Multi-Criteria of Location Selection of Suitable Fire Stations for Country Fire Authority in City of Melton and City of Wyndham

Group 12

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Executive Summary

This report examines the location selection of the new fire stations for the Country Fire Authority in City of Wyndham and City of Melton. The criteria for location allocation include population density, locations of existing fire stations, land use, historical fire incidents, transportation and Housing development data, which is used to identify the growing areas.

Due to development in City of Wyndham and City of Melton with an increase of local population and properties, existing fire stations may be insufficient in providing quality services to safeguard the wellbeing of residents, local businesses and the environment. This project is to evaluate the quality of service areas of current fire stations and potentially propose new fire stations to enhance the fire service coverage. The location allocation is the primary objective in this project to ensure the best qualities can be achieved with minimum costs.

Assessment of new fire station needs

The assessment of the needs for new fire stations is calculated as:

$$Fire\ service\ demand\ assessment\ *\ (1-\ Mitigation\ factor)$$

Fire service demand assessment

The overall fire service demand weighted average of four data layers:

- Population Density (on a scale of 0 to 10)
- Housing Development Data, which is to assess the growth of an area (either 0 or 3)
- Historical fire incidents (data observed as 0, 1, 2 or 3)
- Different types of land use (on a scale of 0 to 10).

The overall fire service demand is rescaled to 0 to 10 and the calculation is

$$\frac{1}{2.6} * (Population\ Density\ (0{\sim}10) + Housing\ Development\ Data\ (0\ or\ 3) + \text{Historical Fire Incidents}\ (0\sim3) + \text{Land Use}(0{\sim}10))$$

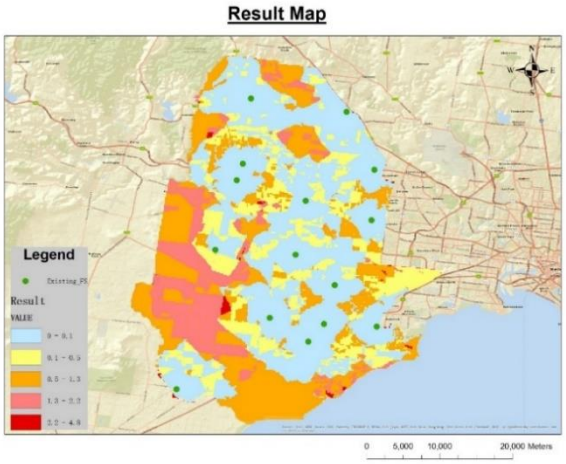
Mitigation Factor assessment

The mitigation factor is assessed based on the service analysis given the road networks and existing CFA stations and MFB stations in City of Wyndham, City of Melton and their neighbouring cities.

Given the service areas of existing fire stations and its coverage within 3.5, 7 and 10 minutes, the mitigation factors are assigned as

Response time	0~3.5 minutes	3.5~7 minutes	7~10 minutes	>10 minutes
Mitigation factor	100%	80%	20%	0%

Result map

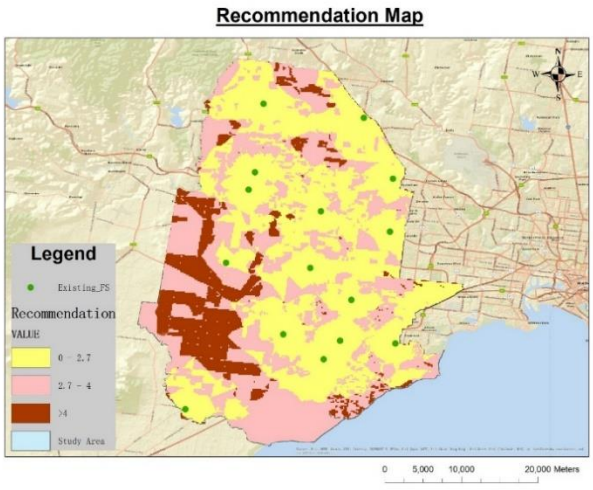


The result map illustrates the requirement for new fire stations in each grid.

The map is on a scale of 0 ~ 10 and the data is in a range of 0 ~ 4.8 (No data with values above 4.8 were perceived). The value represents the varying demand of new fire stations.

The map vividly demonstrates that the demand around existing fire stations is low, corresponding to the services fulfillment by the existing stations. Interestingly, the result map highly correlate to the map which identifies growing areas (shown in Map 6-3-1). This suggests that the growing areas may have been recently developed, where public facilities, like fire stations may be inadequate.

Recommendation



Overall the recommendation includes:

- For the dark areas shown on recommendation map, initiate a plan to select locations in their centres or nearby areas, such that the perceived requirements can be fulfilled.
- Further monitor the changes of demographics and constructions in the pink area shown on recommendation map. New fire stations may be required with population growth. But no urgent needs have been observed.
- Possibly streamlining the existing services in the yellow areas on recommendation map, such that some existing fire stations can relocate to serve greater areas.

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1. Introduction

This report examines the location selection of the new fire stations for the Country Fire Authority in City of Wyndham and City of Melton. The criteria for location allocation include population density, locations of existing fire stations, land use, historical fire incidents, transportation and Housing development data, which is used to identify the growing areas.

Due to development in City of Wyndham and City of Melton with an increase of local population and properties, existing fire stations may be insufficient in providing quality services to safeguard the wellbeing of residents, local businesses and the environment. This project is to evaluate the quality of service areas of current fire stations and potentially propose new fire stations to enhance the fire service coverage. The location allocation is the primary objective in this project to ensure the best qualities can be achieved with minimum costs.

This report encompasses the detailed illustration of data and illustrates the impacts of such data on the demands or the mitigation of additional fire services. The final location selection is determined by the residual demands of fire services after the mitigation of existing fire stations. Finally, the report recommends on the areas where new fire stations should be considered.

2. Current issues and prior research on location allocation of fire stations

City of Melton and City of Wyndham have both witnessed a surge in population growth during the past decade. As of 2018, the population in Melton reaches more than 160,000 and it is expected to further grow to 485,000 by 2051 (City of Melton, 2019). Similarly, the population of City of Wyndham is forecast to grow from 250,000 in 2016 to 435,000 by 2036 (City of Wyndham, 2018). The significant surge in population and the expected further growth raise a question on whether the current public facilities are sufficient.

Fire stations, which safeguard the livelihood and wellbeing of residents and local businesses, are among the most vital services that cannot be overlooked during the process of population growth.

This report is to evaluate the potential insufficiencies of fire stations for Country Fire Authority. In the event of identified insufficiencies, a list of fire station locations is proposed to ensure quality services to be provided to the most needed residents or local facilities.

Prior research has identified the following factors to be considered in the process of fire station location selection:

- Projected population growth. (Murray 2013) As two of the highest growing communities in Melbourne, the population data is the most important factor to be considered. Considering that the fire stations may provide long-lasting services, the population projection may look ahead a few years.
- Historical fire incidents data. (Yang et al. 2007) The distance between fire incidents and fire stations are the fundamental factor in assessing the fire service qualities.
- The different types of facilities. (Schreuder 1981) Different facilities may have varying priority in fire service allocation. For instance, population centres are particularly of the interests of the project considering its relative high riskiness in fire incidents and

potential high severity in damages, such as schools with underage students. (Schilling et al. 1979)

The location selection combines the above identified criteria and considers the existing CFA stations, such that the proposed addition fire stations can address the current insufficiency in fire services allocation.

3. Raw Data Explanation

3.1 Criteria of selection of location

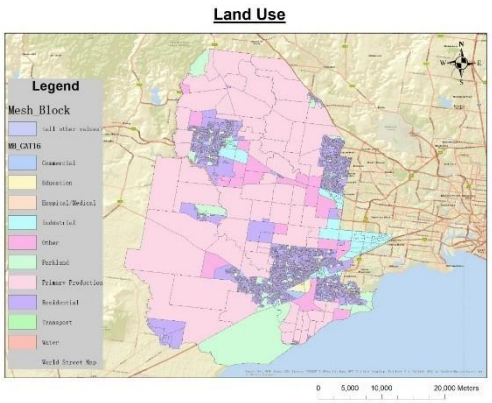
According to the previous research, six aspects are considered.

3.1.1 Land use

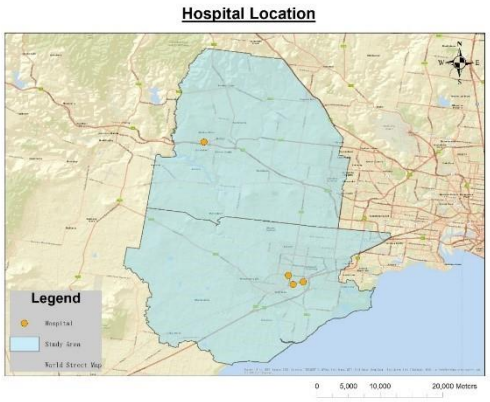
The functional partition of a city is one of the significant factors when considering the site selection for fire stations. This is because most of the fire incidents might take place in the chemical factory which contains flammable and explosive material, or some restaurants mainly use gas facilities for cooking, and these always have the negative impact on the surroundings and safety of people. The different type of land use represents the varying likelihood of fire occurrence and its severity in damages.

Therefore, combining different types of land use is an essential perspective for deciding a possible location of fire station. For example, how to deal with the blocks for industrial and educational purpose and generate a layer based on a certain range could determine the site selection.

The map (3-1-1) below presents the category of land use for each mesh block within the city of Melton and Wyndham, while the other map (3-1-2) shows the accurate locations of public and private hospitals in point format.



Map 3-1-1 Land Use



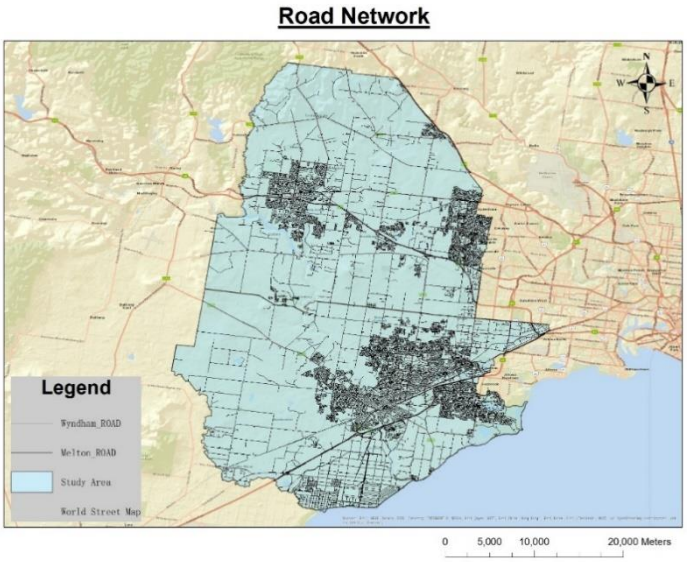
Map 3-1-2 Hospital Location

Map 3-1-1 Land Use

3.1.2 Transportation

It is imperative to consider the distribution of road network as the criteria of transportation, since the traffic condition might have an influence on the response time of fire vehicle. Based on several studies and the current performance, setting the certain standards for response time plays an essential role for the final choice of location of fire departments. For instance, although the fire trucks are normally not restricted by the traffic rules on the way for rescue such as the

traffic lights or the limited speed of various types of roads, the road accidents might cause the traffic congestion on a particular road or period, which indirectly leads to the increase of response time. The following map (3-2-1) shows almost all roads in two cities and this project would concentrate more on the areas with dense roads and provides a reasonable plan of possible locations for fire stations.

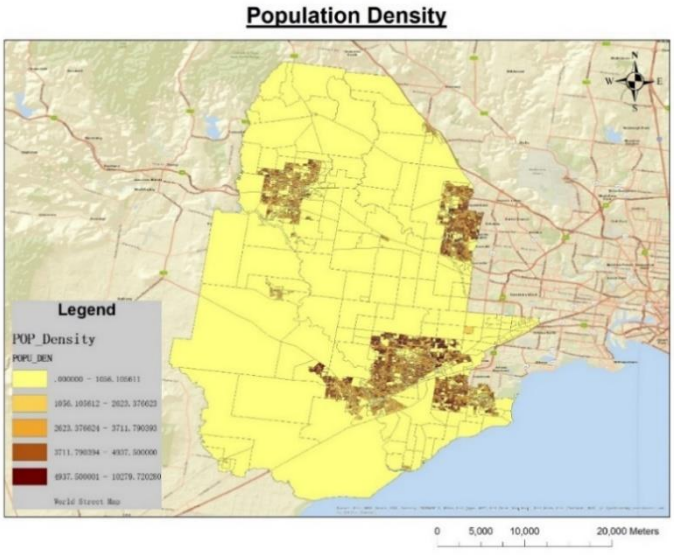


Map 3-2-1 Road Network

3.1.3 Population density

When making the choice of criteria, population density is another factor which requires to be accounted for. After analysing the dataset, more attention is focused on the blocks with high population density due to its higher likelihood of fire occurrences and higher damages with more people impacted.

The map (3-3-1) below displays the overall distribution of population for city of Melton and Wyndham. The blocks in dark colour represent the densely populated areas, while the rest of blocks are under development at that time.



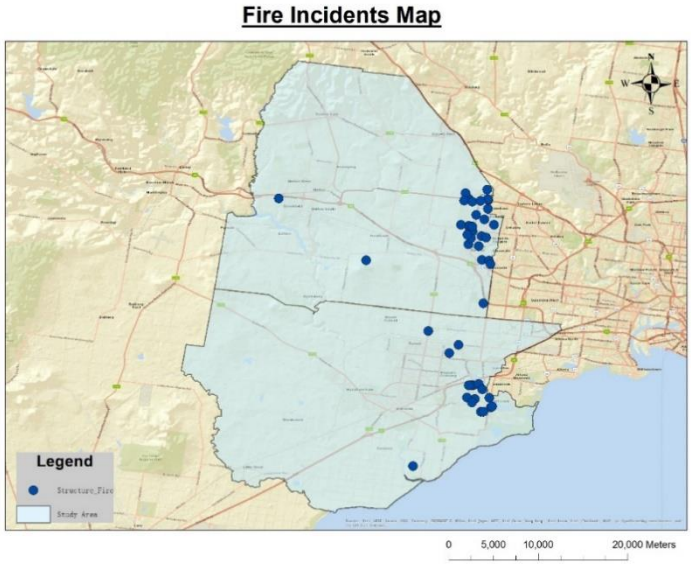
Map 3-3-1 Population Density

3.1.4 Fire incidents

Regarding to the fire incidents, the past fire incidents may also be relevant in determining the current and future fire service needs despite the changes of landscape and land uses.

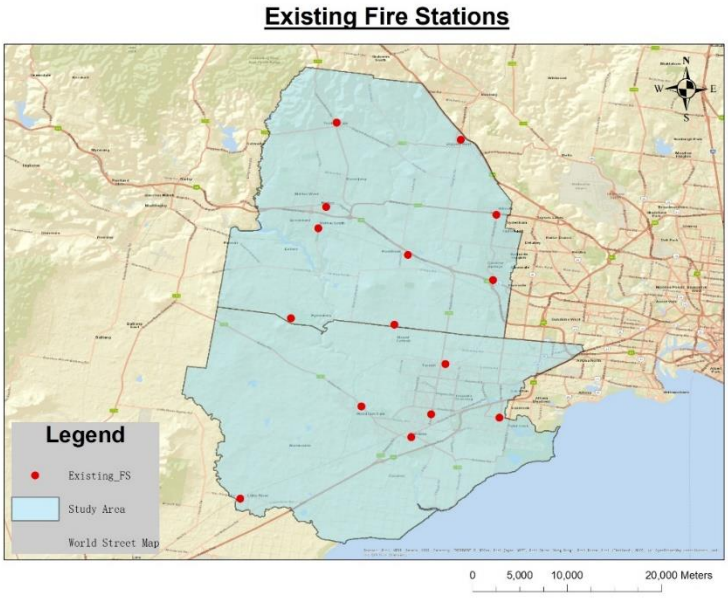
This report primarily focuses on the structure fire, which involves the residential, commercial and industrial fire. The grass fire is not the primary focus in this analysis due to the lack of reliable data source on the location of ignition and the relative lower requirement in arrival time of fire services considering the relative lower damages.

According to the classification of fire types, there are mainly two types of fire being considered in this part, structure fire and wildfire respectively. The following map (3-4-1) demonstrates the location of fire occurred in commercial or residential buildings (blue points).



Map 3-4-1 Fire Incidents

3.1.5 Existing fire stations

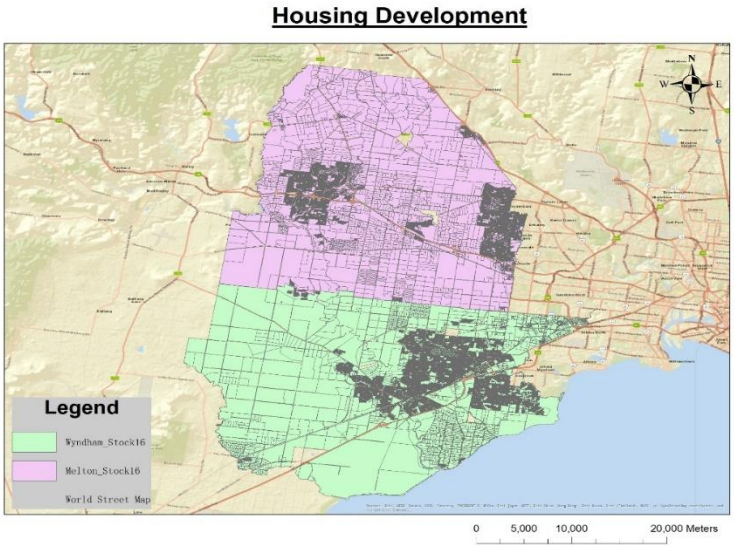


Map 3-5-1 Existing Fire Stations

Current fire stations serve the mitigation purposes in determining the demands of additional fire stations. The fire stations will be analysed regarding its service area within a reasonable

response time. The less covered area with high demands in fire service according to the assessment will be the places for which additional fire stations are likely located.

3.1.6 Housing development data



Map 3-6-1 Housing Development Data

Considering the projected population growth, the housing development data details the buildings under construction, which reflects future population growth. Unlike census data, which reflects the previous population as of a time point, housing development data indicates the project population in the future.

As fire stations are to provide long-lasting services primarily focusing on residents and local businesses, it is important to consider the location of fire station according to the areas already inhabited and areas to be developed in the future. The housing development data, hence, offers a more detailed perspective into the growth areas while providing an indication on how the areas are to be developed.

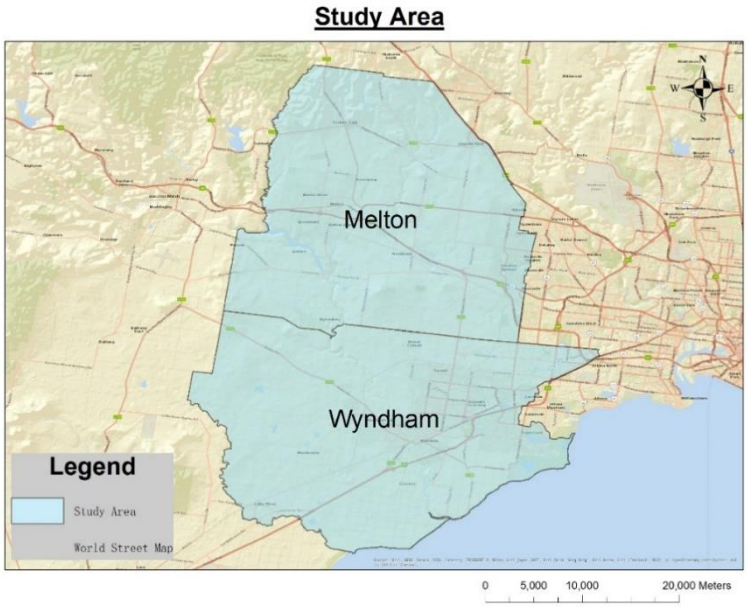
The housing development data is analysed to identify the current and projected future demands of fire services such that the location allocation of fire stations will closely represent and reflect such demands with minimum costs. In this way, the fire station will give full play to its greatest value.

4. Methodology and tools

4.1 Project objectives and overall framework

The objective of this project is to generate a map on which a list of new fire stations is proposed. The project is to focus on the service areas of Country Fire Authority in City of Wyndham and City of Melton.

Map: Focused region (CFA service area in City of Wyndham and City of Melton)



Map 4-1 Study Area

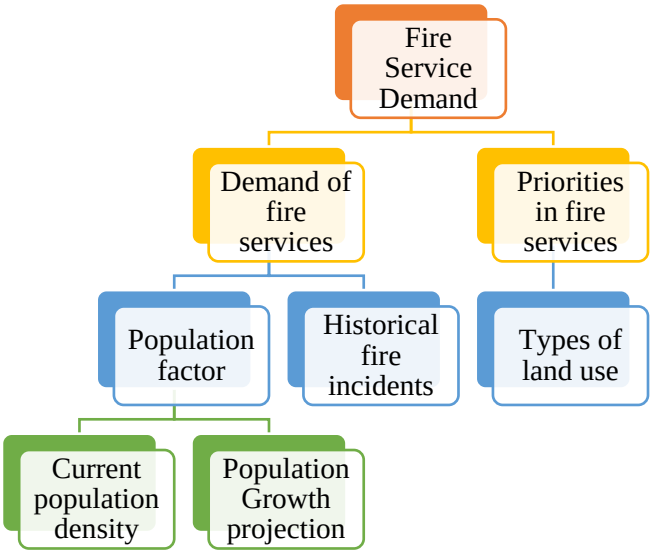
4.1.1 Overall assessment framework

Overal framework	Fire service demand assessment
	(minus) Mitigation: service areas covered by existing fire stations
	(residual) The additional fire service needed to be covered

The overall framework of this project includes 3 main process:

1. Fire service demand assessment: This is to assess the overall demand of fire services dependent on the likelihood of fire occurrence and the fire service allocation priorities determined by the potential damages.
2. Mitigation - service areas covered by existing fire stations: The current fire stations provide services to nearby areas. Dependent on varying response time, different mitigation factors are assigned.
3. The additional fire service needed to be covered: This is calculated as the subtraction of the fire service demand and mitigation (service areas covered by existing fire stations). The location selection of the new fire stations is based on the residual demand of fire services which is uncovered by the existing fire stations.

4.2 Fire service demand assessment



4.2.1 Factor identifications and processing

The factors that affect the overall fire service demand include: Population (2016 census data); Historical fire incidents data (combination of structure fire and forest fire) ; Land use; Housing development data (2016) and all data are converted to raster data.

Population density

- The population density is calculated based on the census data in 2016 and the housing development data.
- For each mesh block, the density will be calculated as the total population / the area of land.
- The data is classified on a scale of 1 to 10 based on a uniform distribution.

Home Development Data

- The statistics of vacant houses in Home development data is to assess the growth area, which reflects the recently completed properties and properties under construction.
- The layer is assigned either 1 (for vacant areas) or 0 otherwise.

Historical Fire Incidents

- The historical fire incidents are primarily focused on the structure fire incidents, which include residential, commercial and industrial fires.
- The report does not consider grass fire due to the lack of reliable data on the fire ignition place and the relative more generousity in the arrival time of fire services.
- Buffer analysis is performed on the historical fire data.

Land use

- Different riskiness and urgency to fire services are assigned to different types of land use.
- Land with the Industrial, hospital, transportation, education and commercial purposes is assumed to have either high riskiness or high urgency to fire services.

4.2.2 factor parameters

Factors	Processing (after converted to raster data)	Results deliverables
Population Density	1. Calculate population density on each mesh block. 2. Assign population density to 1~10 based on uniform distribution **U**(0,1)[1] 2. Uncovered mesh blocks are assigned as 0.	0: uncovered areas on mesh block 1~10: Based on ranking of population density
Housing Development Data	1. Locate vacant properties on housing development data and assign value as 3. 2. Other areas are assigned value of 0.	3: Vacant properties 0: Elsewhere
Historical Fire Incidents	1. Perform Buffer analyses on historical fire incidents. 2. Assign 0 to the areas with no incidents within 4km. 3. For each incident occurred within 4km, add 1 to the assigned value.	0: no incidents within 4 km. 1: 1 incident within 4 km. 2: 2 incidents within 4 km. No area with a score of 3 and above.
Land Use	1. Identify mesh blocks for different uses. 2. Assign 0~10 to each mesh block based on its land use.	0: Water 1: Farmland 3: Other 5: Residential 8: Commercial 9: Education, Hospital, Transport 10: Industrial

4.3 Multiple criteria aggregation: An assessment of fire service demand

The overall fire service demand is calculated as:

$$\frac{1}{2.6} * (Population\ Density\ (0{\sim}10) + Housing\ Development\ Data\ (0\ or\ 3) + \text{Historical Fire Incidents}\ (0\sim2) + \text{Land Use}(0{\sim}10))$$

Raster calculator is used in the calculation and the overall demand assessment is on a scale of 0~10.[2]

4.4 Mitigation: service areas covered by existing fire stations

The mitigation of additional fire service requirement is determined by the existing CFA stations and Transportation (road map).

4.4.1 Transportation (Road Map)

The road map will be implemented to calculate the service area of CFA stations with the metrics of

[1] For more information, please reference to https://en.wikipedia.org/wiki/Uniform_distribution_(continuous)

[2] Note: 1/2.6 is the scaling factor to rescale the results to 0~10.

time (in minutes).

For each road, the speed is assumed to be 70 km/h.

No delay is assumed in junctions.

4.4.2 Existing Fire stations

The service areas of current CFA stations will be taken into consideration.

New stations are meant to enhance the response time of the less-covered areas with high fire service urgency.

Fire stations (including MFB stations) in nearby suburbs are also taken into consideration.

All data are converted to raster data.

4.4.3 Mitigation factor assignment.

Three break points are selected in network analysis: 3.5 minutes, 7 minutes and 10 minutes.

Response time	0~3.5 minutes	3.5~7 minutes	7~10 minutes	>10 minutes
Mitigation factor	100%	80%	20%	0%

4.5 Residual: The additional fire service needed to be covered

The additional fire service needed to be covered is calculated as:

$$Fire\ service\ demand\ assessment\ *\ (1-\ Mitigation\ factor)$$

Raster calculator is applied in the calculation.

4.6 Location allocation and review

The residual layer illustrates the areas where additional fire stations are required. Different levels of urgency are also provided based on the calculation.

4.7 Location review

The selected locations will be further scrutinised to ensure the feasibility in construction of such stations in such areas. For instance, other factors including the accessibility to water and spare land in fire station construction are to be evaluated in the review process. Field trips may be necessary in the event of result presentation.

5. Step-by-step process

The step-by-step process in analysing the location allocation of new fire stations is as follows:

1. Determine the study area of city of Melton and City of Wyndham, which is combined in one polygon layer.
2. Population data (from mesh block)
    1) Clip the mesh block layer based on the study area.
    2) Create an additional column in attribute table and calculate the population density as dwelling population / area size.
    3) Convert the polygon data into raster data.
    4) Reclassify the raster data into 10 classes (based on uniform distribution) and assign the population data from 1 to 10. Also assign no data as 0.
3. Population growth data (from Housing Development Data)
    1) Clip the Housing Development Data layer based on the study area.
    2) Convert the polygon data into raster data (based on whether the properties are vacant).
    3) Reclassify the raster data into 2 classes. Assign the vacant data as 3. Assign non-vacant data and no data as 0.
4. Historical fire data
    1) Buffer analysis on historical fire data with distance of 4 km.
    2) Convert the polygon to raster data.
    3) Reclassify the raster. Assign 0 to the areas with no incidents within 4km. For each incident occurred within 4km, add 1 to the assigned value.
    4) Clip the raster data with the polygon.
5. Land use data
    1) Clip the land use data with the study area.
    2) Add additional column in attribute table and assign values based on different types of land use. (see section 4.2.1 for detailed assignment)
    3) Create a raster data based on land use.
    4) Reclassify the no data areas with 3, which is the same as “other type of land use” assignment.
6. Network analysis.
    1) Add data of CFA stations and MFB stations (where applicable) in study area and nearby cities.
    2) Add road network in study area and nearby cities.
    3) Start network analysis and set the road speed as 70 km/h for all types of road. No delay is assumed on junctions.
    4) Identify the service area with 3.5 minutes, 7 minutes and 10 minutes cut-off.
    5) Create another layer based on the service area data and create a raster data layer.
    6) Reclassify the raster data with values of 0, 0.2, 0.8 and 1. (see section 4.3.1 for reference). Assign no data as 0.
7. Aggregate the fire service demand.
    1) Use raster calculator. The output is calculated as (population density + growth

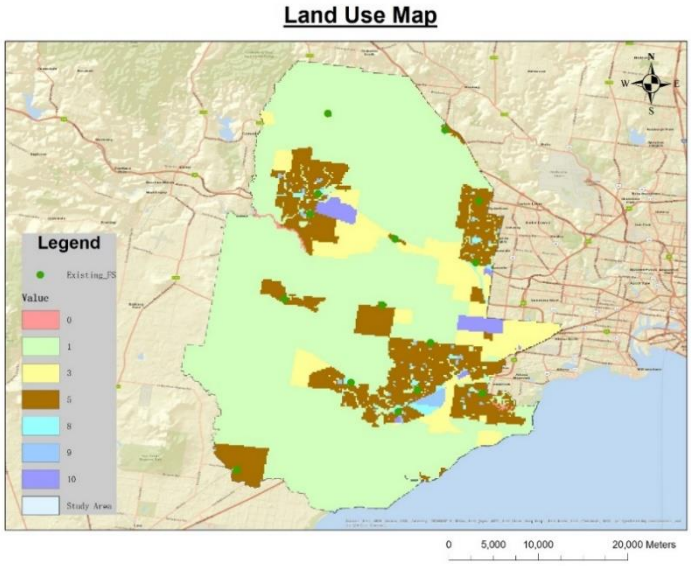
indicator + historical fire + land use) / 2.6. The data is on a scale of 0 ~ 10.

2) Create a new layer and save it as the aggregate fire service demand.

8. Calculate the final result map.
    1) Use raster calculator. The output is calculated as the aggregate fire service demand (result in 7.2) * (1 – mitigation). The mitigation layer is the result from step 6.6.
    2) Save the layer as the final result map. The final result map is on a scale of 0 ~ 10 and the data is in a range of 0 ~ 4.8. No data with values above 4.8 were perceived.
9. Create the recommendation map.
10. Set 2 cut-off points of 2.7 and 4.
    1) Create 3 intervals of 0 ~ 2.7; 2.7 ~ 4.0; above 4.0 for colouring purposes.
    2) Produce the recommendation map.

6. Results and discussions

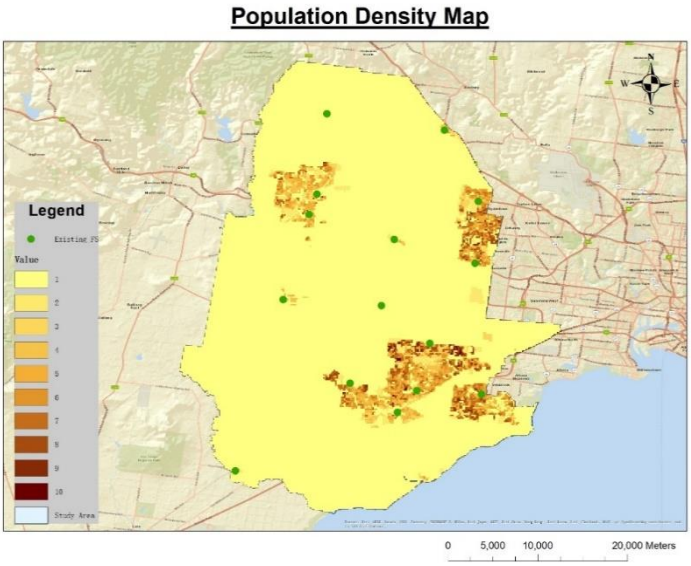
6.1 Land Use Map



Map 6-1 Land Use

Based on the analysis and processing of the land use data, the above raster map is then generated, and the relation between site selection of existing fire stations (green points) and the functional partition of two cities could be clearly seen in this map. There are a few existing fire stations in different residential areas in order to satisfy the current requirements. In addition, the criteria of site choosing for fire stations shown in the map considers most of the regions with high value of risk (areas in blue and purple) such as the factories, shopping centres and schools. However, it is still necessary to select new stations for the areas which the existing services could not cover currently such as the residential blocks located in the middle west or southeast of city of Wyndham and Melton.

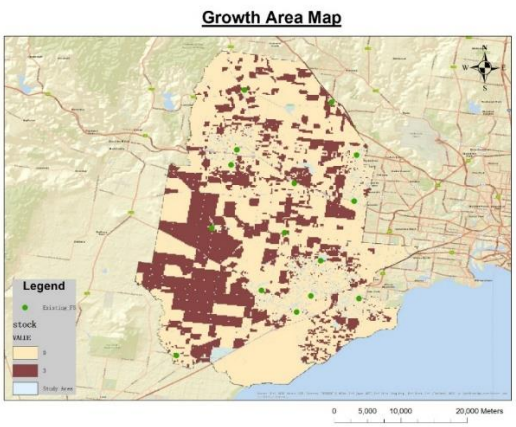
6.2 Population Density Map



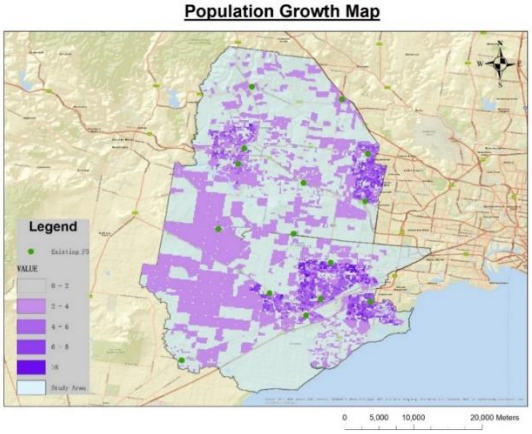
Map 6-2 Population Density

Through the basic process on the original data, this raster map of population density is produced and the whole study area is mainly classified into 10 categories. While the areas with higher value (display in dark colour) indicates the regions with dense population, most areas in two cities (show in light colour) are sparsely populated. Also, over half of the existing fire stations are located in the regions with high population density. This map is roughly consistent with the previous map of land use so that it is possible for us to validate the result for each step of operation.

6.3 Growth Area Map



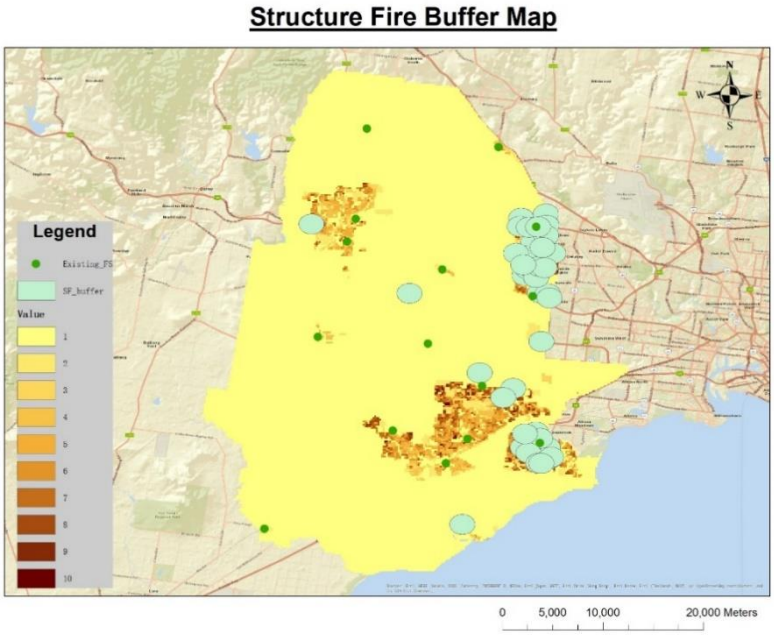
Map 6-3-1 Growth Area



Map 6-3-2 Population Growth

This map for population growth area is created using the housing development data. Considering the increase of population in the next few years, the raster data for this layer also plays a relatively important role in determining the result. As can be seen from the map, the regions with vacant houses are displayed in dark brown and it indicates that those areas are still under-developed. After comparing with the previous two maps, most of the growth areas are located in the south and west of two cities, which corresponds to the regions for farmland use in Map 6-1 and low population density in Map 6-2 respectively. Besides, Map 6-3-2 is generated through aggregating the data of population growth in the future and current population density and rescaled to 0~10 by dividing a scale of 1.3. As is illustrated in Map 6-3-2, the existing fire stations could only meet the requirements of the developed area therefore selecting locations for new fire departments in growth area may be necessary.

6.4 Structure Fire Buffer Map



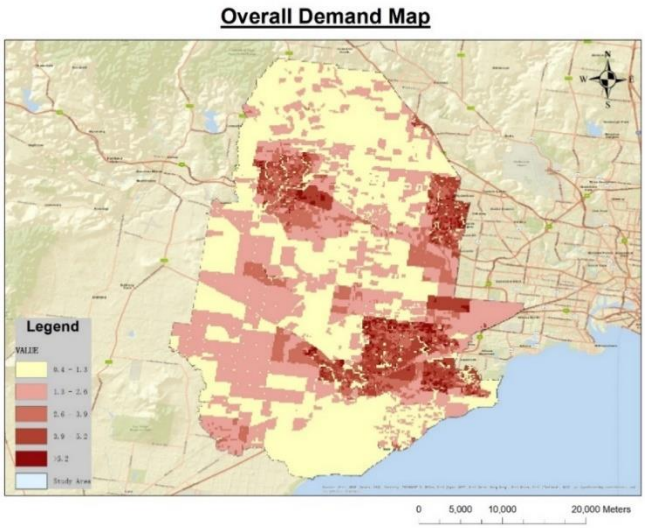
Map 6-4 Structure Fire Buffer Map

The Structure Fire Buffer Map is generated by analyzing and processing historical structure fire data. It illustrates the risky index of each grid based on past fire accident data, which is one the factors of the Overall Demand Map (Map 6-5).

In the map, the historical fire data is buffer with distance of 4 km. After converting to raster data, the data is reclassified as 0 to the areas with no incidents within 4 km, and one more for each incident occurred within 4 km. Thus, the dark colours (high values) in the map are considered as highly risk grid, while most areas with light colour are low risk grid (mainly because of not enough data).

The historical fire map records data which spans over the past 80 years. over the past 80 years. The map clearly reveals that the historical fire incidents generally occurred in historically population dense areas. But due to the changes in landscapes during the 80-year period, the likelihood of fire incidents in recently constructed population centres may be underestimated. Therefore, the weight of structure fire layer in the overall multi-criteria aggregation is set at 30% of the population density layer, which reflects the lagging data records in comparison to population data etc.

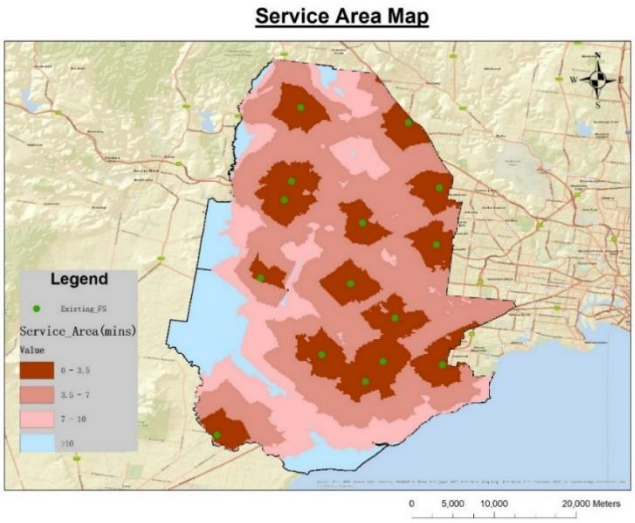
6.5 Overall Demand Map



Map 6-5 Overall Demand Map

This map combined all factors and using formula (1/2.6)∗(Population Density (0~10)+Housing Development Data (0 or 3)+ Historical Fire Incidents (0 ~2)+Land Use(0~10)) to get a value to represent that how much extent fire stations are needed in this area. The reason that 1 divide by 2.6 is to make sure all values are between 0-10. It is much easier to understand and explain. Dark red (>5.2) area means this area highly need a fire station to serve. The yellow area means a fire station is not that important in this area. As is illustrated in Map 6-5, the overall demand of fire services is overall related to the population density and population growth. The result is unsurprising because high population represents the high likelihood in fire incidents occurrences and potential damages.

6.6 Service Area Map

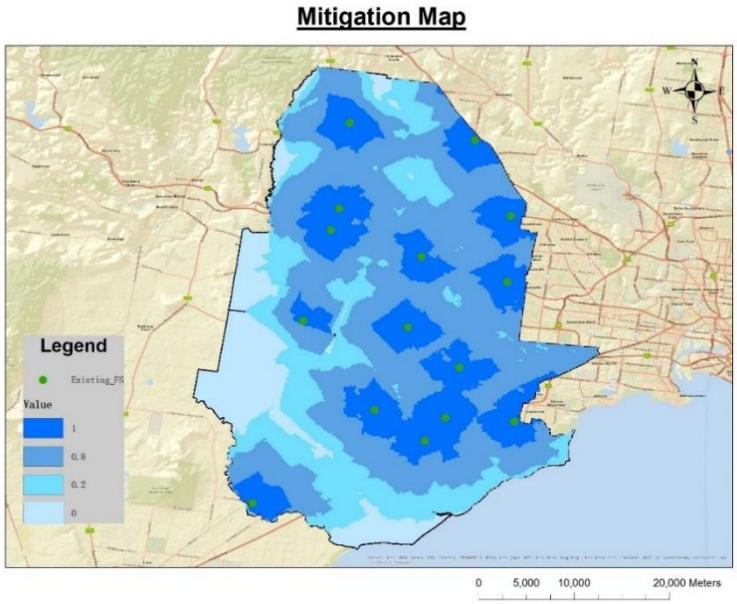


Map 6-6 Service Area Map

To investigate location allocation of the new fire station, the existing fire stations and the radius

that these fire stations should be considered. Hence, the service area analysis tool is applied to analyse the area served by existing fire stations. The service areas with the arrival time of the fire trucks in the intervals of 0-3.5min, 3.5-7min, 7-10min, >10min, are created and then marked with different colours. Noticeably, the fire stations are generally located in the population dense areas, but in recently developed areas, the coverage of the existing fire stations seems to be underserved. Considering the objective of the Melbourne fire department, which aims to deliver services within 7 minutes, areas which are located outside 7-minute coverage radius may be the focus of this examination where new fire stations are likely recommended.

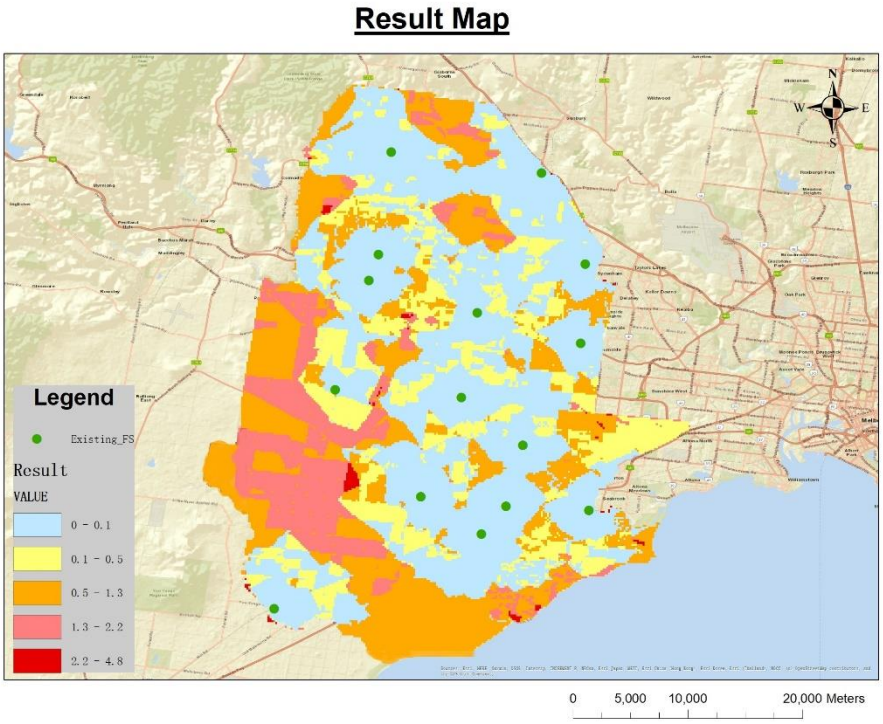
6.7 Mitigation Map



Map 6-7 Mitigation Map

This mitigation map is created based on service area map, the different response time represents different levels of mitigation in the calculation of location selection for new fire station. For example, if response time is 0 ~ 3.5 minutes or 3.5 ~ 7 minutes, that means fire truck can arrive on time, and there is little need to build a new fire station at that area. Therefore, a mitigation factor of 100% is assigned to 0 ~ 3.5 minutes areas. Similarly, a mitigation factor of 80% is assigned to areas with 3.5 ~ 7 minutes response time, 20% to 7 ~ 10 minutes response time, and 0% to >10 minutes response time. In doing this, the needs for new fire stations with fire service response time over 7 minutes are particularly highlighted. New fire stations will therefore be more likely to be built in the currently underserved areas that is the areas with fire response time above 7 minutes.

7. Result Map Explanation



Map 7 Result Map

The result map is generated based on aggregate fire service demand layer and mitigation layer, which are Map 6-5, Map 6-6, respectively. The map illustrates the requirement for new fire stations in each grid.

The output is calculated as the aggregate fire service demand (result in 7.2) * (1 – mitigation). The map is on a scale of 0 ~ 10 and the data is in a range of 0 ~ 4.8 (No data with values above 4.8 were perceived). The value represents the varying demand of new fire stations.

The map vividly demonstrates that the demand around existing fire stations is low, corresponding to the services fulfillment by the existing stations. Interestingly, the result map highly correlate to the map which identifies growing areas (shown in Map 6-3-1). This suggests that the growing areas may have been recently developed, where public facilities, like fire stations may be inadequate.

8. Scenario analysis in result map and Identification of cut-off points

To identify the cut-off points for recommendation, scenario analysis has been conducted.

Areas with overall scores above 4.0 are identified as the areas in which new fire stations are required. This is based on a list of combinations provided in 7.1.
For instance, a residential area with historically high population and low growth and yet located relatively far from existing fire stations will likely require new stations built nearby. (first scenario in 7.1).

Additionally, areas with overall scores above 2.7~4.0 are identified as the areas in which new fire stations may be required in the future, yet no urgent needs currently. A list of combinations is provided in 7.2.
For instance, a residential area with historically low population but observed high growth and yet located relatively far from existing fire stations will likely require new stations in the future. (first scenario in 7.2).

Areas with scores less than 2.7 are not recommended have new fire stations built nearby. For instance, areas with existing fire stations within 7 minutes' drive have already been covered by the existing fire stations, considering that objective of MFB and CFA is to cover all areas within 7 minutes. Alternatively, farmland with low population are assessed with low fire occurrences or low potential fire damages. It is also not recommended to build new fire stations nearby due to high costs in fire station construction and maintenance.

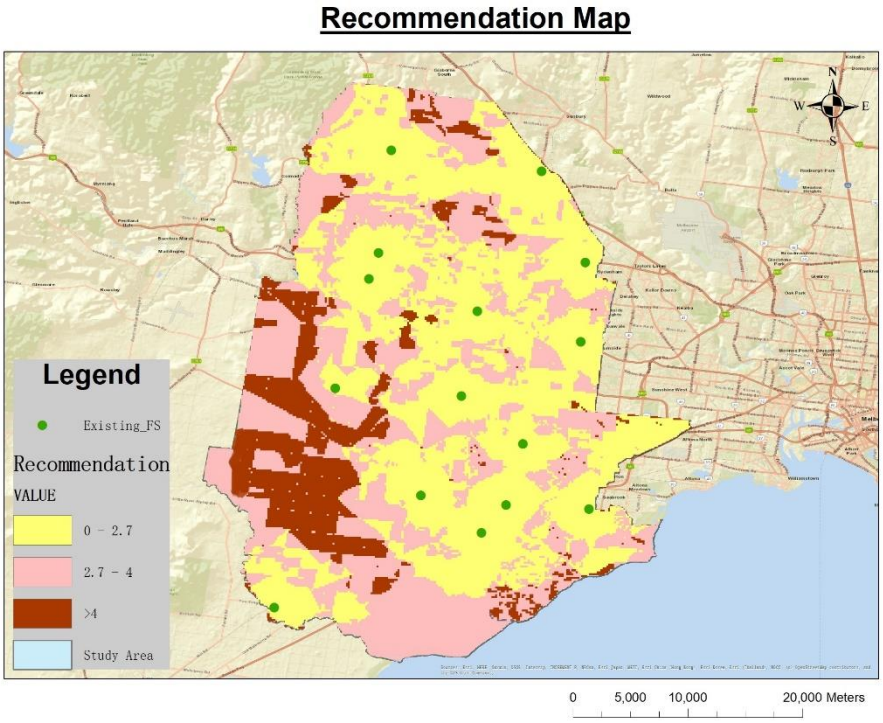
8.1Scenarios with overall score above 4.0

Scenarios with overall score above 4.0	Population & Growth	Land Use	Historical Fire	Distance & Mitigation	Overall Score
High population Density; Low growth; Low historical fire; Residential land; far away from existing stations	Density: high (8) Growth: Low (0)	Residential (5)	Low (1)	7~10 min (1- 20%)	(8+0+5+1)/2.6 *0.8 =4.3
Medium population Density; Growing area; No historical fire; Residential land; far away from existing stations	Density: Med. (5) Growth: High (3)	Residential (5)	No (0)	7~10 min (1- 20%)	(5+3+5+0)/2.6 *0.8 =4.0
Low population Density; No growth; Industrial land; Low historical fire; far away from existing stations	Density: Very low (2) Growth: Low (0)	Residential (10)	Low (1)	7~10 min (1- 20%)	(2+10+0+1)/2.6 *0.8 =4.0
Medium Population density; No growth; Commercial land; No historical fire; far away from existing stations	Density: Med. (5) Growth: Low (0)	Commercial (8)	No (0)	7~10 min (1- 20%)	(5+0+8+0)/2.6 *0.8 =4.0
Low population density; High growth; Residential; No historical fire; Very far away from existing stations	Density: low (3) Growth: High (3)	Residential (5)	No (0)	> 10 min (1-0)	(3+3+5+0)/2.6 *1 =4.2
Hospital/Edu/ Transport. land; Low population; No growth; Low historical fire; far away from existing stations	Density: high (3) Growth: Low (0)	Hospital (9)	Low (1)	7~10 min (1- 20%)	(3+0+9+1)/2.6 *0.8 =4.0

8.2 Scenarios with overall score above 2.7 ~ 4.0

Scenarios with overall score between 2.7 and 4.0	Population & Growth	Land Use	Historical Fire	Distance and Mitigation	Overall Score
Low population Density; High growth; No historical fire; Residential land; far away from existing stations	Density: high (3) Growth: Low (3)	Residential (5)	No (0)	7~10 minutes (1- 20%)	(3+3+5+0)/2.6 *0.8 =3.4
Medium population Density; Low growth; No historical fire; Residential land; far away from existing stations	Density: Med. (5) Growth: High (0)	Residential (5)	No (0)	7~10 minutes (1- 20%)	(5+0+5+0)/2.6 *0.8 =3.1
Very low population Density; No growth; Industrial land; No historical fire; far away from existing stations	Density: Very low (2) Growth: Low (0)	Residential (10)	Low (1)	7~10 minutes (1- 20%)	(2+10+0+0)/2.6 *0.8 =3.7
Low Population density; No growth; Commercial land; No historical fire; far away from existing stations	Density: Low. (3) Growth: Low (0)	Commercial (8)	No (0)	7~10 minutes (1- 20%)	(3+0+8+0)/2.6 *0.8 =3.3
New area: No historical population density; No growth; Transport; No historical fire; far away from existing stations	Density: No historical (0) Growth: High (0)	Transport (9)	No (0)	7~10 minutes (1- 20%)	(9+0+0+0)/2.6 *0.8 =2.7

9. Recommendation



Map 8-1 Recommendation map

Based on two cut-off points, 4.0 and 2.7, identified from the scenario analysis (see section 7 above). Three intervals are hence determined:

- Interval [4.0~10] (shown as dark red on map 8-1): New fire stations are recommended to be built in the centre of or near the selected areas.
- (2,7,4) (shown as pink on map 8-1): Currently, the area represents no urgency in new fire station constructions, but in the future, if such area witnesses further population growth, new fire stations are likely required.
- [0,2.7] (shown as yellow on map 8-1): The areas represent low needs in new fire station constructions. The existing fire stations have already been able to fulfil the fire stations requirement for now and in the near future.

Overall the final recommendation includes:

- For the dark areas shown on map 8-1, initiate a plan to select locations in their centres or nearby areas, such that the perceived requirements can be fulfilled.
- Further monitor the changes of demographics and constructions in the pink area shown on Map 8-1. New fire stations may be required with population growth. But no urgent needs have been observed.
- Possibly streamlining the existing services in the yellow areas on map 8-1, such that some existing fire stations can relocate to serve greater areas.

10. Conclusion and Limitation

To conclude, this report identifies the potential demand in fire services against the service abilities of existing fire stations. Overall, the existing fire stations can cover the majority of fire service demands perceived in the analysis. Yet new fire stations are suggested to be built in the centre of or near the dark red areas demonstrated on the recommendation map (see map 8-1).

The report may also have following limitations and future work may be required to solve such shortcomings:

- Both cities have undergone significant development in the past decades, making the historical fire data less reliable.
- Census and land use data are not most recent, and hence having deviations from the reality.
- The projection of population growth may require more planning data than the house development data. The projection may also be affected by variations in planning and future construction.
- The assigned weights in aggregating multiple criteria may not fully represent the requirement of fire station resource allocation.
- No specific locations have been recommended but rather areas which new fire stations need to service are provided. To determine the specific locations require a list of selectable potential fire stations locations, which may require further research or further data.

11.Reference

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