistics involved in SMRT Operations. It shows that the average car occupancy is 63.4 passengers.

2.3 Current Information Systems (IS)

There are a variety of Information Systems that are set up on MRT stations, platforms and even in the trains as well. These IS provides real-time travel-related information for the commuters. ("Information Systems", 2016).

2.3.1 MRT Stations/ Platforms

There are Information Systems such as Rail Travel Information System (RATIS).

RATIS is a system that shows the destination and the estimated arrival times (ETA) of the next two trains at each platform on the plasma displays, RATIS Extension and LED displays that are either found on the platforms or around the MRT station.

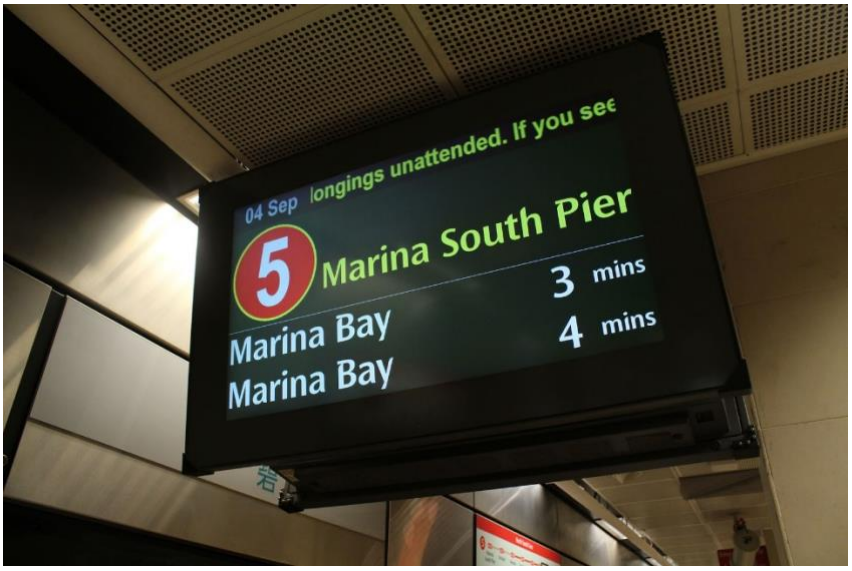

Figure 1: A plasma display showing the destination and ETA of the next two trains. ("Information Systems", 2016)

2.3.2 MRT Trains

One of the Information Systems found in trains is the SMRT Active Route-Map Information System (STARiS). It is almost similar to the RATIS system, however, it has two different functions: a dynamic route map and a textual Vacuum Fluorescent Display (VFD). ("Information Systems", 2016)

The system would be able to retrieve information about the location of the train when leaving or arriving the MRT station. The dynamic route map then displays the route information for commuters, and also informs them on which side the doors will open.

Figure 2: A route map showing the next station that the train is approaching. (Unique & Dynamic Travel Information System, 2016)

The VFD screens retrieves the information of the precise location of the train and then provides information on the current and next station, the terminating station and transfer information and textual representations of audio announcements played in trains. ("Information Systems", 2016)

Figure 3: A VFD screen that indicates 'doors opening' when the train is arriving the next station. (Unique & Dynamic Travel Information System, 2016)

3 Research Framework

3.1 Case Study

On 22 August 2014, TodayOnline published an article titled “10 more MRT stations to get “traffic lights” showing crowd levels”. It is reported that 10 more MRT stations are implementing the “traffic lights” system (Fang, 2014). With these traffic lights, commuters are able to adjust their travel planning accordingly. However, as Nanyang Technological University Assistant Professor, Walter Theseira (2014) said, this system is useful only in situations where good transport alternatives are available for commuters. Otherwise, these traffic indicator lights would not affect passengers’ decision-making. Therefore, this system has some limitations to some degree.

Our team was inspired by this system. Although SMRT has installed traffic lights to inform commuters about the general crowd level in the station, we believe that indicator lights could be used in a better fashion. Our team uses indicator lights to show a more accurate interpretation of the crowd level in every carriage. Our prototype system will make use of its indicator lights to give advice to commuters on which doorway to queue for emptier carriages.

Figure 4: The photo shows the current ‘traffic light’ system in operation.

3.2 Hypotheses

Problem: MRT is the most heavily depended mode of transportation in Singapore. According to Land Transport Authority (LTA), more than 2.5 million people take SMRT everyday ("Riding a Train | MRT & LRT Trains | Public Transport | Land Transport Authority", 2015). However, there has been a steep increase in the number of MRT commuters. Because of this, congestion has become a critical problem, especially during peak hours. Most commuters are uncertain on which train carriage is emptier. Hence, they are unsure of where to queue on the platform. This uncertainty has led many commuters to stand at the nearest door after coming up or down from the escalators, which results a build-up of crowd in front of those doors.

Consequently, it is not possible for these commuters to board quickly due to the crowd. Sometimes, they may even fail to board the train. This situation will cause longer waiting time for the commuters to board the train.

In order to solve this problem, SMRT has adopted some systems. For example, SMRT employs their staff to disperse the crowd across the platform. However, this solution is not effective because many commuters do not listen to the staff. In this situation, our indicator lights would be very useful to commuters and SMRT, which will be elaborated further in our hypotheses below.

- **Hypotheses 1 (Benefits for Commuters):** Installing crowd-level indicators will improve the efficiency by providing advisory for the passengers. Commuters would have a better insight on emptier carriages and be more certain of where to queue before the train arrives. This will lead to having more passengers being able to board quickly per day, thus, resulting greater efficiency for the organization and less unhappiness for commuters.

- **Hypotheses 2 (Benefits for SMRT Operational Level):** By installing crowd-level indicators, it will maximize the distribution efforts of crowd on station platforms because the prototype would give the advisory on where is there space for boarding, the informed commuters would have more reasons to queue in front of less crowded carriages. Thus, lesser efforts, labour and expenses is needed, in deploying staffs to disperse the crowd during peak periods.

- **Hypotheses 3 (Benefits for SMRT Managerial Level):** The installation of crowd-level sensors (built in MRT trains) allows SMRT to collect data about commuters that can be used for further analysis of inside-train-carriage congestion situations, providing opportunities for SMRT to better strategize on other congestion-easing measures or efforts that can be done during the specific hours of congestion more accurately, like adjusting the trains' intervals. Thus, SMRT will be able to plan accordingly and maximize the usage of its resources and reduce wastage as much as possible, which will ultimately, be beneficial for the organizational planning of the organization.

- **Hypotheses 4 (Benefits for SMRT Executive Level):** With the crowd-level indicators, the executive level of SMRT will also get more information and resources to be used and analysed for future master planning, like buying more trains or building more MRT stations. For example, after analysing the data of commuters' activities, the executive levels found out that more than 300,000 commuters travel between Jurong East and Clementi every day, causing congestion and overcrowding at the various stations. Then, SMRT may consider an additional MRT line between these two stations, deploy a new bus service, etc.

4 Proposed Methodology

4.1 Technology Solution

Our technology solution is to implement an Information System that gathers information on the capacity of train carriages and converts them into signals understood by commuters so that commuters can make an informed decision as to where to queue before the train arrives.

In general, our proposed solution is the use of an Information System to facilitate in easing the crowd congestion. The system captures data, such as the number of people in different carriages, which will then be analysed. The system will then return a response to the light indicators at the respective doorways. These light indicators will display colours (green, amber or red) according to the responses received in real-time which will then provide appropriate advisory for the commuters. Aside from the real-time capabilities, the aim is to solve congestion problems in the long run. The prototype system proposed also comprises of a database allowing data to be stored and analysed. The data stored can be transformed into meaningful information, which can be further used for future prediction which can aid in improving the congestion issue.

Refer to 5.1 with regards to the functionality of the prototype system and 5.3.4 for details on the database.

4.2 Current Case Study

As mentioned previously in our hypothesis, there is a steep increase in the number of commuters. Singapore's Mass-Rapid-Transit is run by 2 subsidiaries, namely SMRT Trains Ltd and SBS Transit Limited. They are both regulated by Land Transport Authority (LTA). The North-South Line, East-West Line and Circle Line are run by SMRT while the North-East Line and Downtown Line are run by SBS. (Land Transport Authority, 2016). It is estimated that more than 2 million rides are taken per day (Land Transport Authority, 2015) via MRT 125000 of which come from the morning peak hours alone. (Channel News Asia, 2015) The peak hours are between 07:30 hrs to 09:30 hrs and 17:30 hrs to 19:30 hrs on weekdays and between 12:00 hrs to 14:00hrs and 18:00hrs to 23:00 hrs on weekends. The busiest stations are Jurong East, City Hall and Raffles Place. (Land Transport Authority, 2016).

4.2.1 Online Data

Some initial research is done by retrieving online data on the train capacity and the most congested stations. By studying the statistics, it helps to estimate the number of commuters the prototype system has to cater to.

One of the research components is to understand the train intervals and train capacity. The intervals between trains are usually 2 minutes. The trains on North-South, East-West and North-East lines holds a capacity of 1,400 passengers per train arrival while the trains on the Circle Line and Downtown Line holds a capacity of 700 passengers per train arrival. ("Passenger capacity to increase up to 50%", 2011)

Table 2: ("Many issues with study hailing Singapore as best in class in public transport", 2014)

	Capacity per train arrival	Interval between trains (seconds)	Peak hour capacity (number passengers per hour)
North South line	1,400	120	42,000
East West line	1,400	120	42,000
North East line	1,400	120	42,000
Circle line	700	120	21,000
Total capacity	4,900	480	147,000

From Table 2 (shown above), it lists the total train capacity for Singapore on each MRT line. Another aspect of the research is to find out the most congested stations so that our team will be able to note the number of commuters the prototype system has to cater for. In reference to Table 3 in Appendix C, the top 5 stations with the most number of passengers entering the station in a 15-minute interval are as follows, Raffles Place, Tanjong Pagar, Yishun, Orchard and Tampines in November 2011.

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4.3 Online Survey

A survey, titled, General Public Survey on (Mass Rapid Transit) MRT, has been constructed by our team and put up on Google Forms. The purpose of the survey is to find out the location of congestion and understand how the congestion has affected commuters during peak hours (weekdays: 7.30a.m. - 9.30a.m. and 5.30p.m. - 7.30p.m.; weekends: 12-2pm and 6-11pm). The responses of the survey would help to shape the prototype system better.

Refer to Appendix B for screenshots of the General Public Survey on (Mass Rapid Transit) MRT put up on Google Form.

This is the link to the survey on Google Form:
https://docs.google.com/forms/d/e/1FAIpQLSegjHPu7KgMsMGZbzqSZYyg40EmSzqUphyGlfdc2yP4LFJlow/viewform

The following are the questions asked in the survey (See Appendix B for the options provided for the questions):

a. Which station do you find is the most congested?
b. How often do you take the train during peak hours?
c. How satisfied are you with the train schedules?
d. How crowded are the platforms during your journey?

e. Rate your experience during congestion period.
f. How often do you take the train per week?
g. How long do you usually take to board the train during peak hours?
h. Which sections of the station do you usually move to board onto the trains?
i. Do you think it will be helpful to implement this system?
j. Would you take advisory from the light indicators on the MRT platform if this prototype was implemented?

4.4 Field Study

A field study is conducted to observe and gather more details of the crowd-congestion scenario. This is to provide a more comprehensive coverage for the prototype design. The following 4.4.1 provides the methodology for conducting the field study while 4.4.2 reports the observations from the field study done.

4.4.1 Participants, Setting & Procedures

Participants:

- Daily MRT commuters (especially those who travel during peak hours) who are of various age, occupation and other demographical characteristics.
- SMRT Station staff - who have been working at the station for at least 3 months.

Setting:

- Morning peak and evening peak
  - Weekdays: 7.30a.m. - 9.30a.m. and 5.30p.m. - 7.30p.m.
  - Weekends: 12 - 2p.m. and 6 - 11p.m.
- Morning to non-peak period and night time to non-peak period

Location:

- MRT interchanges such as Paya Lebar, Outram Park, City Hall, Raffles Place, Jurong East, Buona Vista and Dhoby Ghaut
  - Generally more congested platforms
  - MRT stations that has more commuters who come from different regions of Singapore

Procedures:

- Observe the number of passengers who managed to board the train and those who did not
  - Select doorways whereby there is the most number of people waiting to board.
  - Have one team member stand to observe one such doorway with a counter.
  - He or she takes note of the total number of people in the ‘queue’ and then record the count of those who did board the train.
  - Number of surveyors needed will depend on how crowded the train station is.
  - Identify any patterns exhibited by commuters in terms of queueing and utilization of the train
- Note the crowd-level on the MRT platforms
  - Have 2 to 3 team member with counters walk individually around the train platform and count the number of people on the platform within their areas.
  - Record and consolidate the findings when regrouped
- Take note of the commuters’ behaviour when boarding and alighting trains

    - Another member to standby the stationed member who is doing the counting near the doorway.
- Conduct some casual interviews with the station staffs on duty to have a better insight of the passenger's travelling experience in boarding trains during peak-hour periods
    - Interviews are causal in nature and takes about 5 minutes.
    - Members approach the staffs and interact casually before asking the prepared questions.
    - Questions are as follows:
        - How is the general crowd like (behave) on the train platform?
        - Do you face any problems during peak hours? (That is during peak hours when you are deployed onto train platforms)
        - Do you see some people just rushes into the train without letting other passengers alight?
        - Do people tend to crowd at certain areas of the train platform?
    - Should the staff be busy or decline to answer then the interview would either suspend or close.

4.4.2 Field Study Observations

Observations are presented in this section from the 5 different MRT station studied: Jurong East, Bishan, City Hall, Outram Park, Dhoby Ghaut. They are done during Peak Hours and Non-peak hours of 6 weekdays (Monday, Wednesday & Friday) and 5 weekends (Saturday). The top five observations of major concerns are as follows:

a. Commuters tend to crowd more towards the doorway with the shorter queues and near the escalators while waiting for their trains.
b. SMRT plays announcements asking commuters to move to the centre of the carriage. Some commuters are observed not following the announcements and would stand beside the doorway inside the carriage after boarding. There are also posters displayed - on train platforms and inside the train - encouraging commuters to move-in to allow others to board too. (Refer to Figure 5).
c. SMRT staffs are deployed on the platforms during peak hours. However, the main protocols done is to facilitate the alighting of passengers first then for people to board by telling people to waiting to board to queue at the sides. There are little instances where the staffs actually recommend the crowd to move to other areas of the platforms where it may be less crowded.
d. There are many instances whereby some commuters could not board the train at where they queued, only later observed as the train leaves the platform that some carriages further away have some room for which they could have boarded.
e. Extreme cases for some stations like Jurong East whereby it got crowded to the point where passengers end up queuing on the stairs during peak hours. (Refer to Figure 6)

***Figure 5*:** The image is a poster displayed inside trains to promote a thoughtful ride for every commuter by persuading them to move in and make space for other commuters to board.

Figure 6: A photo showing the remaining crowd that did not manage to board the first train at Jurong East taken at 0730 hrs on 17 September 2016, Saturday.

4.4.3 Field Study Discussion

4.4.3.1 Assessing Current Initiatives

From the observations presented, it has shown that there are current initiatives carried out that allows more commuters to board the train, such as announcements reminding passengers to move to the centre of the train and to place their bags on the floor. Hence we have conducted a survey (that was discussed in Section 4.3) to find out from the commuters their behaviours and attitudes towards taking the train on the platforms; we can assess also the effectiveness of the current initiatives further from their feedbacks. Nonetheless, crowd congestions remains a real issue that the current SMRT initiatives has not yet alleviate.

4.4.3.2 Assessing Current IS

Also, passengers are only informed with train arrival timing but there is lack of other information like the ideal place to queue to board the train which is subjective. There is currently no way to tell which cabin is the emptiest. This creates a problem whereby spaces in the train are not fully utilised with the exception of monitoring the crowd level in train carriages.

4.4.3.3 Assessing Extreme Cases

Lastly, extreme levels of crowd congestion is a major concern for our prototype which would have to be quantified and taken into considerations as limitations of our prototype. (See 4.5.4 for quantifying such cases and 7.2 for the limitations of prototype.)

4.4.3.4 Interviews Result

For interviews with the frontline staffs, there is little gathered from the staffs as most of them were either too busy to answer the interviewer(s) or decline to share about their observations. Only a couple shared superficially about some commuters being anxious when boarding the train and tends to rush into the train without letting others alight first- which sometimes results in others being upset or angry.

4.5 Quantifying Prototype Performance and Crowd Level

With the field survey (as stated in Section 4.4) done, the data collected would be used to formulate a quantitative measure of our prototype performance and occupancy level. These would be useful in designing our prototype such as setting threshold for the advisory lights (Refer to Section 5.5.3 for the threshold details). Most importantly, we are able to assess the prototype performance and set our goals accordingly.

4.5.1 Observation & Formulation

It has been observed in the field study that if a person could not board a train, he or she would have to wait for the next train to board and it is subjected to the train's occupancy level. Therefore we can use the time it took for the people who are waiting to board the train to quantify the performance of the prototype implementation. We can find out how much time can be saved with our implemented prototype.

4.5.2 Quantifying Variables

- The train arrives in average of 2 minutes intervals during peak hours while an average of 4 minutes during non-peak hours.
- This can be termed as '1 train timing' - time needed for the next train to arrive for the people to board the train. It is equivalent to 2 minutes for peak hours and 4 minutes for non-peak hours.
- The first train that a person can board is assigned to be 0 train timing.
- For example, should a person could not board the first train that he or she has waited for initially, and if the next train he or she can board on, it would be counted as 1 train timing for the person.
- This is with 3 assumptions:
    - Not taking account of the waiting time for the initial train to board, and
    - Only relevant to a person who could not board the train due to high occupancy level; not accountable for passengers who run after a train that has occupancy for passengers to board.
    - Train frequency is constant during its respective peak and non-peak hours
- With train timing, we can set our prototype performance goals to reduce commuters' waiting time by 1 to 2 train timings. This equates to 2 to 4 minutes saved for commuters during peak hours and 4-8 minutes saved during non-peak hours.

4.5.3 Quantifying Train Occupancy

Given that a train carriage maximum capacity is 400, we can categorize the occupancy level as follows:

- Not Crowded - 0 to 200 passengers
- Moderately Crowded - 201 to 400 passengers
- Overcrowded - More than 400 passengers

4.5.4 Quantifying Extreme Crowd Cases

There are some extreme crowd cases observed in the field study observations (Refer to 4.4.2 for the field study observations) that may have implications for the prototype which would be discussed further in Section 7.2. Therefore, we would need to quantify such extreme cases.

Extremely Crowded:

- (The number of passengers inside + the number of passengers outside – the number of those alighting) > 400 passengers
- Assumption: The platform is so crowded that everyone is queuing at every doorway.
- Our prototype seek to slightly speed up the train timing of commuters waiting in such queues at the doorway. This is done by providing advisory for the people who could not board the train to move to areas with higher occupancy, thus reducing the queue length after the first wave of commuters have board the initial train.

Extremely Not Crowded:

- (the number of passengers inside + the number of passengers outside – the number of those alighting) < 400 passengers /6 cabins
- Assumption: The platform is not crowded that everyone can move into only one carriage and still have more than enough space for others to board. Therefore 400 divided by 6 cabins.
- The prototype would not be as useful as there is not much need to disperse the crowd for that particular station since the occupancy is sufficient for the number of boarding passengers.
- Nonetheless, it would benefit the subsequent commuters waiting in the next stations.

5 Technology Prototype: SMRT-Q

5.1 Purpose

The purpose of this prototype is to:

- Improve the efficiency of boarding trains.
- Reduce human congestion on train platforms.
- Carry more passengers per train during congestion hours with greater distribution of crowd across platform.

5.2 SMRT-Q System Overview

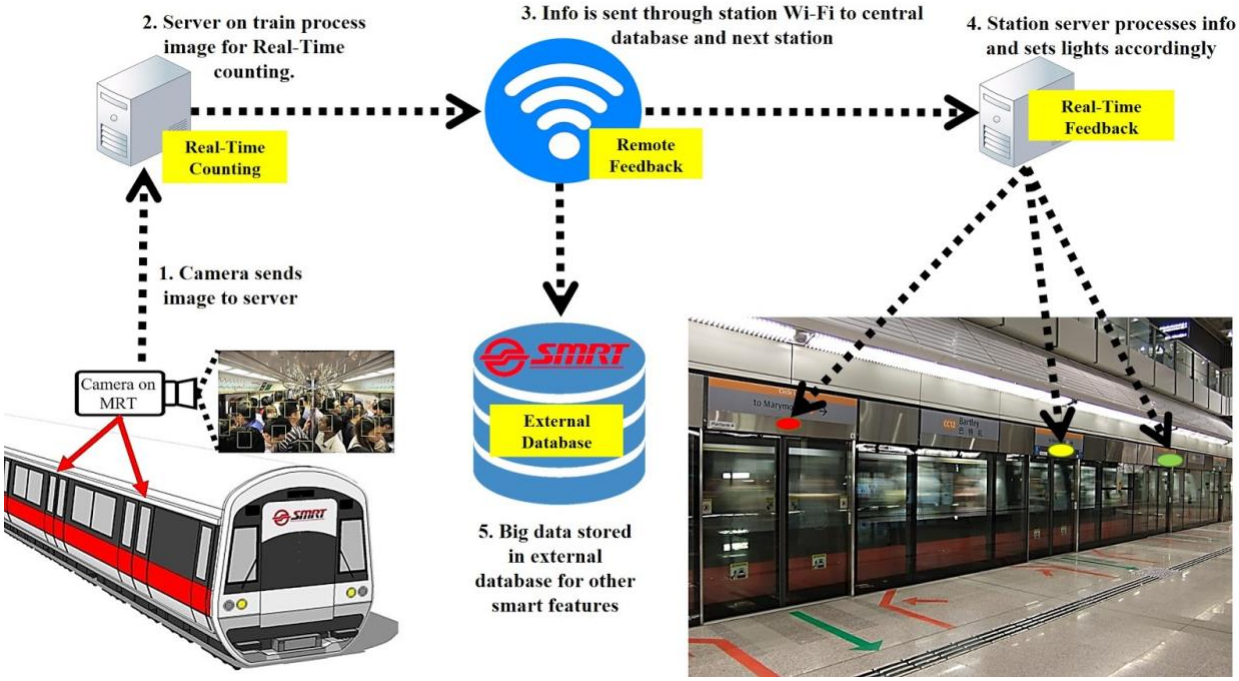

Figure 7: An overview diagram of the SMRT-Q steps.

SMRT-Q works in 5 simple steps:

a. The SMRT Closed-Circuit Television (CCTV) will take real-time image at regular intervals to provide update information of carriage occupancy level.
b. The image is processed by the application on the server on-board the train. The application does counting by detecting the number of people.
c. The server then connects to the Wi-Fi and sends the data to the server at the next station and to an external central database for other SMART systems.
d. The stations processes the information and sets the light colours of the indicators according to the pre-set threshold.
e. The data is then stored in the external central database for organization learning and higher level decision making.

5.3 SMART Components

The prototype components consists of: real-time counting, real-time feedback, remote feedback and external database.

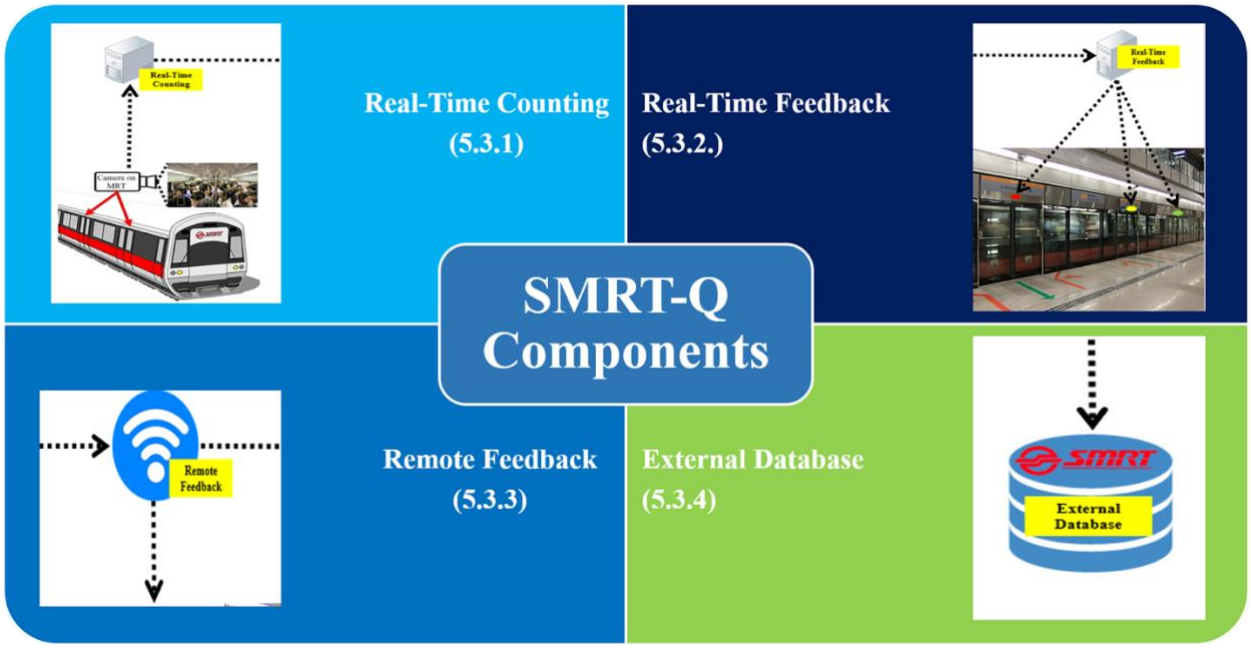

Figure 8: SMRT-Q components overview

5.3.1 Real-time Counting
Real-time counting counts the number of people in real-time based on the camera feed.

5.3.1.1 Software
The two software are Open CV and Camlytics.

a. Open CV

Open CV (Open Source Computer Vision) is an open source computer library with many features. In our prototype, we primarily utilized its facial recognition ability and modified it to do counting of people ("Open CV: Face Detection using Haar Cascades", 2016). In order to develop our program we also used EMGU CV which is a wrapper class for Open CV so we could code it in C#.

Open CV's Features

- **Cost Effective** - Open CV is an open source which means it is free to use.
- **Dynamic** - Being an open source, it is constantly being improved on as algorithms are honed and discovered. This will allow for SMRT-Q to be always up to date in terms of technological advancement.
- **Facial Recognition** - It has many versions of facial recognition. In our implementation we use the Haarcascade algorithm. The Haarcascade algorithm works through machine learning and it learns to recognize human features. The algorithm detects edges as well as show in Figure 9 below. It is also able to detect multiple faces and heads at the same time which we use in our implementation for the counting of people.
- **High Malleability** - It does not need proprietary software or hardware in order to work Thus it is easily modifiable and can be implemented with other features such storing information into a database.

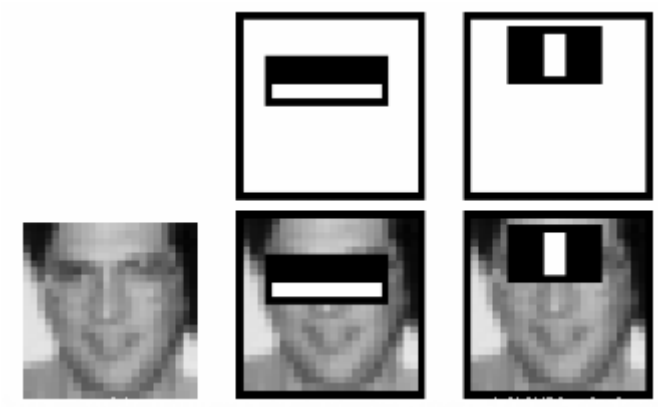

Figure 9: The Haarcascade algorithm determines where the eyes are supposed to be and then, detects where other features are.

Proposed Design and Implementation

The highly modifiable nature of Open CV means that we can create a program that can do anything. Using Open CV as the main way to detect faces and heads, we can create a program that counts faces and heads and stores other information to an online database. The feed used will be from the cameras on the train. These cameras should be connected to a central computer which will contain the program used to detect and count faces and heads. The cameras should be places at the ends of the carriages at a high elevation to capture as many people as possible. Figure 10 shows a visual illustration as to what is processed by the program.

Figure 10: This is a visual representation of what is being processed.

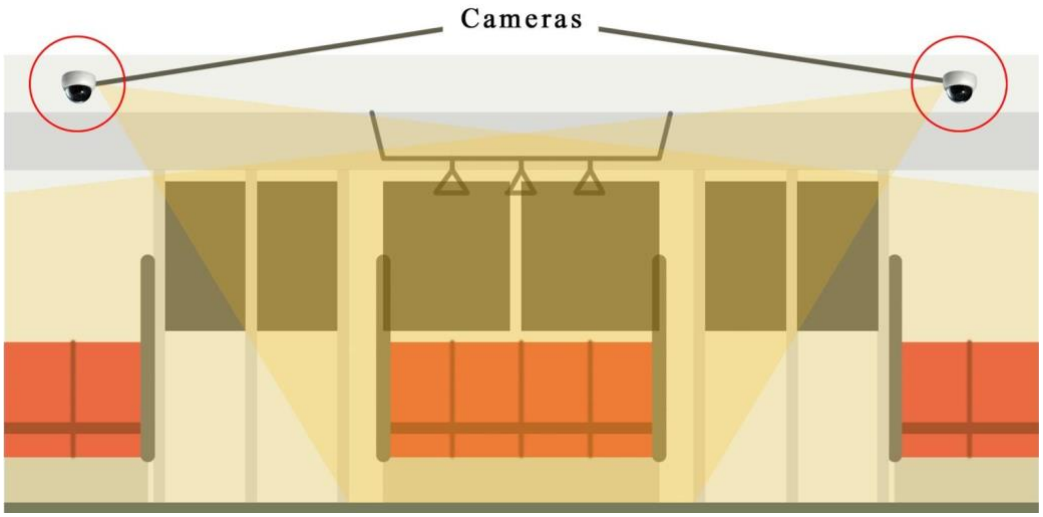

Figure 11: The illustration (not drawn to scale) shows the ideal placement of cameras in train cabins.

The program itself will use the algorithms in Open CV to detect and count heads. This number will be sent via the internet to the next station where another program will change the lights on the platform according to the numbers received. Other future implementations can include counting of people boarding and alighting the train and comparison of faces against a database for security purposes.

b. Camlytics

Camlytics is a multi-camera management software that comprises functions such as recording and video analysis. The software integrates into the user's CCTV or even Web Camera (Webcam) and allows user to conduct video recording and analyse events, which they may deem necessary to keep track of. The Camlytics provides a user friendly-interface for even non-programmers, who can configure their CCTVs to their needs. For programmers, Camlytics software can be integrated using REST API.

Refer to http://camlytics.com/help/api.html for more details.

Camlytics' Features

Basic features of the free version are as follows:

- **Integration with Unlimited Cameras** - enables the organisation to utilize the software for all of their CCTV when implemented.
- **Object Detection** - can do counting and tracking of objects detected.
- **Unlimited Video Recording** - enables recording of what is captured by CCTV for additional functions besides counting.
- **Video Archive -** videos are stored into computer with software installed which can be reviewed again for analysis.

Premium features:

- **Full video analytics integration** (as specified in Camlytics.com.) - enable organization to perform various analysis of video for various functions by setting up camera events for Camlytics to execute such as counting, crowding, motion detection and speeding etc. by objects within a designated area of interest..

- **Camera Scene Statistics with Charts and Heat Maps** - The software represents data using charts or heatwaves for easy analysis.
- **Multiple Profile Settings for Video Analysis** - User can save many video analysis setting easy switching of video analysis methods for different purposes.

The details of the features and operation manual can be found in Camlytics User guide at http://camlytics.com/help/index.html.

Proposed Design & Implementation

The value proposed by Camlytics for the prototype is that it can count the number of people by setting up trip lines, and record events in video playback. (Refer to Figure 12 and 13 for screenshots of their video demonstration.). The software allows user to set trip lines which can do counting of the number of people that crosses them as shown in figure 12 and 13. In their YouTube Videos, Camlytics proposed 2 possible setup designs - one is an overview 2-triplines setup design and another is a 1-tripline setup design. These two designs are considerations for the prototype design should Camlytics software be integrated as the real-time counting software.

The overhead CCTV design in Figure 12 shows that the software can identify the direction of movement of the objects intelligently in the video recording thus allows it to do counting of people entering and exiting the store. There is no double-counting by the two trip lines when a subject crosses the two trip lines; the software accounts for the subjects' direction. When subject moves from outside and into the store, only the 'entry trip line' does the counting, and vice versa for the 'exit' trip line. A possible integration of this design into SMRT's case would be to install a CCTV above the safety barriers where people are boarding and alighting on the train platform. There would be 2 trip lines - 'entry' and 'exit' counting the number of people boarding and alighting.

The angled CCTV design in Figure 12 shows that the software can track the movement of the objects in the video recording thus allows it to do counting of people entering and exiting the store on two different doorway using one trip line setting. However should it be implemented into the MRT, it needs to be reconsidered as the MRT doorway is two ways with passenger boarding in and alighting. The single trip line may need to be remodified, if possible, to avoid double counting of passengers coming and out of the train.

Therefore, the easier implementation of design would be the direct overhead CCTV design as in Figure 12.

Figure 12: Camlytics' direct overhead CCTV 2- trip lines setup.
Source: Free people counting software (YouTube Video)

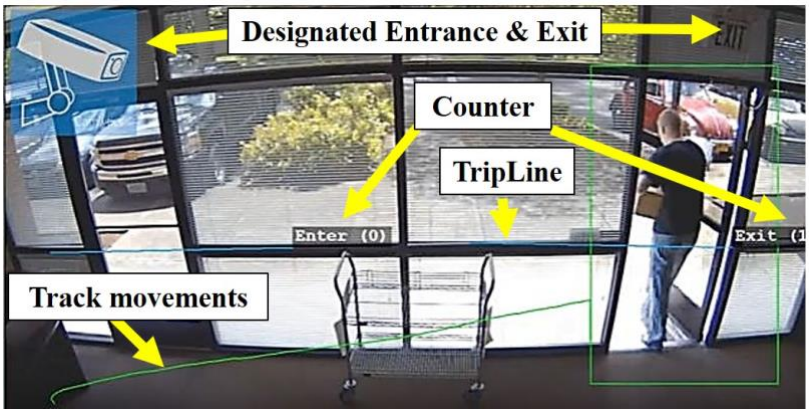

Figure 13: Camlytics' angled CCTV trip line setup
Source: Webcam people counting software (YouTube Video)

5.3.1.2 Comparison of Software
The table below gives an overview of the comparisons between the two software, Open CV and Camlytics.

Table 4: The table below shows the comparisons between Open CV and Camlytics

Software	**Open CV**	**Camlytics**
Features	Basic features: • Integration with any camera • Face and object detection • Free and open source • Can be linked to an online database to store data	Basic features: • Integration with unlimited cameras. • Object detection • Unlimited Video Recording. • Video archive into computer with software installed. Premium features: • Full video analytics integration as specified in camlytics.com. • Camera events supports, recording & notifications • Camera scene statistics with charts and heat maps

		• Multiple profiles for video analysis
Advantages	• Free and open Source • Can be integrated with existing CCTV's on MRT • Low cost to set up • Highly modifiable	• User friendly interface for non-programmers. • Easy integration into existing CCTVs.
Limitations	• High level of programming skill required to take full advantage • Not very quick in terms of counting heads • Not very precise • Accuracy depends on the positions of the CCTV • Not able to to counting by crossing a line without additional hardware	• Specialized software that needs to pay premium for more advanced features such as setting up lines and calibrations for counting purposes • Once implemented, may be costly to switch software. • Subject to CCTV positions. If existing CCTV positions are not ideal for counting, tracking or recording, then user may have to change positions of their CCTV or install new ones at the ideal location to overcome camera angle problem

5.3.1.3 Conclusion: Which software to use for real time counting?

Open CV is chosen to be implemented into SMRT-Q as it meets the needs of the SMRT-Q system and is much cheaper to implement. Its malleability allows future improvements to be implemented more easily without having to rely on a third party unlike Camlytics. A detailed discussion of our choice is presented in the next few subsections: "Criteria" and "Discussion".

a. Criteria

Given that SMRT-Q is an advisory system, its data input or collection components (which is the real time counting components) need to be very reliable and accurate with the counting of passengers.

- **Real Time Counting** - Real-time counting components need to monitor the situation with re-counting or updating counts at reasonable intervals so as to deliver advisory as close to the actual situation in the carriage. Continuous update should be avoided as it may be redundant or that sudden shift in passengers preparing for alighting may cause a need for system to do a recount and may stall the advisory output while doing the recount.
- **High Reliability and Accuracy** - The component needs to be able to count actual people and not objects. Also, the components must not double count the same person twice in the counting. Lastly, the system needs to account for

possible changes to the number of passengers in the carriage like. Shifting to another carriage etc.

- **Malleability** - The component need to flexible to be integrated into existing information and would be a huge advantage if it can be modified to perform other functions as required by user.
- **Low Cost** - It will be a strong justification for the component to be considered for integration into the organization's business.

b. Discussion

- **Real Time Counting**
  The Open CV enables SMRT-Q to do real time counting of the people in the carriages thus SMRT-Q would be able to know how many people are in a particular carriage at one time. With the data, the SMRT-Q can process the data and sends the instructions to the real time feedback system in the next station to give advisory of the carriage occupancy level to the commuters.

  Camlytics, with overhead design, can do real time counting of people boarding and alighting at the specific doorway. SMRT-Q then can take in the data and do computation of the total passengers in that particular carriage since the start of the train journey. This may be more complicated in the backend program design with the required computation.

- **Comparing Reliability & Accuracy**
  Open CV has a greater accuracy of data in the counting because it accounts for passengers that may have shifted to another carriage; that which cannot be accounted by Camlytics because Camlytics overhead design it assumes that the passengers, having boarded the train, would not move to another part of the carriage or change carriages. Camlytics would only account for the people boarding and alighting the train at which doorway in one event. Thus, Open CV is more reliable in giving SMRT-Q the data for advisory.

- **Malleability**
  Open CV being a computer library allows us to build custom software that is suited to SMRT-Q's needs. It can be combined with other future SMART features easily. Being Open Source, it allows developers to go into the low level code in order to tweak algorithms to their needs.

  Camlytics is a proprietary software which means that it cannot be modified at all. It also provides a limited API for its system. In addition, it requires the Camlytics program in order to work- i.e. its features cannot be implemented into a custom program.

- **Low Cost**
  Open CV is released under a Berkeley Source Distribution (BSD) license and hence it's free for both academic and commercial use.

  Camlytics premium costs a minimum of USD$99 for one license for a Personal Computer (PC). These would meant that SMRT may need to buy more than one license for each PC that is managing the CCTVs in stations.

5.3.2 Real-time Feedback
The overview of the procedure is, as follows:

a. The counter sends a signal based on the number of people counted.
b. The Central Processing Unit (CPU) is to process the numbers and converts the signal into colour code (red/amber/green) and sends the signal to the appropriate light indicators to be displayed.
c. The coloured lights are to display the colours according to the threshold to represent the crowd level inside each carriage. Then, commuters can choose to queue at the doorway that suggests an emptier carriage.

5.3.2.1 SMRT-Q Real-time Feedback System
Figure 14 shows the features in real-time feedback system of SMRT-Q.

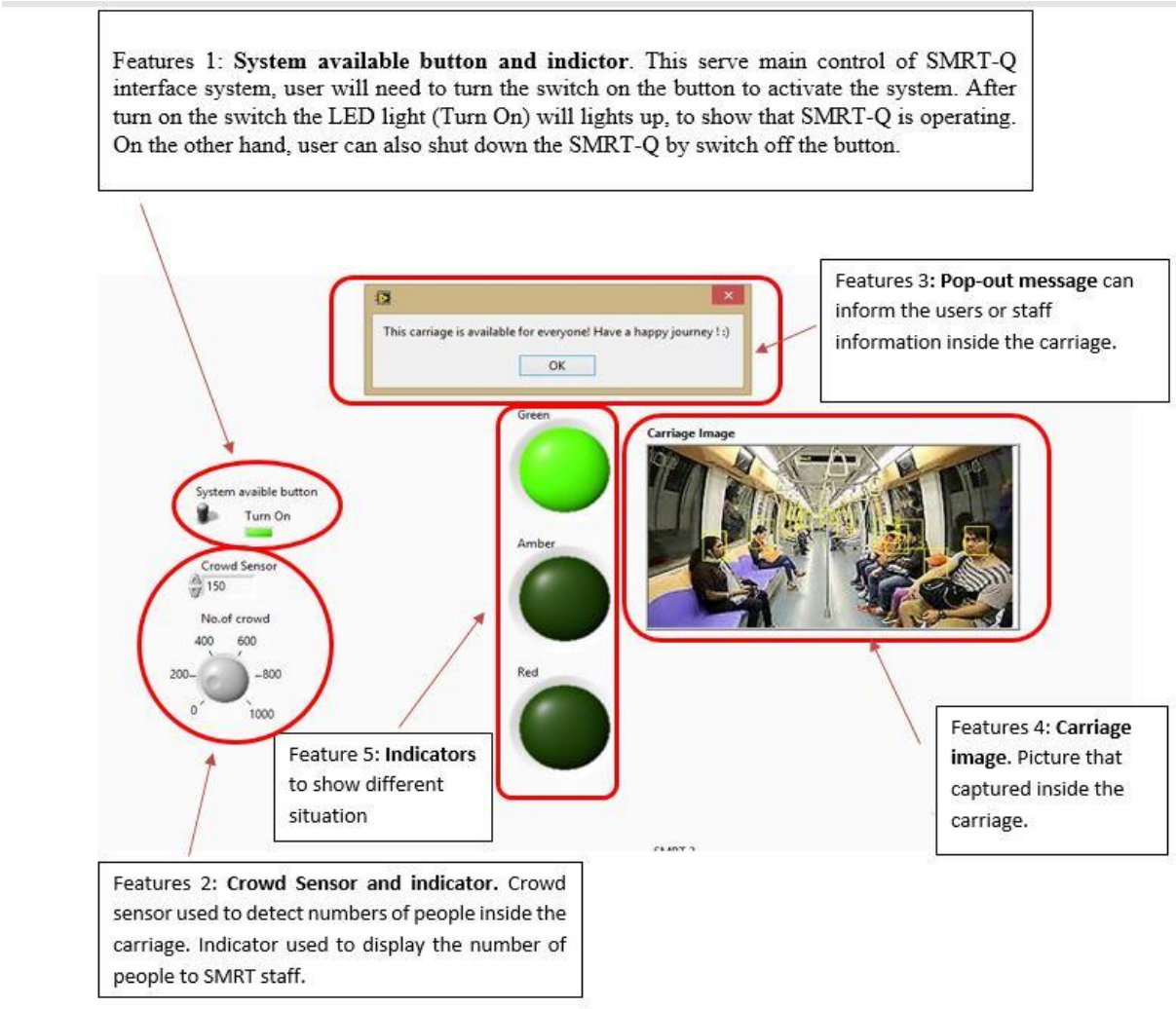

Figure 14: Real-time Feedback System overview (Using LabView interface)

5.3.2.2 Feedback System's Settings & Scenarios

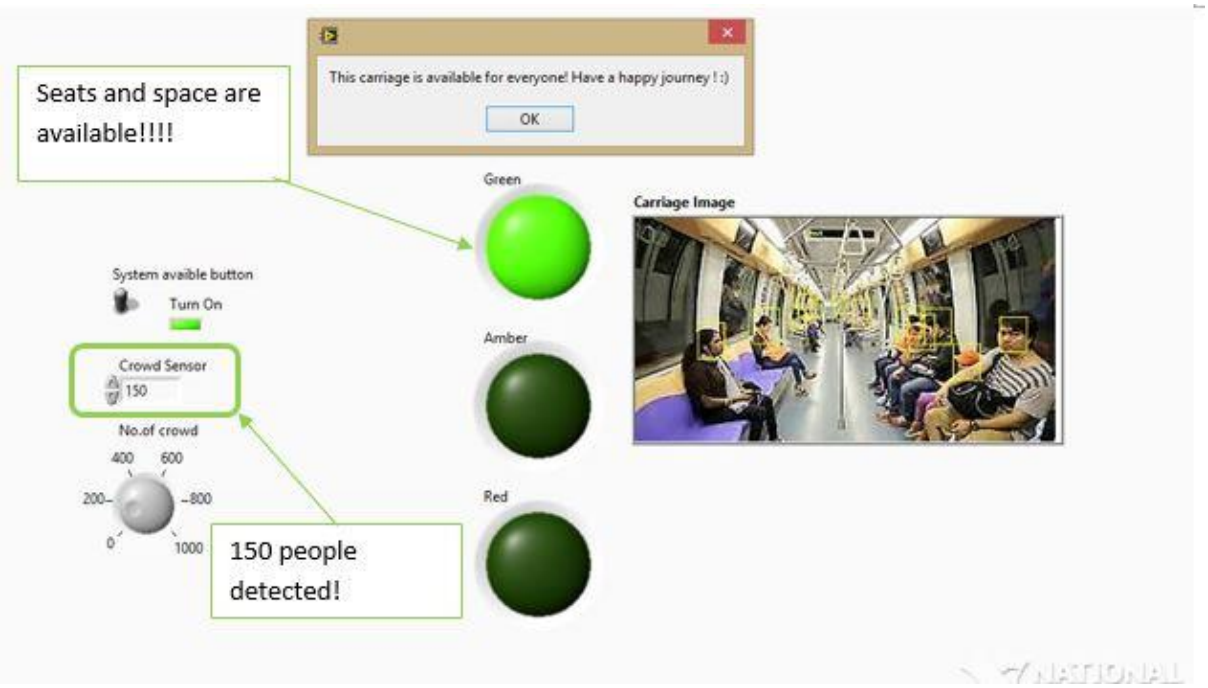

Figure 15: 'Not crowded' scenario

From Figure 15, it shows the system available button is turn on so it shows that the system is in operation. The crowd sensor detected 150 passengers inside the carriage, thus, the Green LED light turns on and a pop-out message comes up as "This carriage is available for everyone! Have a happy journey! ". This suggests there are a lot of empty seats in this carriage.

Figure 16: 'Moderately crowded' scenario

From Figure 16, it shows the system available button is turn on so it shows that the system is in operation. The crowd sensor detected 350 passengers inside the carriage, thus, the Amber LED light turns on and a pop-out message will show “This carriage has “Seat Available”, “Standing”, “Limited Standing”. This indicates that there is still space for standing, however, there are limited empty seats for commuters in this carriage.

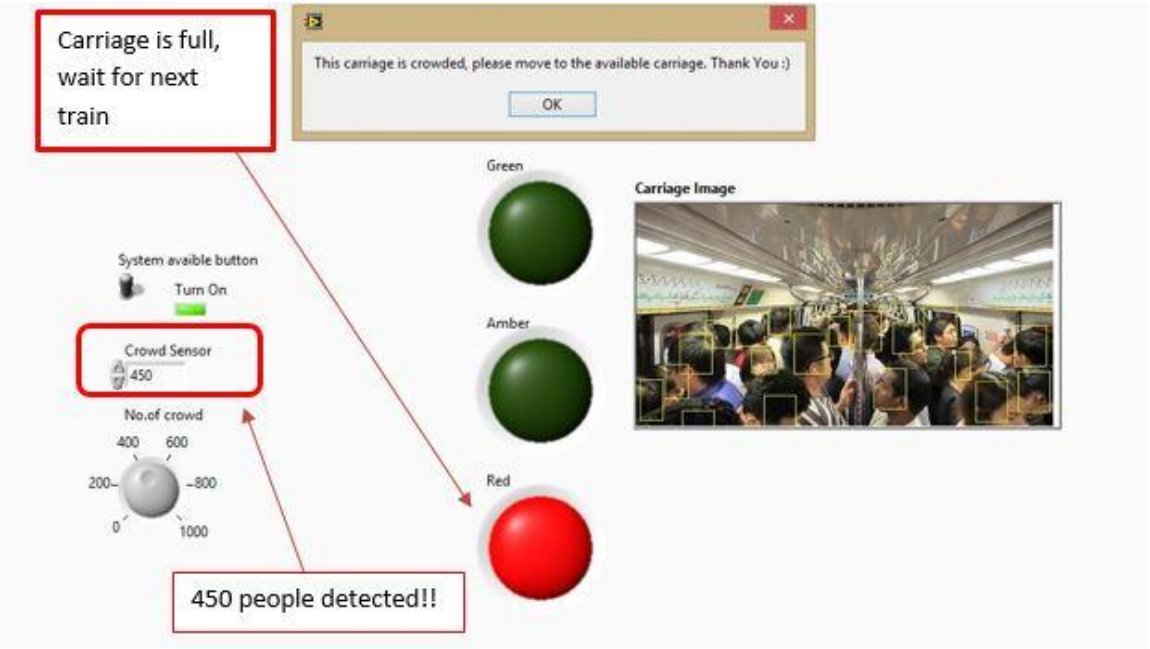

Figure 17: 'Crowded' Scenario

Figure 17 shows the system available button is turn on so it shows that the system is in operation. The crowd sensor detected 450 passengers inside the carriage, thus, the Red LED light turns on and a pop-out messages “This carriage is crowded, please move to another carriage. Thank You.” will come out. This means there is no empty seats available nor any standing space available for commuters. This also suggests for commuters to wait for next train or find an emptier carriage to board.

Table 5: The table shows the conditions to determine the different LED light colours:

Green (Not Crowded)	0 to 200 passengers
Amber (Moderate Crowded)	201 to 400 passengers
Red (Crowded)	> 400 passengers

*** **Important Note**: The number of people detected by sensor to display different LED light colours can be changed by programmer based on the different train capacities. ***

5.3.2.3 Feedback System’s Backend Programming

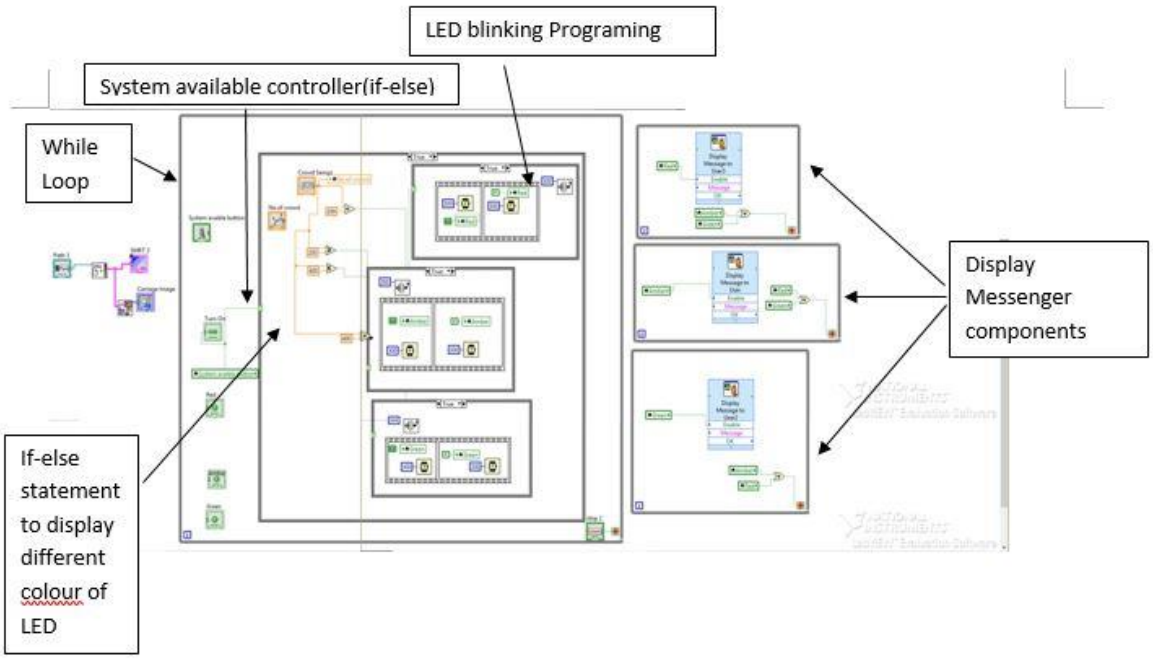

Figure 18: Block Diagram Programming for backend system (Using LabView)

Lab-View is a highly productive development environment for creating custom application that interacts with real-world data or signals in field such as science or engineering.

Graphical Programming Language:

- Intuitive, flowchart-like dataflow programming model
- Shorter learning curve than traditional text-based programming
- Naturally represents data-driven applications with timing and parallelism

Hardware Support:

- Scientific instruments
- Data acquisition devices
- Sensors
- Cameras
- Motors and actuators

5.3.2.4 Benefits of SMRT-Q Interface

SMRT-Q is designed in simple and efficient way, so it does not provide information overload to users. Users able to understand system easily.

It can be implemented in SMRT Data or Monitor Centre, to allow them to get the information inside each carriage or raw data for future improvement.

5.3.3 Remote Feedback

The remote feedback compiles all numbers collated by the program into one file and sends it to the receiver on the MRT platforms. This is done by connecting to the WIFI at each station and transmitting the file through the internet.

5.3.4 External Database

The data collected by the real time counting components upstream are added into an external database for documentation and further processing. The data collected is processed into useful information in the database for analysis to aid in organizational learning, future planning or forecasting, decision-making and adapting organization strategy.

Some useful information stored in the database are the 'Day & Time' of collection, Number of People, Train carriage number and/or door number, status of the occupancy level, camera identification number etc.

Refer to Figure 19 for a sample of an external database of SMRT-Q.

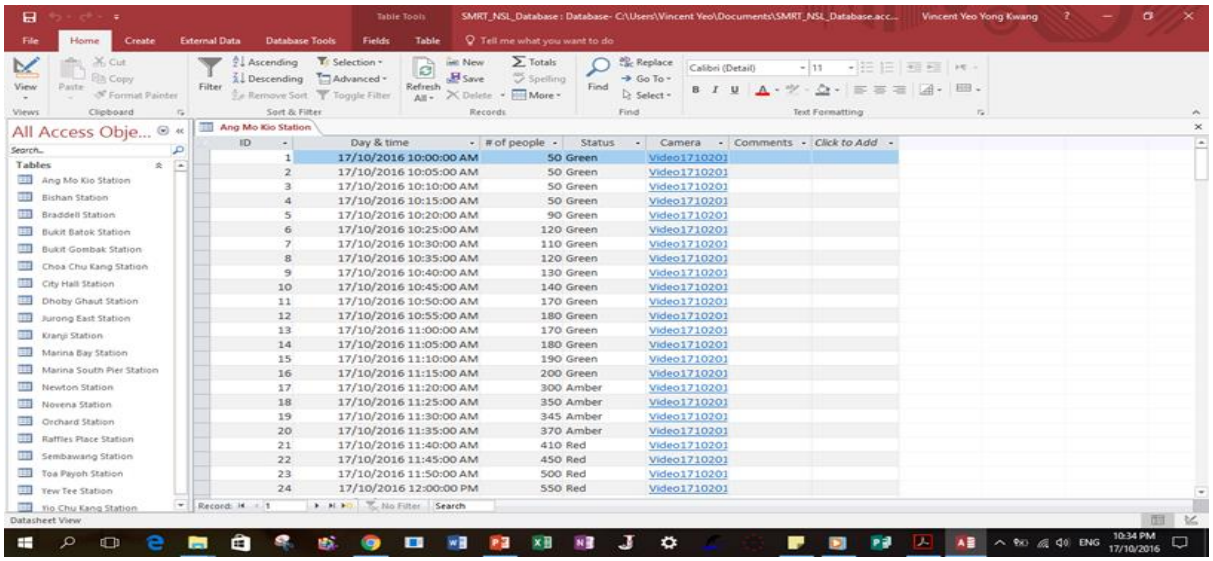

Figure 19: The image shows the External Database used for Big Data collection for higher level decision making.

5.3.4.1 Implementation

The external database of SMRT-Q can be the current database software that SMRT is using. SMRT would only need to connect its database to the SMRT-Q components for them to send the data via Wi-Fi into the database.

5.3.4.2 Benefits of External Database in SMRT-Q

For Organizational Learning:

With an external database, SMRT can improve on its organizational learning. Information stored in the database can be utilized in data analytics to increase SMRT's knowledge about its train operations and commuters' behaviour (i.e. tendency of boarding at a certain doorway of station platform) in commuting the trains. This will help SMRT understand and solve problems better.

For Visual Studies of Commuters:

Also, data collected can be used to present the relationships between variables and parameters such as the number of passengers at which day and time of the week. With data analytics software like Microsoft Excel, such relationships can be visually displayed. Some information like the most congested time period can be revealed in such visualization data and SMRT can identified the right time to increase frequency of their trains.

For Projections & Future Planning:
SMRT executive can make more detailed projections of commuters' demand at the stations and aid in making comprehensive decisions in important matters such as in the master planning of train lines or expanding its stations' facilities.

For Decision-Making at Various Levels:
Data analysed can provide a more comprehensive coverage of subject matter and aid in decision making at various organizational levels. For example:

- At Operational Level - can decide when would be a right time to manipulate or guide the traffic flow of the crowd by i.e. changing the directions of the escalators or adding barricades to guide the traffic flow better within the stations.
- At Managerial Level - can decide the ideal time to increase train frequency so as to accommodate the large crowd at a particular period of the day.
- At Executive or Strategic Level - can assess whether their strategies of increasing frequency of trains are working etc. If strategy is not performing as intended, the information from the analysis can be used to identify where the strategy have failed. Thus improve or modify the strategy.

Some possible decisions that SMRT faces are as listed below:

- *Considering when is the time to increase the trains' frequency at which train lines?*
  - This is to maximise the effectiveness of train frequency.
- *Is the current strategy of increasing train frequency working? Why and Why not?*
  - Organizational learning for SMRT to better understand commuters' situation and to test their current management strategy
- *Which stations does the human traffic flow needs to be improved? Why a certain doorway or a particular carriage is occupied for this station than other carriages of the train?*

6 Statistical Findings

The survey, General Public Survey on (Mass Rapid Transit) MRT, came back with a total of 102 respondents. Based on the survey results, inferences can be made on the congestion problem that has been affecting many MRT commuters.

Refer to Appendix D for the overview of the results done by Google Forms. It summarises the data and results in forms of graphs and pie charts.

Question 1: Top 5 Congested Stations
For question 1, respondents are required to list down the MRT station that they believe is most congested. The results show that the top 5 stations voted to be most congested are in the following order:

a. Jurong East (36 votes)
b. Bishan (13 votes)
c. City Hall (9 votes)
d. Buona Vista (8 votes)
e. Tampines (7 votes)

As shown below, the graph represents the number of votes casted over the different stations based on the survey.

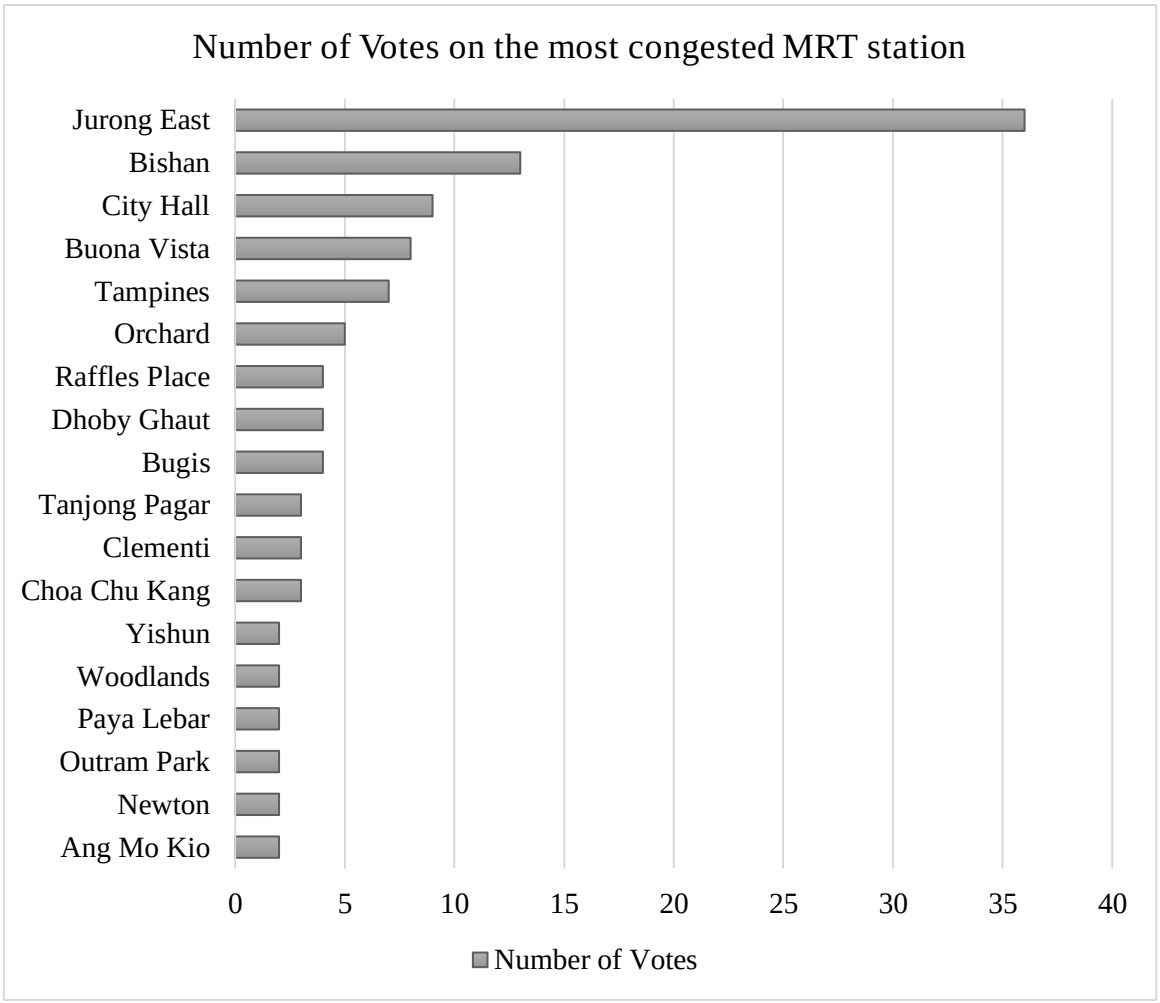

Figure 20: The graph shows the number of votes for the most congested stations.

Question 2: Peak Hour Commuters
In question 2, respondents are to declare how often they take the train during peak hours, ranging from option 1 to 4 (option 1 - never, option 4 - always). The options that was voted most was option 3 and 4. This concludes that 81.4% of the respondents often take the train during peak hours (weekdays: 7.30a.m. - 9.30a.m. and 5.30p.m. - 7.30p.m.; weekends: 12-2pm and 6-11pm). The results hints to us that the prototype should be able to work for a big number of commuters that are taking the train during peak hours on a daily basis.

Question 3: Commuter Satisfaction on Train Intervals
Respondents are to rate how satisfied they are on the train schedules for question 3. It can be deduced from the results that more than half the respondents are dissatisfied with the train schedules. On a scale of 1-4 (1 being very dissatisfied and 4 being very satisfied), 59.8% of the respondents chose option 1 and 2.

Question 4: Crowd Level on MRT Platforms during Commuter's Journey
This question asks respondents to rate the crowd level on the MRT platforms during their train journey, ranging from option 1 to 4 (option 1 - never, option 4 - always). Based on the results obtained, it shows clearly that the platforms has always been crowded for all respondents during their journey on MRT. 92.1% of the respondents responded to option 3 and 4, suggesting that the platforms are always crowded during their journey. These shows that most respondents are involved in the congestion on platforms during peak hours.

Question 5: Commuter's Experience during Congested Periods
For question 5, respondents were to rate their experience during congestion periods on a scale of 1-4 (1 being very poor and 4 being excellent). Only 17 respondents voted excellent while the majority voted very poor.

Question 6: Daily Commuters of the MRT
In question 6, respondents are to state how often they take the train per week. 48 of the respondents have indicated that they take the train 4 to 5 times a week while the second largest group (32 votes) of the respondents have shown that they take the train 6 to 7 times a week. From this, it shows that more than 70% of the respondents are frequently taking the train to travel in a week.

Question 7: Waiting Time to Board the MRT
Respondents are to state their usual waiting time to board the train during peak hours for question 7. Based on the results, 47 of the respondents have a waiting time of 6 to 10 minutes after train arrival, 34 of the respondents waited for 0 to 5 minutes before boarding the arrived train and the remaining group takes more than 11 minutes before entering the train. This shows that more than 67% of the respondents have to wait for a subsequent train before boarding.

Question 8: Preference of Commuters When Boarding the MRT
This question asks the respondents to vote the section of the train that they have preference to when boarding the train. From the responses, the middle of the carriage is the area where least number of people would board from (14 votes). Most of the respondents prefer boarding at the ends of the train (39 votes). Surprisingly, boarding from near to the escalators of the stations have the second least votes (22 votes). The remaining respondents shown that they board from the door with the shortest queue. This would also prove that people favours convenience in terms of finding the shortest queue over the closer door to escalator.

Question 9: Pre-rating of the Prototype

For question 9, respondents are to rate how helpful our prototype is. The responses show that more than 80% (85 votes) of the respondents voted the pre-rating of our prototype as helpful. This suggests a good response about our system. Only the remaining 17 respondents feels that it is not helpful.

From the positive responses, our team believes that this system has the potential to help ease the congestion on platforms and guide the crowd with the advisory on emptier carriages, provided by the prototype system. This will help the commuters get into the trains more efficiently, rather than not being able to board the train due to the crowd, resulting to a longer waiting time to board the next train.

Question 10: Advisory of the Light Indicators Shown in Operation of Prototype

In the last question, respondents are to indicate if they will take advisory from the light indicators suggested by the prototype system on the MRT platforms. It shows that more than 60% (66 votes) of the respondents are willing to accept and take advisory from the prototype system.

Based on the responses, it depicts that the prototype system would be able to persuade commuters to a certain extend to queue according to the advisory given by the system. This will ultimately, manage the crowd better on the MRT platforms, also improve the commuters' current MRT journey and reduce the commuters waiting time during peak hours as they have a higher probability in boarding the first train that arrives at the station.

The responses from question 10 also supports hypotheses 1 (i.e. by installing crowd-level indicators, it will improve the efficiency of managing the crowd in boarding the trains based on the advisory given by the indicators and ultimately, allowing more commuters to board the train quickly per day) and hypotheses 2 (i.e. by installing the crowd-level indicators, it will maximize the efforts in dispersing the crowd during peak hours) as 60% of the respondents also believe that by taking advisory from the indicators, they would be able to board the first train that arrives at the platform.

7 Discussion

7.1 Summary of Findings

From the findings, with at least 80% of people take the train during peak hours and 90% of the population experience congested rides, it is without doubt that the congestion on train platform has been a recurring problem for both SMRT and commuters.

However, with the proposal of the prototype system to give advice on where to board, more than 80% of the population thinks that the advisory would be helpful and they would seek advisory from the device. This shows that the prototype would be better accepted and utilized by commuters with its implementation. With more than 50% of commuters being dissatisfied with the congestion problem, it is expected that the advisory may improve the satisfaction rating of their commuting experience

Also, 38.2% of the people would board from the ends of the train than the middle carriage in hopes of less congested experience. However, majority of people are doing the same thing which creates an uneven distribution of people towards the carriage ends. When coming out with the prototype, we can expect that lights around the middle section will most likely shows that there is space.

So with the use of the prototype, it can potentially lead to a more evenly distributed proportion between boarding at the ends of the train and the middle carriages.

7.2 Limitations of Study

7.2.1 Limitations of Field Study

The following are limitations of the field study that was done as stated in Section 4.4:

- **No Extensive Interview with Higher Management**
  - Given that the field survey is done based on our own initiative, there is little in inputs from the higher management level regarding about the organization's' challenges and opinions on the crowd congestions.
  - The closest opinions that has been gotten are from the frontend staffs working at the platforms which were casual.
  - Much interview with the frontline staffs were declined as the staffs were either busy or were reluctant to share about their observations.
  - Only a couple shared superficially about the crowd being anxious about boarding and some rudely rushes into the train before others alight.

- **Limited Field Study**
  - Given the limited manpower and time, only a few MRT stations has been surveyed and the observations are stated in Section 4.5.

- **Prototype not yet Tested in Pilot Project**
  - No pilot project has been done to test the prototypes' feasibility and performance. Therefore, a need to seek permission and funding from SMRT to do up a pilot program.

7.2.2 Limitations of Prototype

The limitations of the prototype are briefly:

- Extreme Cases of Crowd Level on Platforms
- Camera Angles

7.2.2.1 Extreme Cases of Crowd Level on Platforms

Extreme Crowded Cases

- For situations with very dense human traffic that results in people queuing at every boarding places and/or that some people could not board due to congested train itself.
- This is real and relevant and it seems to make our solution redundant in trying to distribute the people.
- Unavoidably, this large demand can only be met by the increased frequency of the trains already done by SMRT.
- Nonetheless, we can implement this solution to the next train also perhaps projecting the colour code of the next train in advance like on the MRT TV screen. This is so as to reassure the crowd for their next train.

Extremely Not Crowded Cases

- The prototype would not be as useful in situations whereby the train is very empty like at the terminal stations at the ends of the train lines.
- Because there is not much need to disperse the crowd for that particular station since the occupancy is sufficient for the number of boarding passengers.
- Nonetheless, it would benefit the subsequent commuters waiting in the next stations.

7.2.2.2 Camera Angles

- The position of the CCTV is very important and critical as it determines what the camera can detect and count.
- If the CCTVs are placed at an angle instead of a top-down position, there is the possibility that the passengers further away from the camera are blocked by those passengers standing closer to it.
- Thus, hindering the accuracy of the real-time counting by the camera. Therefore, the position of the existing CCTV must be assessed before implementing the Open CV software. A proposed positioning of the CCTV is illustrated in Section 5.3.1.1 Figure 11.

If the existing CCTV angles are not ideal, there is a need for installations of new CCTVs at new positions for the counting to be more effective and accurate.

7.3 Future Directions of Study

7.3.1 Implement a Pilot Project

Using the information collected from the survey done, we aim to test SMRT-Q at Bishan MRT station during peak hours from 7.30am to 9.30am in the weekdays. The purpose of such design for test is to use it during timing which are crowded not to a point of extreme, allowing the system to be measured under optimum performance.

Another rounds of similar field and online surveys will be done to assess the prototype performance and changes to people's commuting experience and behaviours. The procedures of such survey are stated in Section 4.4 with the quantitative measurements formulated in Section 4.5.

This pilot project is necessary to test the prototype in its intended context so as to answer the hypotheses as stated in Section 3.2.

7.3.2 Prototype Evaluation

The prototype SMRT-Q seeks to be an add-on Information System (IS) that seeks to enhance SMRT current IS. It would be ideal to consider other potential uses of the software discussed in Section 5.3.1.1. These are subjected to SMRT additional needs, if any.

Given Open CV's malleability and facial recognition features, it can be utilized for security and surveillance purposes (e.g. tracking down of criminal suspects).

Also, there may be more innovative ways to use Camlytics with its tracking features like tracking crowd movements within the stations instead of counting passengers to better understand and manage crowd movements.

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Appendix A

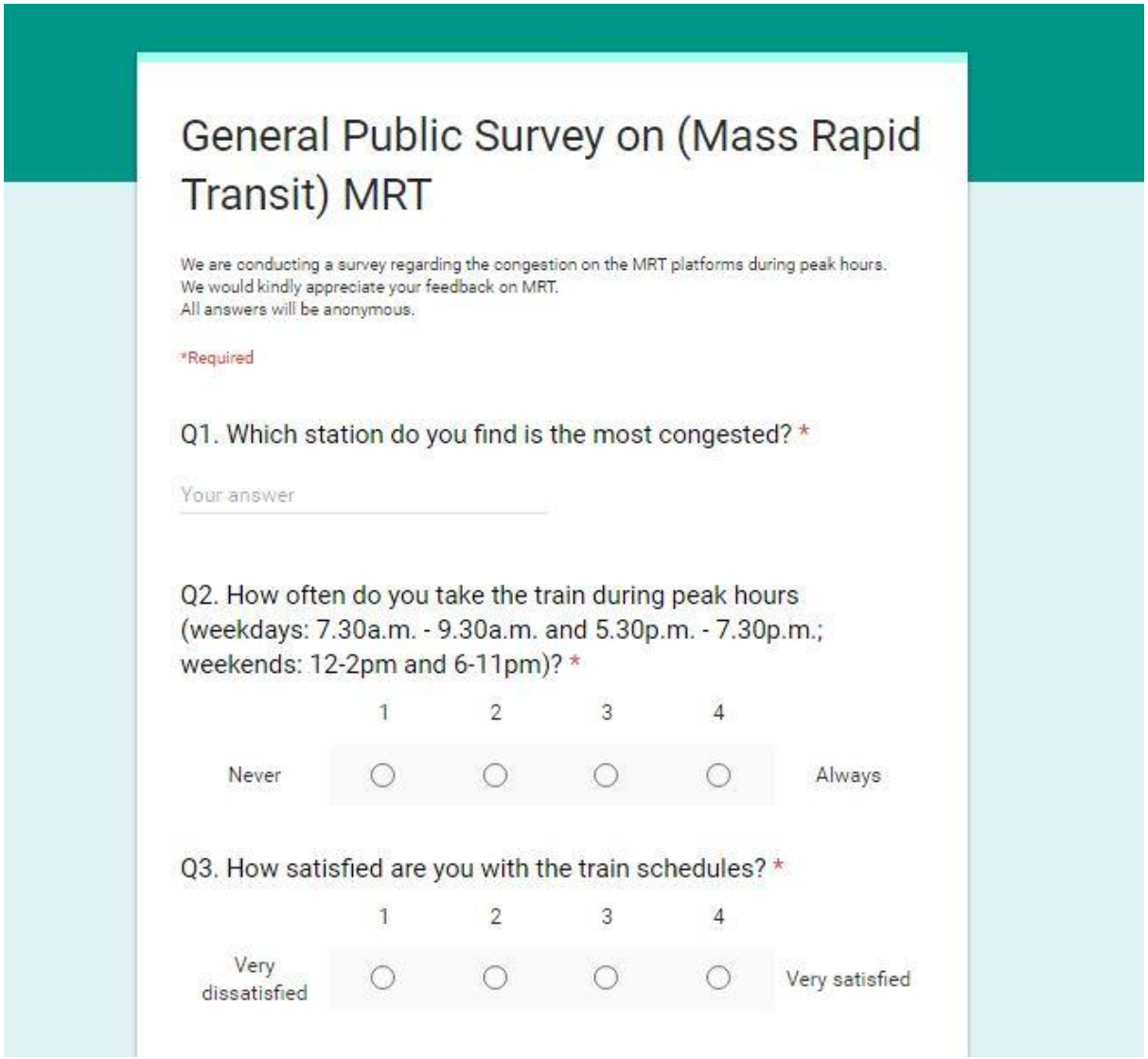
Table 1: Statistics of SMRT Operations ("Information Kit", 2016)

Types of trains	C151, C651, C751B C151A (only on NSL/ EWL) C830 (only on CCL)
No. of trains **Last updated: 15 June 2016**	Over 200
No. of lines	4
Ridership (as of FY2016)	755.7 million
Average car occupancy (passenger per car) **As of FY2016**	63.4
No. of depots	4
No. of underground & elevated stations	EWL: 7 underground, 24 elevated NSL: 11 underground, 16 elevated CCL: All underground BPLRT: All elevated
Train cabin no.	A 4-digit number located near the gangway between train cars
Total route length (NSEWL &CCL) (km)	129.8 km
No. of stations	84 MRT stations 14 LRT stations

Appendix B

The screenshots shown below are the General Public Survey on Mass Rapid Transit (MRT) done on Google Forms.

This is the link to the survey on Google Form:
https://docs.google.com/forms/d/e/1FAIpQLSegjHPu7KgMsMGZbzqSZYyg40EmSzqUphyGlfdc2yP4LFJlow/viewform



General Public Survey on (Mass Rapid Transit) MRT

We are conducting a survey regarding the congestion on the MRT platforms during peak hours.
We would kindly appreciate your feedback on MRT.
All answers will be anonymous.

*Required

Q1. Which station do you find is the most congested? *

Your answer

Q2. How often do you take the train during peak hours (weekdays: 7.30a.m. - 9.30a.m. and 5.30p.m. - 7.30p.m.; weekends: 12-2pm and 6-11pm)? *

	1	2	3	4	
Never	○	○	○	○	Always

Q3. How satisfied are you with the train schedules? *

	1	2	3	4	
Very dissatisfied	○	○	○	○	Very satisfied

Q4. How crowded are the platforms during your journey? *

	1	2	3	4	
Never	○	○	○	○	Always

Q5. Rate your experience during congestion period. *

	1	2	3	4	
Very Poor	○	○	○	○	Excellent

Q6. How often do you take the train per week? *

- ○ 0-1
- ○ 2-3
- ○ 4-5
- ○ 6-7

Q7. How long do you usually take to board the train during peak hours? *

- ○ 0 - 5 minutes
- ○ 6 - 10 minutes
- ○ 11 - 15 minutes
- ○ more than 15 minutes

Q8. Which sections of the station do you usually move to to board onto the trains? *

- ○ Ends of the train
- ○ Middle carriage
- ○ Near the escalators of the station
- ○ The door with the shortest queue

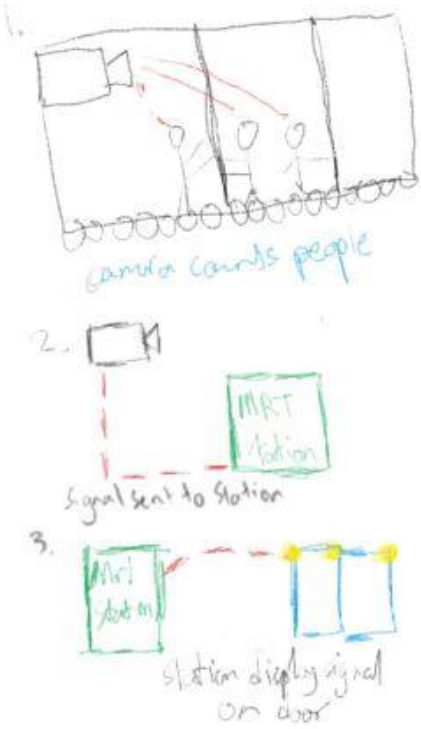
Introduction to Prototype

Due to congestion on platforms, we came up with a prototype to counter this problem.

The prototype helps to monitor the number of people in the trains that are approaching the station, then transmits the information to the light indicators on the MRT platforms. The light indicators are located at each door on the platform. It will respond based on the capacity of passengers in each cabin: GREEN (low), ORANGE (medium), RED (high).

This acts as an advisory for passengers to consider queueing up at the 'GREEN' indicated doors so that they have the chance to board the train.

Illustration of Prototype



Q9. Do you think it will be helpful to implement this system? *

	1	2	3	4	
Not at all	○	○	○	○	Very

Q10. Would you take advisory from the light indicators on the MRT platform if this prototype was implemented? *

	1	2	3	4	
Least likely	○	○	○	○	Definitely

End of survey.

Thank you for taking part in this survey! :)

SUBMIT

Never submit passwords through Google Forms.

Appendix C

Table 3: Top 5 Stations in Various Distributions

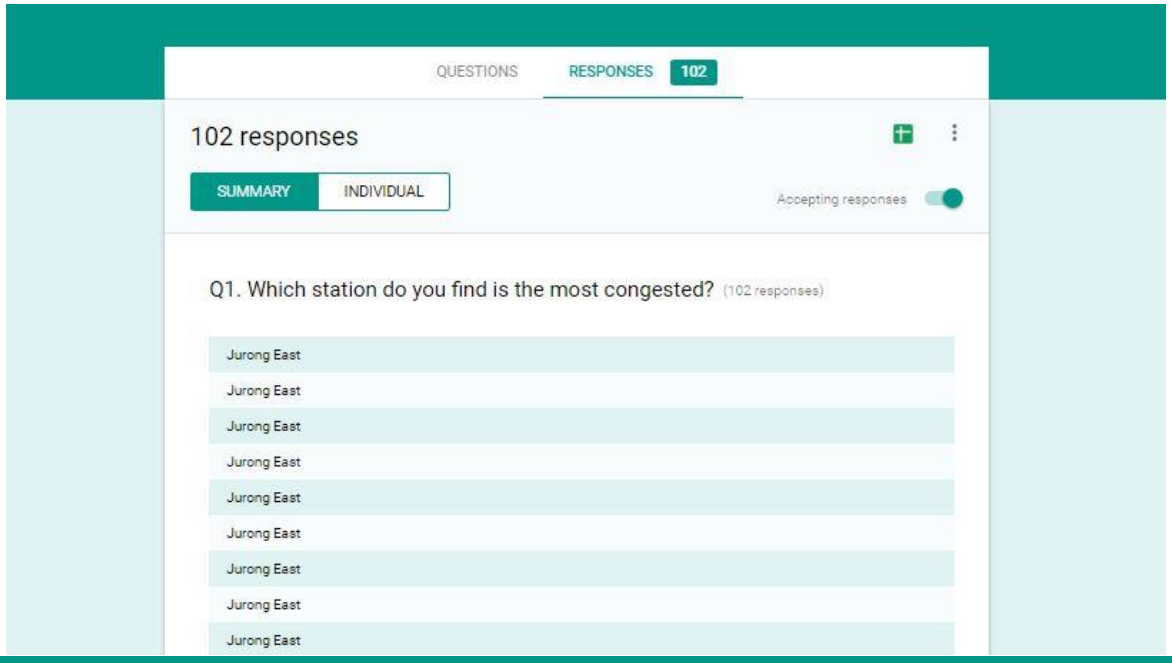
Rank	MRT Station	Value (# of passengers)
MEAN		
1	Orchard	916
2	Raffles Place	796
3	City Hall	757
4	Ang Mo Kio	700
5	Boon Lay	694
MAX		
1	Raffles Place	6322
2	Tanjong Pagar	4604
3	Yishun MRT Station	3019
4	Orchard	2879
5	Tampines	2664
MIN		
1	Ang Mo Kio	54
2	Yishun	40
3	Woodlands	35
4	Bugis	34
5	Clementi	31
SUM		
1	Orchard	1,979,034
2	Raffles Place	1,720,209
3	City Hall	1,636,709
4	Ang Mo Kio	1,513,342
5	Boon Lay	1,499,068

Note that MAX, MIN and MEAN distribution were measured by number of passengers entered a train station in a time interval of 15 minutes while SUM distribution were measured by the total number of passengers in a given train station for November 2011.

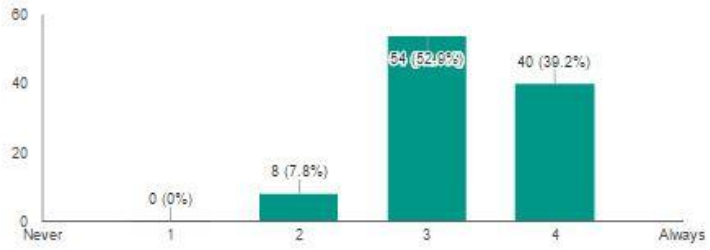
("Time-Series Data Mining in Transportation: A Case Study on Singapore Public Train Commuter Travel Patterns", 2011)

Appendix D

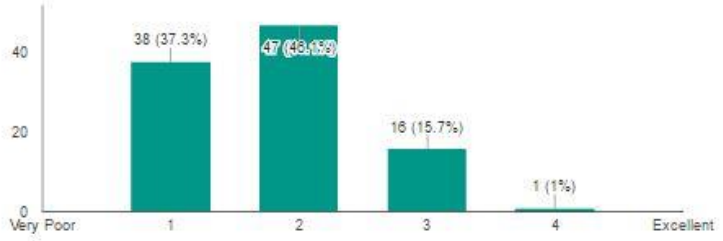
These are the screenshots of the results and tabulation done by Google Forms based on the survey, General Public Survey on (Mass Rapid Transit) MRT.



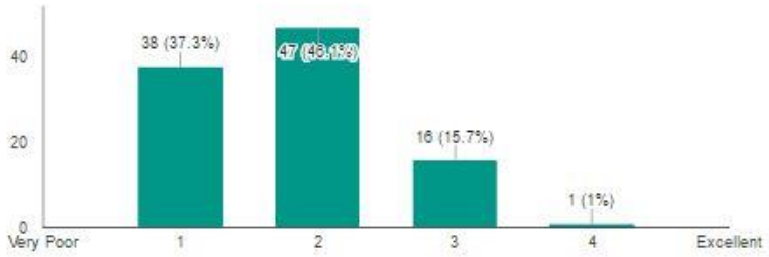
Q4. How crowded are the platforms during your journey? (102 responses)



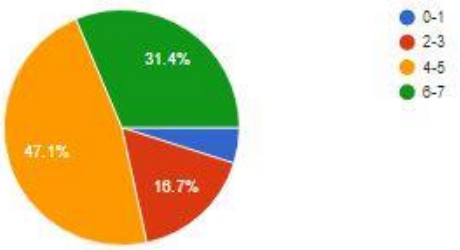
Q5. Rate your experience during congestion period. (102 responses)



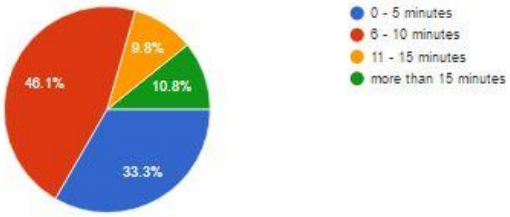
Q5. Rate your experience during congestion period. (102 responses)



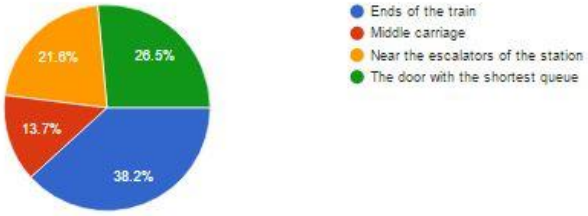
Q6. How often do you take the train per week? (102 responses)



Q7. How long do you usually take to board the train during peak hours?
(102 responses)

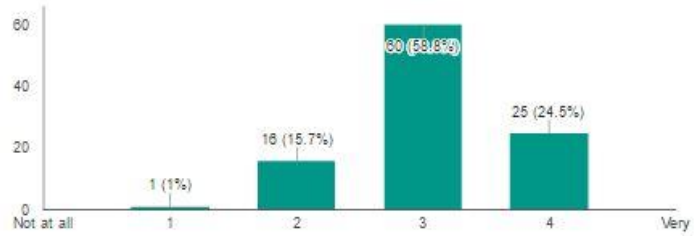


Q8. Which sections of the station do you usually move to to board onto the trains?
(102 responses)



Introduction to Prototype

Q9. Do you think it will be helpful to implement this system? (102 responses)



Q10. Would you take advisory from the light indicators on the MRT platform if this prototype was implemented?
(102 responses)