Project Titan 4.0

2021 Group 11-11

Leow Junn Kai Jonathan(2i210)
Wang Yihua (2i221)

Hwa Chong Institution (High School)

Abstract

Traffic congestion in Singapore causes many problems, such as reduced productivity, stress of physical health, and air pollution. It was found many traffic jams were located near or beside shopping malls, caused by the number of cars queuing to enter the malls' car parks (too few lots), a single entry way to the carpark, and an inability to find “hidden” parking lots. As such, this project aims to lessen traffic congestion by way of an efficient parking system. The final product utilizes an airlock door system, with the car driving onto a metal plate with wheel clamps to secure the car. The replication of similar structures is easy to be done, thus facilitating better car park access. When the driver exits the vehicle, he will key in his particulars to enable retrieval of the vehicle, then proceed into the mall. There will be infrared sensors to ensure no one is in the car, then said metal plate with car attached would be moved to a storage system until retrieval. The process of storing the car is fully-automated, to ensure efficient parking and maximum usage of parking lots. The plate will utilise a rail system to move. The system will allow for vehicles to be quickly parked with the use of light sensors and AI, allowing for efficient parking and better handling of traffic, thus reducing traffic congestion.
(224 words)

1. Introduction

Inspired by the myriad of problems that arise from traffic congestion, it has been decided to combat these problems by killing the problem at its source; traffic congestion. A correlation between the areas with major traffic congestion and the presence of certain malls near to it was observed, and a more extensive investigation of this phenomenon occurred. It was realised that commuters are having to wait 15.6 minutes, up from 11.2 minutes in 2015, with taxis often getting caught in the traffic snarl along Scotts Road, when travelling from Far East Plaza from the 9pm to 10pm peak period. (The Strait Times) One of the main problems that causes traffic congestion is the popularity of malls. This can be seen by the location of the traffic jams mentioned above that occur near popular malls as ION and

Paragon. One of the main problems that causes traffic congestion is the popularity of malls. Some malls, such as Ngee Ann City, ION, and Suntec City, not only attract citizens from all over the island, but tourists too. To find out how to decrease traffic congestion near these popular malls, a visit to the malls, brought about the realisation that most of them have only one entrance to its carpark (IKEA, Ngee Ann City, ION)

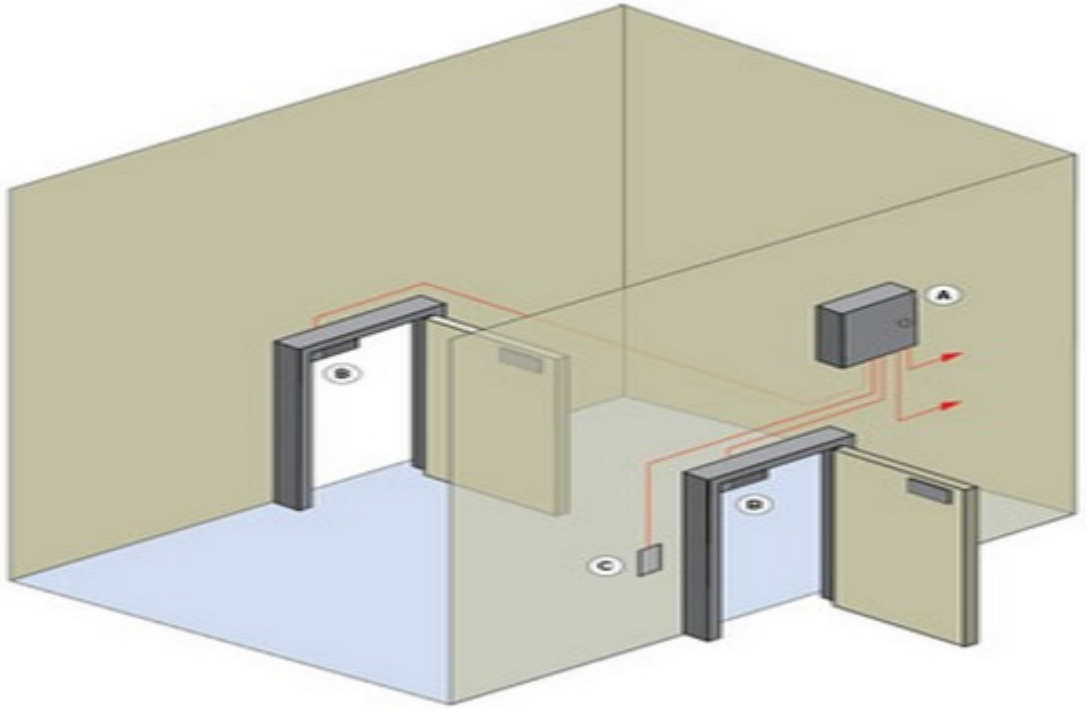
Entrance to IKEA Singapore. Only one entrance.

The realisation that carpark inefficiency was a problem led to the redesign of the whole concept of a carpark. This is because the inclusion of human nature into our current parking system brings out certain problems, including but not limited to, fights between drivers for parking lots, difficulties in parking that cost time, and inability to find available parking spots. All these factors lead to slower parking times, and lead to longer waiting times and thus more traffic congestion. An automated system was decided upon, as the system would know where all the empty lots are, and can send the car there immediately, saving time, and improving efficiency. A plan to integrate both the car storage system, the AI, and sensors, was the final result. It aims to store cars in an hexagonal- shaped structure due to it being the most space-efficient shape (Chamberland, M. 2015, July 22), with sensors directing cars to empty lots. It is automated, and because of lack of human error or human involvement, the

storage method could utilise fast-speeds to get where the lot is, thus again increasing efficiency. The system will have an interface, similar to a mall directory, where customers can key in either a password for retrieval of the car, or simply use their fingerprints. Using this system, the speed of parking a car will be optimised, and the time taken to park will decrease drastically. This will allow for cars to enter the malls more efficiently, preventing queues and blockages, and decreasing traffic congestion. As a result,the new parking system will decrease the amount of traffic congestion near malls in Singapore dramatically, thus achieving the aims of the project.

2. Solution Design

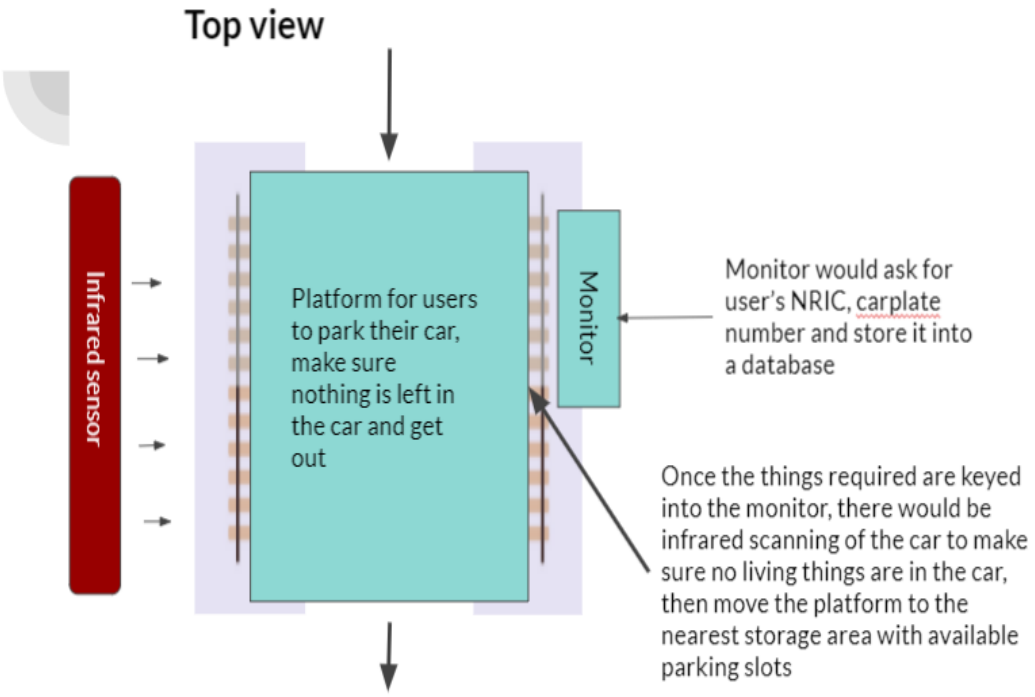
The solution is modelled after several car vending machines around the world. The car will enter the automated parking system through an airlock system.



Airlock door

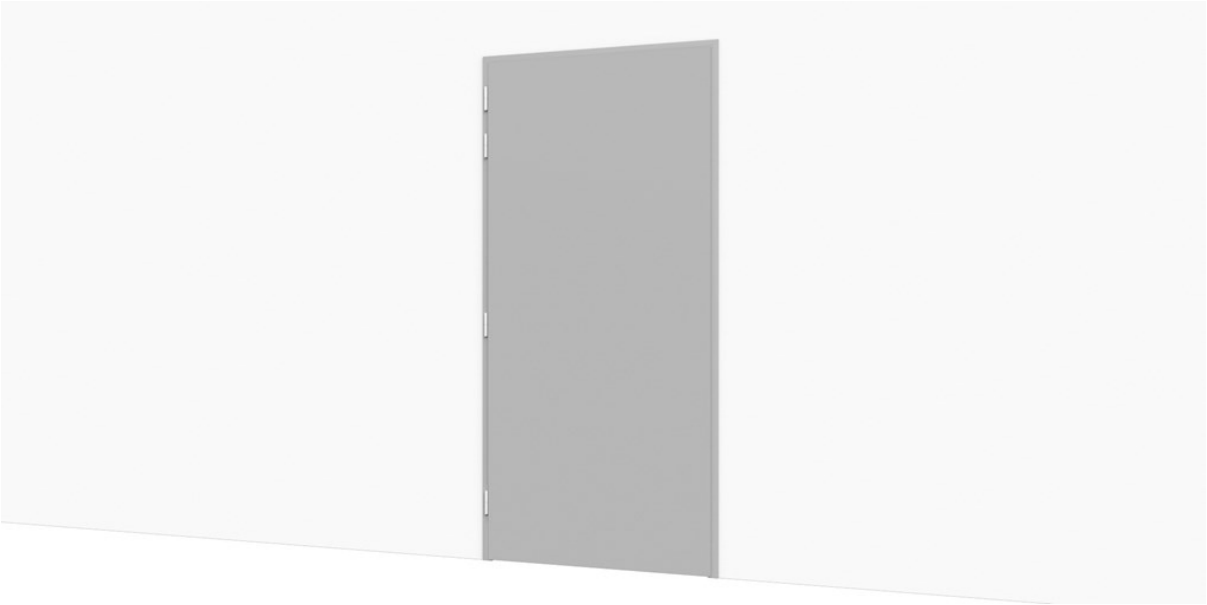
The main difference between this door and the door that would be used is that the entrance will be bigger. A prime example will be Mount Elizabeth's car lift. The only difference is that the system does not need to go up and down, and will include a side door, to allow entrance into the shopping mall. Inside the airlock system, there will be a touch screen console, akin to those used in malls, and an infrared sensor, to make sure that the car does not have any passengers in it before it is sent to the parking lots.

Touchscreen console

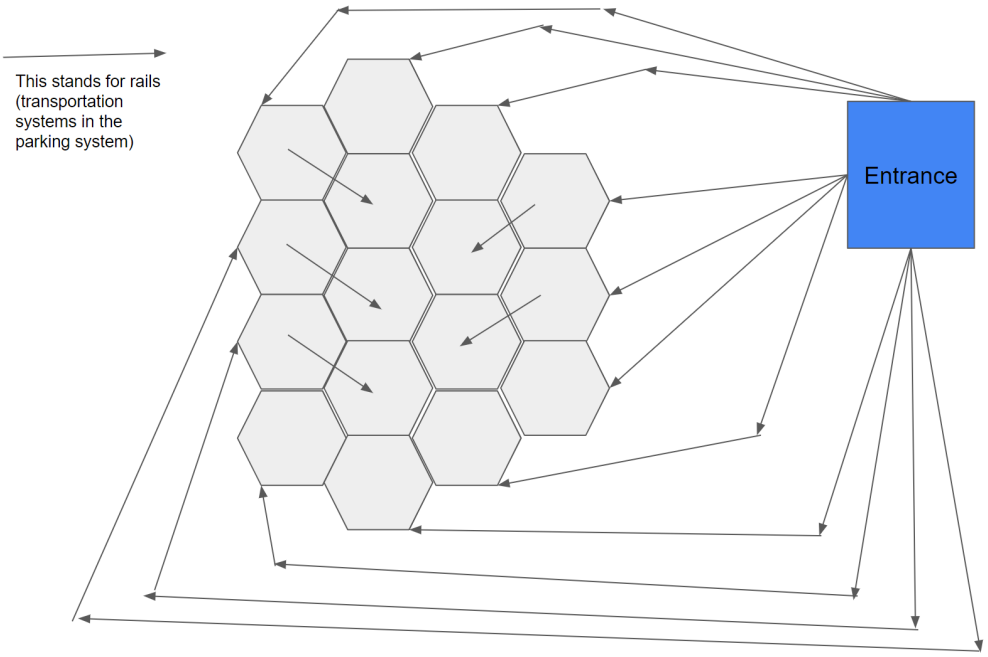


Top view of the system that will be used

This console will be used to allow drivers to key in their car's number plate, and a password they will create. This will ensure the car's safety, as the driver will need to key in both the number plate and password to retrieve their car. After that, shoppers will exit the airlock through the above-mentioned door. The process of storing the car will only occur when the infrared sensor detects no living beings are in the airlock. To ensure people do not re-enter the airlock after exiting it, the door will only have a handle on one side of it, on top of an electronic lock, making sure that no one is able to enter it through the mall.



Emergency door front and back, which can only be opened one way. If someone is able to enter the airlock, alarms will sound, directing security to the offending person.



Hexagonal structures mentioned below

The car itself will be attached to a metal plate by several wheel clamps. This is to ensure that the car will not fall off the metal plate and get damaged during the parking process. The minimum and average size of parking lots in Singapore is 2.4m wide and 4.8m long. Thus, the metal plate on which we will transport vehicles on, will be modeled as such. The actual storage system itself is modeled after beehives. According to research, hexagons are the most space-efficient shape in nature and it was decided to build a system reliant on hexagons, to utilise every bit of space. The storage system will be a structure, instead of a full-built building, with only walls separating the different parking lots. It will be hexagonal in nature, with 6 parking lots available in each level, with the exception of the first level. The bottommost level will not have any parking lots, allowing cars to move past a structure that is fully-filled, to one that is not yet full. The structure will be tilted outwards at 15 degrees, with the middle of the structure being taller than the rest of the structure. In the middle of the structure, there is a platform that can be raised, to bring cars to different levels of the structure. When the car has reached its assigned lot, the system will simply release the car, which is attached to the metal plate, into the lot. To prevent it from falling out, there will be pop-up bollards in place.

Pop-up bollards

When the car is to be retrieved, the bollard simply retracts, and the will gain access to the transport system that will bring it to its assigned destination. The transport system that brings the car to the structure and the one that brings the car to the exit are not linked in any way, and are kept separate from one another. This is to facilitate easier maintenance, and allow for a more efficient parking system. The actual transport system itself is modelled after rails and the MRT and LRT system in Singapore. The metal plate will have wheels attached below it to move along the system, which, like the MRT trains, will use electricity to move. The car retrieval process will be started by the driver keying in both the car's number plate and password, into a similar console at the carpark entrance. The system will identify the car's "particulars", and which metal plate it is parked on, and then recall the car to the exit of the mall.

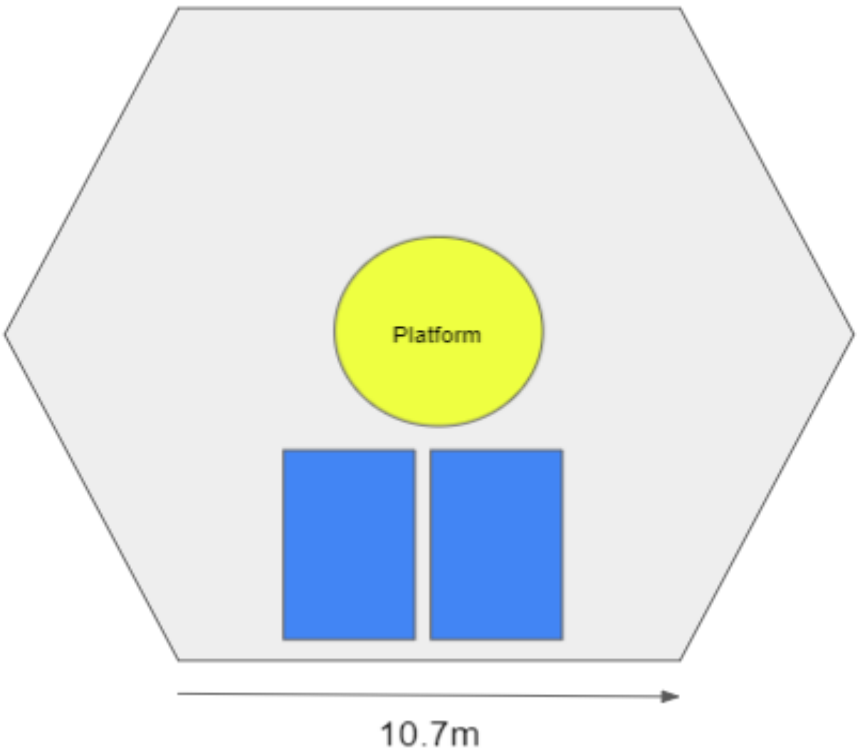
When the car exits the mall, the metal plate will be directed to an empty airlock door system. If all the doors have metal plates, it will be moved towards the bottom of the airlock door system, and, when the metal plate above it is moved, will rise from the under the previous metal plate and be used for the next car entering the parking system.

3. Results & Discussion

3.1 Infrastructure

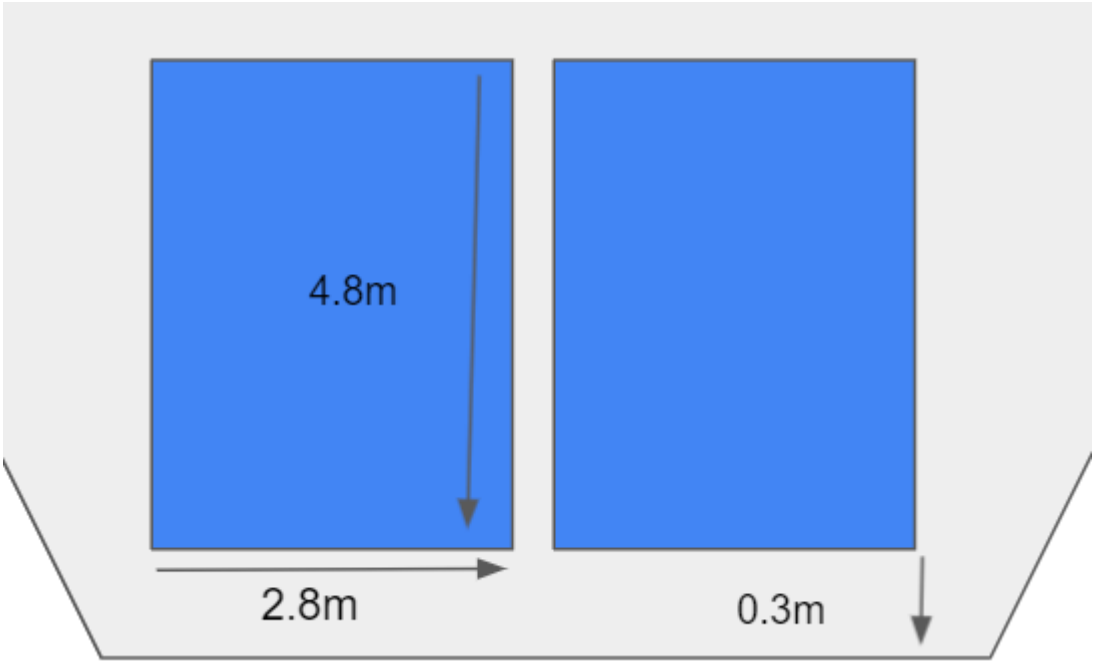
It was decided to find and model our parking system after a specific mall in Singapore, to provide proof of the system's idea's feasibility, reliability, and efficiency. That mall, in particular, is Suntec. The mall was chosen as it is one of Singapore's biggest malls, and if the system could handle such a big amount of cars easily, it would be easily applied to smaller car parks in smaller malls too.

The project was started by establishing certain rules that would have to be followed. One example was the minimum length of 2.4m x 4.8m width and length of a parking lot respectively. (Land Transport Authority. 2019). However, the design was adjusted to 2.8m x 4.8m, due to a necessary widening of the lot required by the code of parking provisions, if there are any obstructions that would be located in the lot. In our design, said obstructions would be the wheel clamps securing the car.



Top view of a level of the structure (Not drawn to scale)

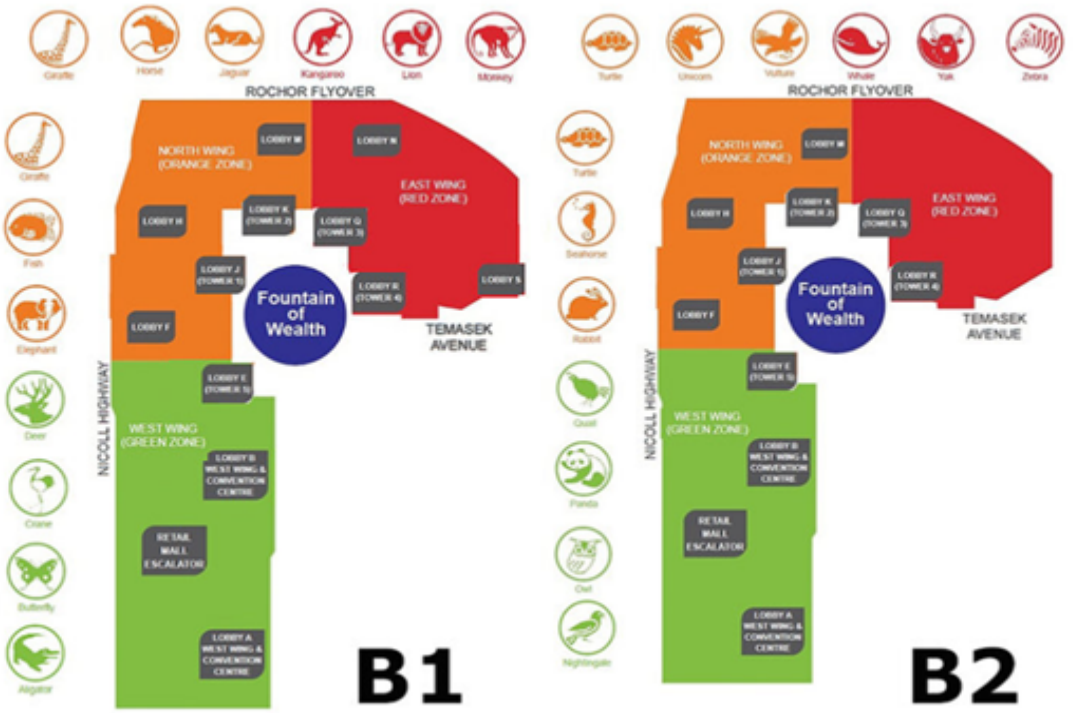
Each structure will have a height of 17 stories, and be 36m tall. Each will have a side length of 10.7m each. The number of parking lots is not fixed as some slots need to be removed to make way for the rails to transport cars in between buildings.

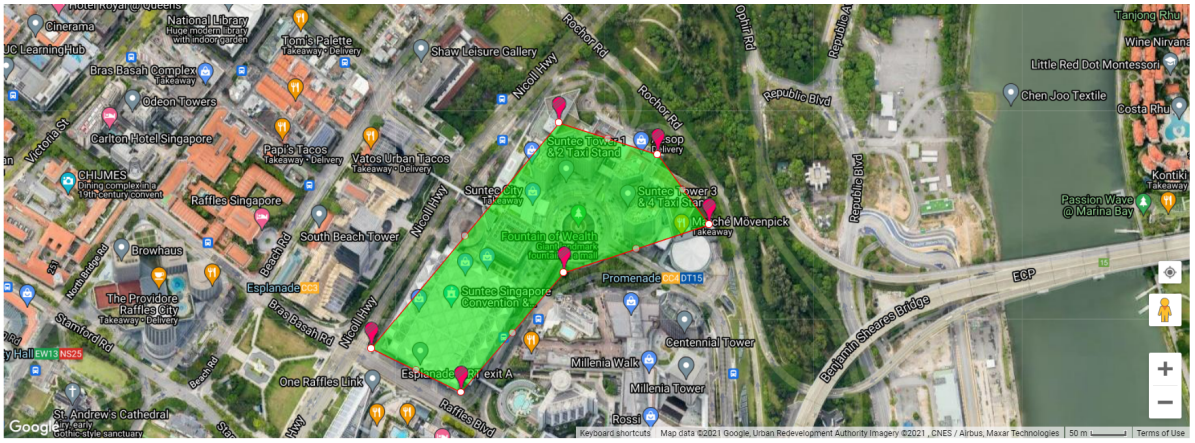


There are over 3000 parking lots in Suntec City, not including the 12 VIP lots. (Eva Suntec. n.d.) According to the same website, Suntec City's carpark takes up the entire space beneath the mall, excluding the space beneath the Fountain of Wealth.

The space the structure will take:
10.7*9.3*3 = 298.53m² (Area of one hexagonal structure)
298.53*17=5075.01m² (Area of the combined structure)
5075.01m²=0.00508km² (Area of structure in km², rounded to 3 s.f.)

Parking lots the structure will provide with 0.00508km² of space:
17*12*17=3468





Output : Current Area

76636.30 m² | 0.08 km² | 18.94 acres | 7.66 hectares | 824906.28 feet² | 0.03 square miles | 0.02 square nautical miles

Current Perimeter

1309.972m OR 4297.809feet

As seen, Suntec City takes around 0.08km² of land. When the amount of space the fountain takes up is removed from the equation (0.00168307km²), Suntec City has an approximate car park space of 0.0783km² (Rounded to 3 s.f.) This means currently, 3000 parking lots takes up 0.0783km².

In comparison, this system needs only about 0.00508km ² of land for 3468 parking lots. If all the current parking space, that would amount to a whopping 53 453

available lots. The project is more than 15 times more efficient than the current parking system.

The project is aimed at decreasing traffic congestion, and other than efficient use of space, it also allows for faster entrance to the carpark. For the Suntec model, it was decided that 100 airlock doors/systems would be required, 50 for entrance, 50 for exit. These doors will be spread around the perimeter of Suntec, taking up about 500m. It is estimated that drivers will take about 40 seconds, at most, to fill in the car's number plate, and leave the system. That means that drivers will spend around a minute inside the system, before leaving, and that 50 cars can be parked in one minute. This would facilitate easy access to parking, decreasing the traffic congestion around Suntec. While 50 cars per minute might not sound like an astonishing number of cars entering a car park per minute, it has to be taken into consideration that once the car enters the system, which means once it passes the second airlock door, another car can take its place, and the car will be automatically parked. Thus, an assumption can be made that once the car is through the second airlock door, it is as good as parked, as the system will park the car automatically.

3.2 Interface

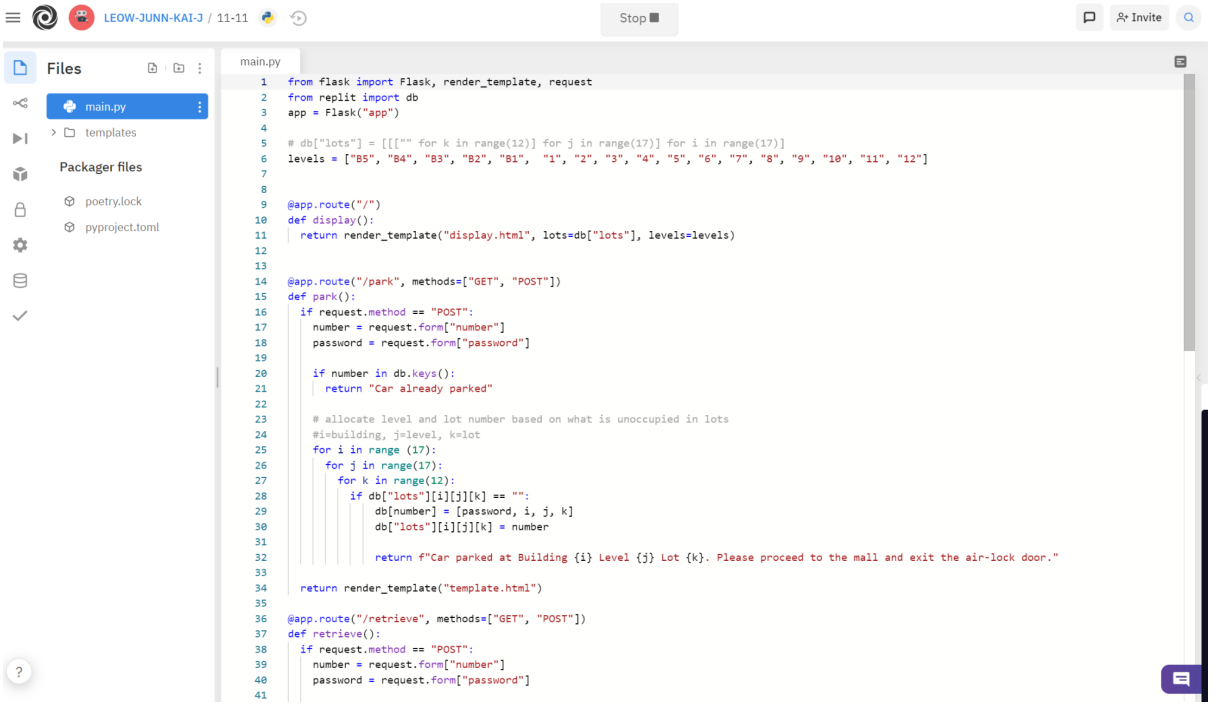
An interface similar to the one that will be used for the actual parking system has been coded to show how the system will function.

https://replit.com/join/xyqfqekrdh-leow-junn-kai-j (Link to replit website where the website was coded)

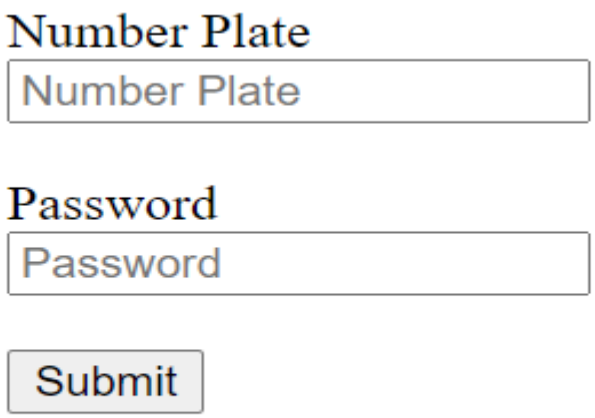
https://11-11.leow-junn-kai-j.repl.co (Link to website that shows the availability of the parking lots)

https://11-11.leow-junn-kai-j.repl.co/park (Link to the interface drivers will see when they enter the airlock door system)

https://11-11.leow-junn-kai-j.repl.co/retrieve (Link to the interface drivers will see when they retrieve their cars)



Sample of the code used to make the website



Page users will see when they enter the airlock door system

Drivers will enter their car’s license plate and a password they choose to create. When done, the screen will show where the car is parked (which structure, level and lot), and ask the driver to exit the system. Drivers will see the same system when retrieving the car. They simply enter their number plate and password, and will receive the car.

If they enter a non-existent number plate, the system will show “Car not parked”. If they enter a wrong password, the system will show “Wrong password”. If the owner forgets the car’s password, a master password can be entered by one of the people overseeing the system. However, the driver must still enter the vehicle’s number plate, and CCTV footage must show him/her to be the real owner of the car. Currently, the master password is “ProjectsDayHCI”.

Structure 1

Level B5	S3467A	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level B4	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level B3	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level B2	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level B1	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 1	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 2	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 3	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 4	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 5	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 6	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 7	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 8	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 9	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 10	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 11	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 12	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY

Structure 2

Level B5	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level B4	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level B3	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level B2	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level B1	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 1	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 2	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 3	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 4	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 5	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 6	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 7	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 8	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 9	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY
Level 10	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY

Availability of lots

If a lot is occupied by a car, it will show up red, showing the number plate of the car that is occupying it.

Conclusion

It was found that the project has successfully helped to increase the efficiency of the parking system. The use of an automated system means no human error or

inefficiency will slow down the parking. The new and updated parking system will allow for faster parking of cars, with the availability of many entrances, rather than only one entrance to the carpark, thus preventing a bottleneck of traffic. The system also allows for more cars to park in a shorter span of time because cars can also enter the airlock system before the previous car is parked. As long as the car is in the system, another car can enter the airlock door, as the car before it is already on the way to a pre-designated spot and will not be affected by the next car entering the system. This system can possibly be applied in airports(with small modifications for security), such as Changi Airport, to allow for safe, long-term storage of vehicles whose owners are overseas, as the system does not allow people to enter the storage area. Another added point is convenience, as the drivers no longer need to bother with parking the car, and can immediately venture into the mall with their family's, instead of parking the car alone and trying to find their family after they have done so. Several limitations include the possible shutdown of electricity/the AI system. This would lead to the cars being locked in the storage area, without any way to be retrieved. Possible solutions to this include adding back-up generators to the system to prevent power losses. Another limitation is the potential backlog of cars trying to exit the system at the same time. This can be solved by the adding of more exit routes at different roads, to allow for less clogging of the system. The system's price is also a potential problem, but this can be solved by the use of cheaper materials, like durable plastic such as ABS, polycarbonate, PPSU, and UHMW, instead of metal for the structure. (Curbell Plastics. 2017) Another potential modification will be additional input of how long the driver will be staying at the mall. This will allow the system to park the cars of those who are staying the longest at the bottommost or topmost levels (longer to retrieve), to allow those who are staying in the mall for a shorter period of time to retrieve their cars faster. This will add to the overall efficiency of the parking system.

References

Walud, Z., & Chen, D. (2018, May 1). Congestion impacts of shopping using vehicle tracking data. University of Leeds.
https://eprints.whiterose.ac.uk/130359/3/shopping%2520congestion%2520accepted%5B1%5D.pdf

Levy, J. I., Buonocore, J. J., & Von Stackelberg, K. (2010). Evaluation of the public health impacts of traffic congestion: a health risk assessment. Environmental health, 9(1), 1-12.

The Straits Times. (2016, January 27). Longer waits for cabs during peak hours in Orchard. https://www.straitstimes.com/singapore/longer-waits-for-cabs-during-peak-hours-in-orchard

Chamberland, M. (2015, July 22). The Miraculous Space Efficiency of Honeycomb. Slate Magazine. https://slate.com/technology/2015/07/hexagons-are-the-most-scientifically-efficient-packing-shape-as-bee-honeycomb-proves.html#:%7E:text=Hexagons%20are%20the%20most%20scientifically,shape%2C%20as%20bee%20honeycomb%20proves

Eva Suntec. (n.d.). Suntec Singapore — VIP Services [Parking]. VIP Services [Parking]. Retrieved August 7, 2021, from https://www.evasuntec.com/55824-vip-parking/373054-vip-parking

Land Transport Authority. (2019). Code of practice Vehicle parking provision. https://www.corenet.gov.sg/media/2268535/cop-on-vehicle-parking-provision-in-development-proposals-2019-edition.pdf

Curbell Plastics. (2017). Impact Resistant Plastic | Tough, Durable Materials. https://www.curbellplastics.com/Research-Solutions/Applications/Impact-Resistant#:%7E:text=Tough%20and%20durable%20plastic%20materials&text=Certain%20plastics%20such%20as%20ABS,applications%20when%20durability%20is%20critical.

Acknowledgements

We would like to thank our mentor, Mrs Ng-Ang Siew Hoon, for suggesting certain materials and methods to use for building our prototype and improving our solution design throughout the project.

We would also like to thank Liu Jie Xu (Robotics club member), our senior who helped us to code the user interface that will be used for our system.