Assignment 3: Decision Making in GIS

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Introduction

This study aims to apply GIS to analyze four proposed railway alignments by the Victorian Rail Authority (VRA) for a new high-speed rail from Melbourne to Sydney. The VRA has proposed specific requirements for the chosen railway which will require an examination of total distance, slope, change in elevation, flood extents, and unsuitable terrain obstacles for each alignment. To ensure a well-informed decision, additional aspects relative to each alignment will be considered: parks and reserves, townships boundaries, existing railways, and public land management. Based on technical and economic viability, the alignments are ranked based on those analyses to help the VRA make their own decision.

Literature Review

To form our methodology, literature was assessed to determine proper considerations for the economic and technical viability of the alignments. According to Canca (2019), generally, a "larger network size" leads to "higher revenue"; however, "higher coverage" means a "higher rolling acquisition cost" (i.e. for train fleet) and "higher operation cost." Canca (2019) says "revenue, variable operation cost and rolling acquisition cost, once a topology is defined, depend on the captured demand and network operation (transit assignment, line frequencies, and train model selection)." In deciding the best alignment economically, it will be important to prioritize the captured demand (i.e. population reach, townships, existing rail) and network topology (i.e. changes in elevation, slope, terrain), which will bring about the highest profit after train acquisition is near complete.

The importance of analyzing slope, paths prone to flooding, and parks and reserves have been previously explained in literature for infrastructure development. First, Mark (1975) writes about the importance of considering slope as it "controls the gravitational force available for geomorphic work." With slope also relating to many other aspects, such as runoff and flow paths, many considerations can be assessed from the slope. Second, Moore (1990) notes a deficiency in hydrologic models with "its inability to represent the effects of three-dimensional terrain on flow processes… and often unrealistic, simplifications." One should be wary of following existing hydrological models when analyzing a digital elevation model (DEM) to prevent oversimplification; it may be more reliable to use official government data on floods calculated on worked models. Lastly, according to Bruschi (2015), "national parks and dedicated conservation reserves are generally considered areas of great environmental value, but often they include at the same time several threats for biodiversity conservation." Parks and reserves are thus important to consider for conservation and sustainability impacts as "railways have a poor permeability to terrestrial wildlife populations" (Bruschi, 2015).

Methodology

The methodology employed in analysing the four proposed VRA alignments is multi-step and lengthy. In brief, four main phases can be identified: i) importing data ii) performing analysing on the VRA requirements iii) Calculating ratings for analysis iv) Search the allocated data. Each of these main phases will be discussed in the following sections in no particular order. The datasets used in this study are the 100-year flood extent, park and conservation reserves, township boundaries, existing railway infrastructures, and public land management from the Victoria State Government.

VRA Requirements

One of the requirements by VRA is that it could not travel through a slope of 25 degrees. It is important because it should allow the train to decrease the amount of time it decelerates in order to reach the destination faster. This calculation could be done by creating a slope raster with 2 unique values given. Then the raster is converted to polygon, where the attribute table of the polygon shows summarised details of the slope.

Another constraint is that it cannot follow a path prone to flooding. For instance, when the flood level is much higher than the railway alignment in height, it would cause the train to slip off the track. This analysis is done by importing the 100 years flood extent in Victoria.The comprehensive coverage of a century of flood occurred in Victoria would provide a crucial factor in ranking each alignment.

Other than that, the total distance of each alignment climbs or falls which could be referred to as a change in elevation. This is required because the more frequent the change in elevation, the less comfortable the commuters are while it also increases the infrastructure cost of the project. This is analysed by using the math raster function on the points along the line at a 20 m interval for each alignment. Then, the calculated raster value is extracted to points and is used with the summary statistics function to get the total distance of change in elevation for each alignment.

A map displaying all slopes over 25 degrees on the proposed alignments, and another map of the overlap of flood-prone areas and proposed alignments are created for visualisation in Fig1 and Fig2 respectively in the results.

Unsuitable Terrains

There are several types of unsuitable terrains present along the proposed alignments. These include parks and reserves, existing railways, townships, and public land where the proposed alignment is on rivers. Unsuitable terrains require the VRA to go through much more work to build the alignment, in addition to increased budgets and costs. Besides, unsuitable terrains might affect the construction of the railway and propose a threat to the safety of construction workers during the construction process.

Parks and Conservation Reserves

The chosen alignment should minimally intersect with parks and conservation reserves as these areas serve local and greater communities and are important for the conservation of biodiversity. It is important to minimize crossings as building railways over significant environmental areas will result in fragmentation of ecosystems and destroy reserves. To measure the crossings, clip the alignments to the parks and reserves dataset to obtain a total length in meters for each alignment. A map is created to visualise the intersection of proposed alignments on parks and conservation reserves, which is shown in Fig3 in the results.

Township Boundaries

The chosen alignment should maximize crossings with townships to reach the most communities possible and increase demand. 2km and 5km proximity is assessed to increase the considered reach to neighbouring areas and distant areas. To measure crossings, clip the alignment to the proximity layers and obtain a total length in meters for each alignment and proximity value. In Fig4 and Fig5, the towns within proximity of 2km and 5km respectively from the proposed alignments are shown in the form of maps.

Existing Railway Infrastructure

The chosen alignment should minimize overlap and proximity with existing railways as it should capture new populations to increase current and future demand for long-term economic benefits. Existing railways can be upgraded or extended to increase connectivity in future projects to connect our chosen alignment to communities that already have rail access. First, use "Summarize Nearby" to form an appropriate polygon of a 2km radius, to analyze the close surrounding area, along the existing railway lines. To measure the overlap, clip the alignment to the new polygon layer and obtain a total length in meters for each alignment. A map is then created to visualise the overlap of existing railways and proposed alignments in Fig6.

Public Land Management (PLM25) Generalised

The chosen alignment should minimize intersections with land managed by government departments and public authorities to decrease the deforestation required for the railway alignment. This is crucial as deforestation would lead to negative environmental impact. To measure the crossings, clip the alignments to the PLM25 dataset to obtain a total length in meters for each alignment. To visualise, create a map showing the intersection of proposed alignments with public land, as shown in Fig7.

Calculating Ratings for Analysis

Table 1 shows the scoring for the proposed alignments, the lower the total score, the better the alignment. The scores for each category are calculated by dividing the value in each category of each alignment by the length of its own proposed alignment, which gives the ratio between each category and length of the alignment. The final score is calculated by adding up the scores for each category, except for train rails and townships, where these two are deducted from the total scores, because of the higher these scores, the better the alignment. The scores for distance for each alignment is calculated by giving the longest alignment a score of 1 and finding the ratio of each alignment against the longest alignment. In this case, Alignment C has the shortest length while Alignment D has the longest length, so Alignment D has a score of 1, while Alignment C has a score of the length of Alignment C divided by the length of Alignment D. For townships, the number of townships within certain proximity for each alignment is divided by the length of each alignment and multiplied by 1000, giving the number of townships per 1000 kilometres. Similar to townships, the ratings for unsuitable terrains in each alignment is also calculated by finding the number of unsuitable terrains per 1000 kilometres.

Results

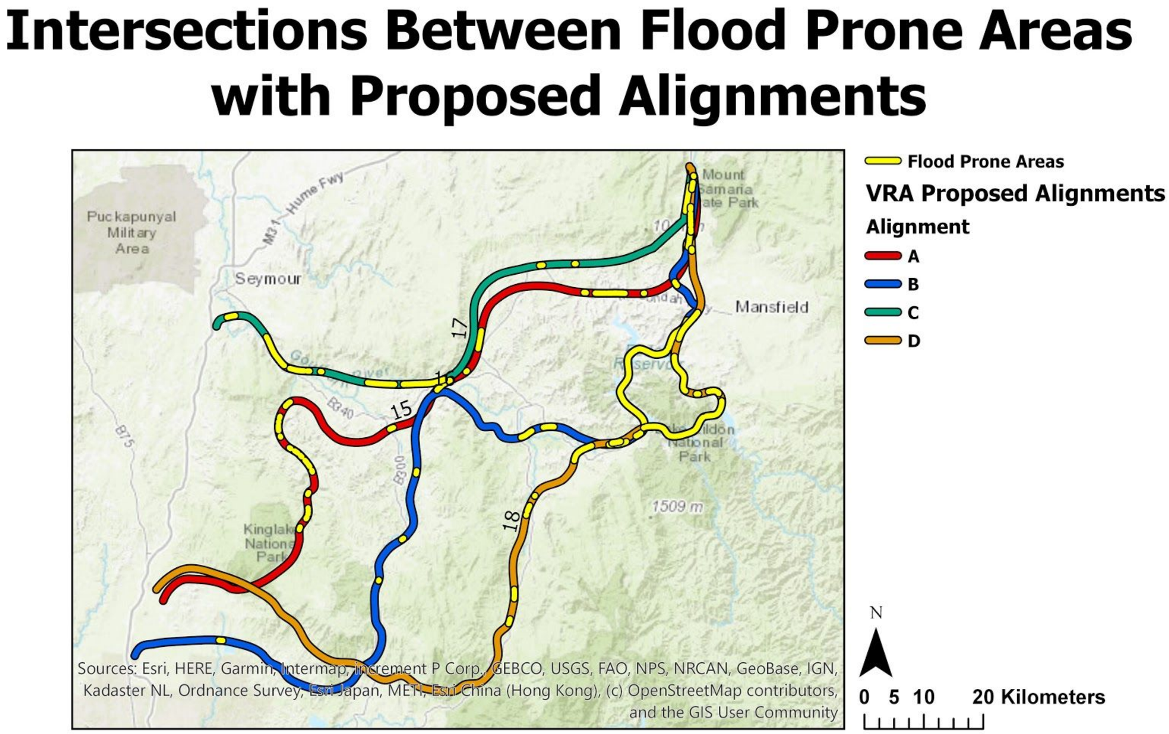

Fig1. The intersection of flood-prone areas with proposed alignments

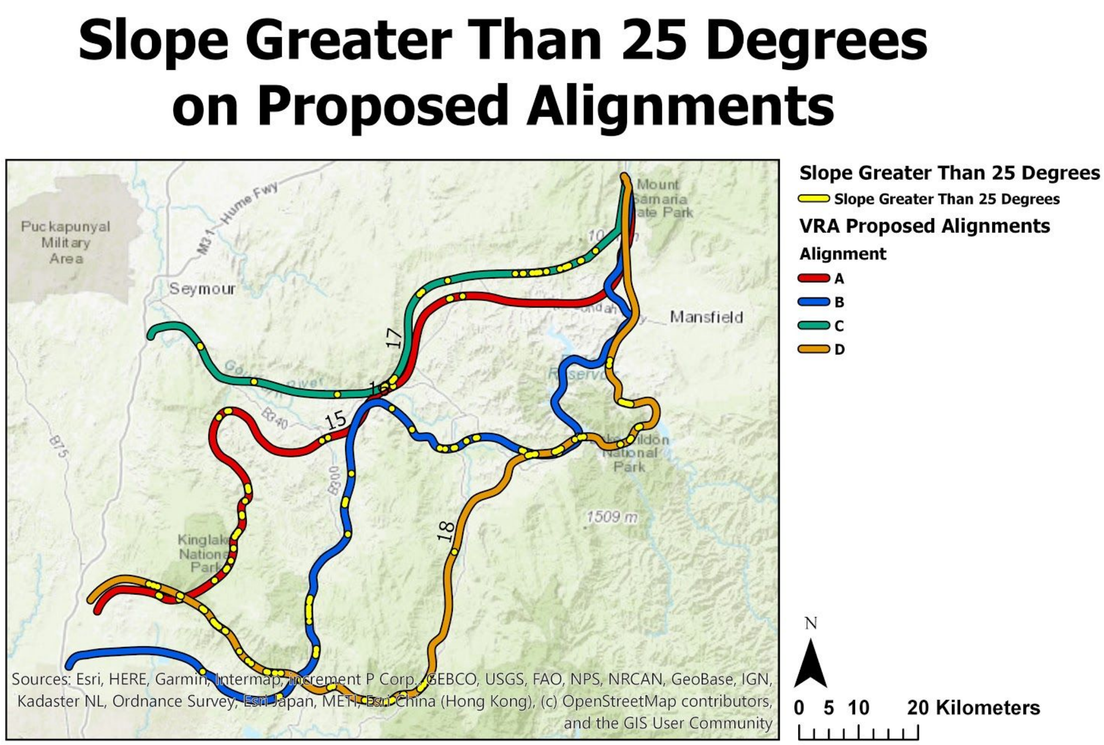

Fig2. Slope Greater than 25 Degrees on the proposed Alignment

Intersections Between Park and Reserves with Proposed Alignments

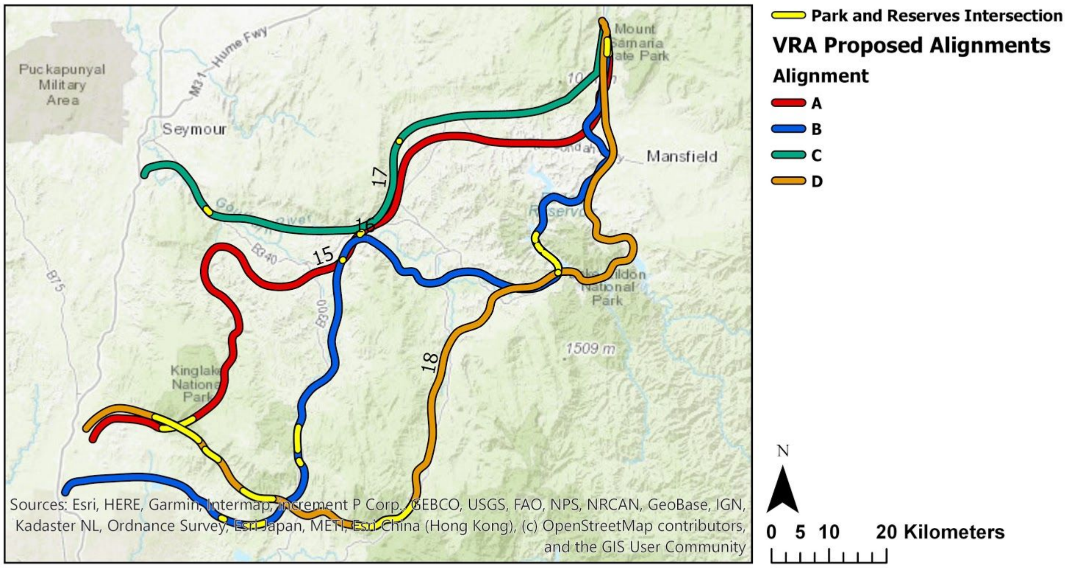

Fig3. The intersection between Park and Reserve areas with Proposed Alignment

Towns in 2km Proximity of Proposed Alignments

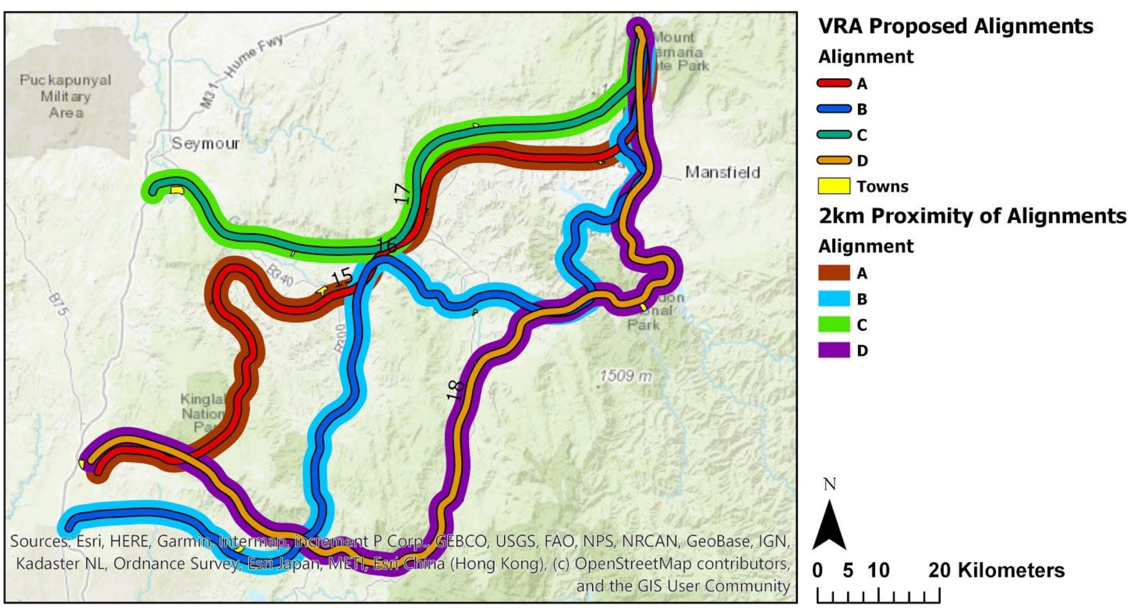

Fig4. Towns in 2km Proximity of Proposed Alignment

Towns in 5km Proximity of Proposed Alignments

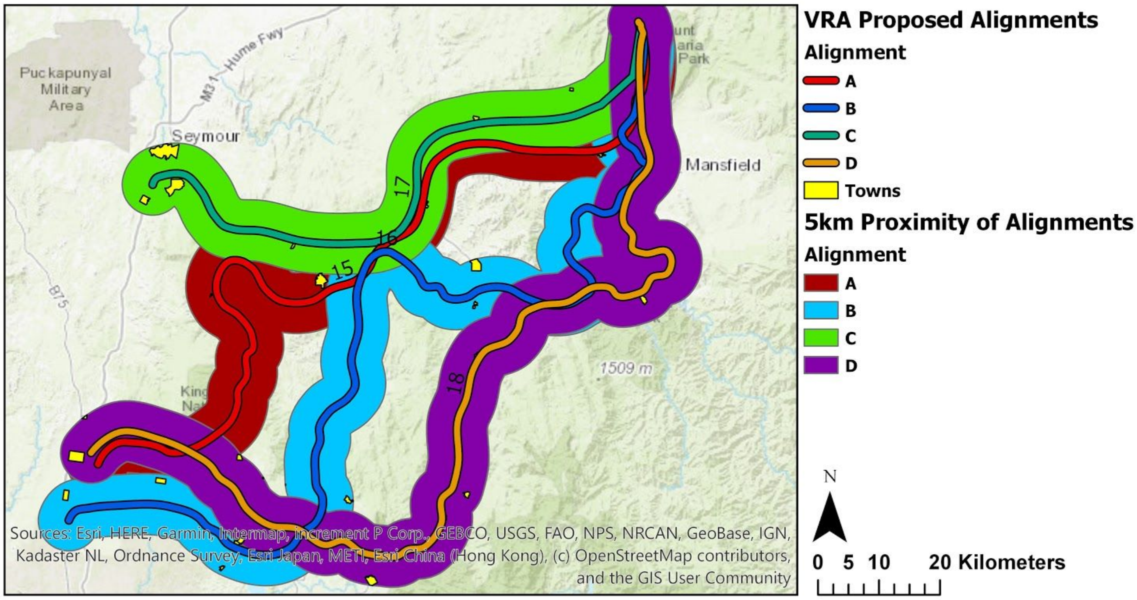

Fig5. Towns in 5km Proximity of Proposed Alignment

Intersection Between Train Rails and Proposed Alignments

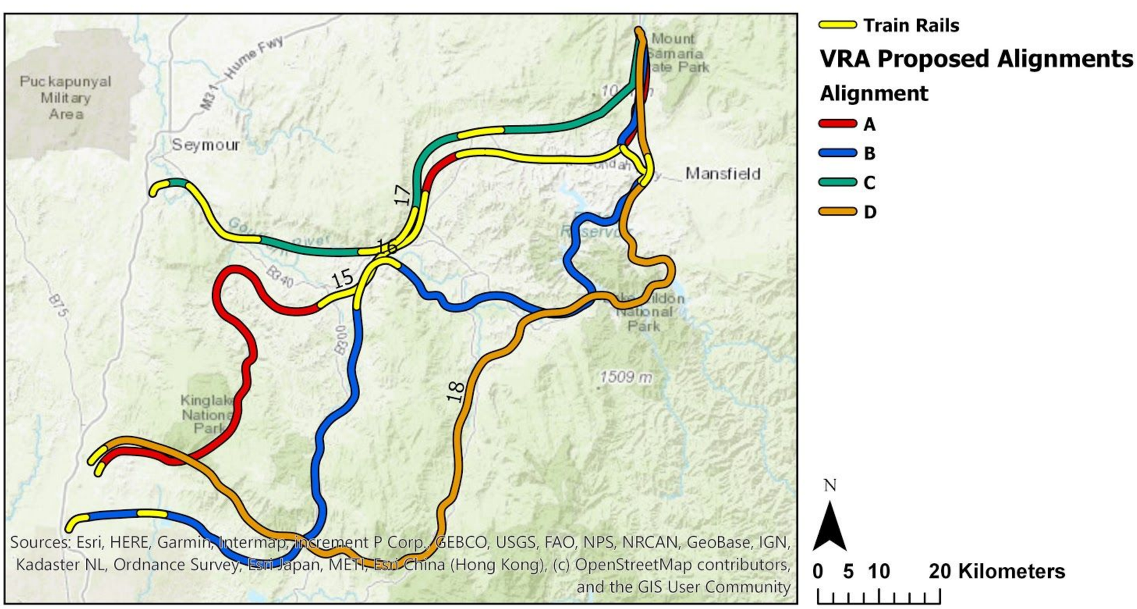

Fig6. Intersection Between Train Rails with Proposed Alignments

Proposed Alignments on Public Land

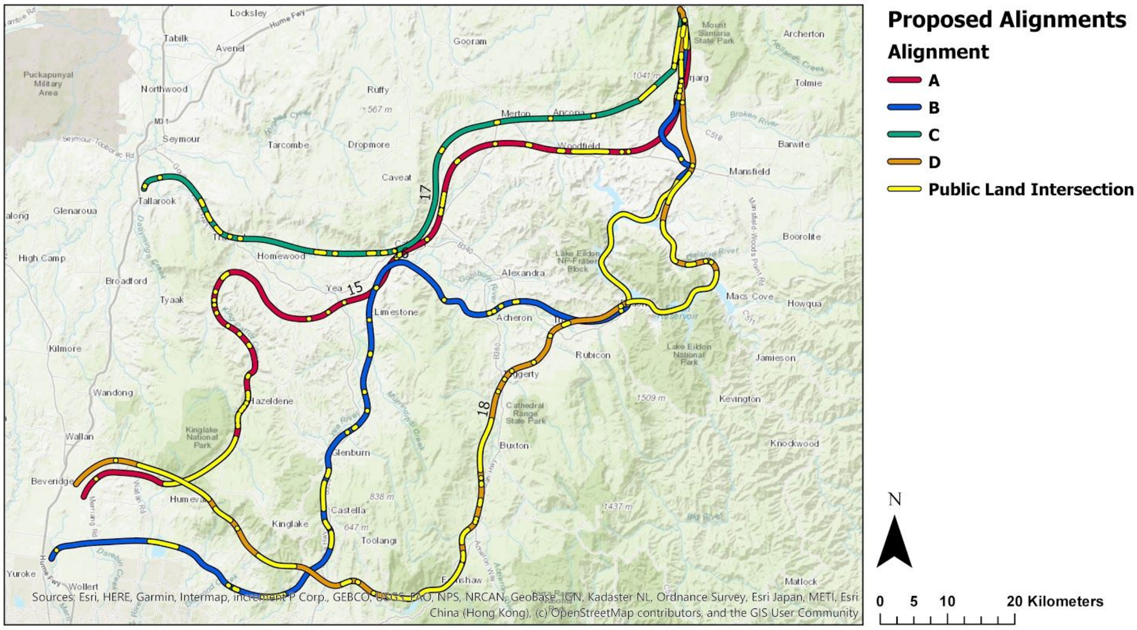

Fig7. Proposed Alignments on Public Land

Table 1: Rating for alignments based on analyzed categories

Categories	Points for Each Alignment			
	Alignment A	Alignment B	Alignment C	Alignment D
Distance	0.826	1.0	0.566	0.961
Climb and Fall in Alignments	0.115	0.124	0.120	0.139
Unsuitable Terrain Obstacles	0.139	0.078	0.175	0.119
Slope Greater Than 25 Degrees	0.016	0.019	0.015	0.028
Flood Prone Areas	0.115	0.195	0.243	0.219
Parks and Reserves (PR)	0.055	0.086	0.008	0.156
Townships per 1000km (2km proximity)	0.038	0.021	0.055	0.022
Townships per 1000km (5km proximity)	0.057	0.052	0.083	0.054
Train Rails (TR)	0.347	0.143	0.348	0.042
Public Land Management (PLM)	0.170	0.245	0.124	0.432
Total Points	**0.994**	**1.609**	**0.765**	**1.936**

Table 2: Data for each alignment and their categories (corrected to integer number)

Categories	Points for Each Alignment			
	Alignment A	Alignment B	Alignment C	Alignment D
Total distance (m)	158326	191682	108544	184142
The total distance of each alignment climbs/falls (m)	18272	23682	13076	25686
Number of unsuitable terrain obstacles **PR**: Parks and Reserves **TR**: Train Rails **TB**: Township Boundary **PLM**: Public Land Management	PR: 1 TR: 2 TB: 4 PLM: 15	PR: 5 TR: 2 TB: 1 PLM: 7	PR: 1 TR: 4 TB: 4 PLM: 10	PR: 3 TR: 0 TB: 3 PLM: 16
Total distance over the slope of 25 degrees (m)	2528	3595	1628	5148
Total distance on path prone to flooding (m)	18226	37389	26338	40277
Total distance on the path over parks & reserves (m)	8698	16505	828	28638
Township Boundaries (2km proximity)	6	4	6	4
Township Boundaries (5km proximity)	9	10	9	10
Total distance on the path over 2km proximity of existing rail (m)	54863	27424	37820	7709
Total distance on the path over public land management (m)	26968	46933	13433	79572

Discussion

Among the four proposed alignments, Alignment C is ranked highest in the recommendation as to the proposed high-speed railway among the factors included in the analysis. From Table 2, we can see that Alignment C has the shortest distance, most minimal change in elevation, shortest distance over a slope of 25 degrees.

Alignment C is ranked highest relative to other proposed alignments throughout the analysis because first and foremost it has the shortest distance among all alignments. This would reduce the economical cost of the high-speed railway project while also reducing the commuting cost for passengers. Other than that, alignment C has the shortest distance in climb and fall which can also be referred to as a change in elevation. This would allow maximum comfort for commuters on the high-speed train among other proposed alignments. It also has the shortest distance that is needed to travel through a slope of 25 degrees which consequently means that lower infrastructure cost is needed while making sure the high-speed train would maintain a constant high speed. However, when taking into consideration the possibility of flood after analysing 100 years extent of the flood dataset, alignment C has a relatively high number of distances that is prone to flooding compared to alignment A. This disadvantage can be offset by the high number of other benefits that alignment C brings and the fact that all alignments are prone to flooding. One of the critical reasons of ranking alignment C as the highest among other proposed alignment is due to the fact that it has a relatively high tendency to pass through townships which are 6 and 9 townships within 2km and 5km proximity respectively. This tendency would allow the high-speed railway to connect communities across the region to commute between Melbourne and Sydney which allow local communities to thrive and be connected to the metropolitan areas. With that connection to metropolitan areas brings about tremendous benefits to these towns, one of which is to increase the job prospects of its local town citizens. Moreover, alignment C has the shortest distance on the path of land management. This is crucial because the lesser the proposed alignment is on the path of land management by the Victoria government, the lesser the deforestation is required hence the lesser the negative impact on the environment. In essence, alignment C has remained the most optimal after taking into consideration other factors that are important in deciding which alignment to choose.

Conclusion

Overall, analysing proposed railway alignments by taking into account both the technical and economical viability needs to consider various factors which are all weighted based on how critical it is to the feasibility of the project. With that, the report strongly suggests and recommends alignment C to the VRA because it is the most optimal among the four proposed alignments. This is by no means a definite alignment that VRA needs to proceed with but it allows VRA to build upon this alignment. As in the report suggested, this alignment is still prone to flooding and further analysis is required as the best possible alignment would avoid the possibility of flood entirely.

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Individual Reflections

Hok Him Lu (Marcus)

For Assignment 3, I would love to thank every groupmate that shares the workload equally, which we all have contributed in the report and find out the best alignment. The challenged that I have faced is commonly in the technical issues, except the computer system issues, how to find the shape length back in the attribute table and how to clip the slope data into alignment were my major challenged too. Thanks to tiffany and Kenn, discussing with them and approach with various methods, the data can be officially analyzed.

The report has enriched my skills in forming various layers in ArcGIS software, from clipping the features into alignments to calculate the result out. My major is human geography and parts of my degree are in the spatial system, due to my interest in locating the linkage between geographical limitation with the sustainable development in various society. While we consider which data should be approached which is our biggest contrast, due to less interaction with the existed data might lead to the further plan on urbanization, however, the more interaction with it can also achieve as reducing the cost of infrastructure and the amount of deforestation. Therefore, it has become one of the socio-economic vs. environmental discussion between the group. After our conversation, what economic opportunities that can bring through the railway shall be the biggest concern in this assignment, therefore alignment C was selected.

Hester Lim

Throughout this analysis and report, I am fortunate to be in a collaborative environment where each member contributes equally to the report. The discussions are often informative and each member does voice out their own opinions regarding the factors that should be taken in. Special mention to Kennedy for guiding me on using the raster function which I am not familiar with and also contributing actively on the project. Not forget to mention Tiffany for continuing to monitor the team's progress. Lastly, I would like to thank Marcus for voicing a lot of his suggestions. The skills that I have learned through this assignment is how to clip datasets, calculating raster functions and searching for a dataset relevant to the assignment. Other skills that I have learnt are how to work in a remote team environment and how to communicate across various online communication channels. I’m responsible for alignment B and also on writing the initial draft for methodology, discussion and conclusion which the team suggest and improve upon.

Tiffany Lim

For A3, we worked as collaboratively and equally as possible remotely and with different time zones (for me). Besides generally helping out with the project components, I mainly worked on the introduction, literature review, and methodology, analyzed Alignment C data, and led discussions on the approaches for our analyses. I messaged the group chat a lot and I hope I was not overbearing, but I wanted to make sure we were all on track and in agreement in the decided approaches/project plan for both our analysis and report. A3 definitely felt more difficult than the previous assignments as it was hard to control when things got done in a collaborative project due to individual circumstances; however, I would like to thank my group for working through this with me until the end. Everyone was very responsive and took initiative; we all tried our best to troubleshoot any issues via our group chat.

For context, I am an exchange student from the U.S. majoring in Civil Engineering. Learning to manipulate raster data, using spatial data to create graphics that answer analytical questions, and creating effective maps are all applicable to my field from local infrastructure to major capital projects. As a prospective structural engineer, most of my project scopes are limited to structural tasks during my internships and structural theory in academia. This project has provided me an opportunity to contemplate other aspects of infrastructure development and gain experience working with GIS to do so. Though it may sound corny, this project has honestly shown me the power and significance of both data and the visualization of data in decision making and shaping people's perspectives. In the fall, I will start working on my senior thesis (potentially on coastal design) and I hope to apply GIS to analyze relevant spatial data for my site investigation and create effective visualizations to convey my project's impact.

Kennedy Guok

I was in charge of analysing all data regarding Alignment D in this assignment. After analysing, collecting and recording data, I came up with the idea of creating a point-based system to analyse all categories for each alignment and rank the alignments, where the other group members helped me improve the system. With their suggestions, I created the rating table as shown in Table 1 and provided explanations on how the rating is done in methodology, especially the ratings for townships and distance.
I created all the maps for this project, where I had to clip all requirements and additional datasets to all the other alignments, and create decent and consistent maps for visualisation.

Through this assignment, I learnt how to use ArcGIS Pro even better, even though it takes hours to load this particular assignment, and crashes out of the blue. With the guidance of tutors in the tutorials, I learnt how to use tools like Raster Function and Clip Tool, how to read data from Attribute Tables, and also how Symbology should look like in a decent map. These allow me to understand how to use raster spatial data to isolate data by space and attribute filters and produce maps that support my analysis effectively. I also know how useful the website data.vic.gov.au is, and how to request data from them. I realised there is a lot to take into consideration when proposing suitable alignments based on geographical issues, what affects the alignments and what other factors are affected by these alignments.

I am eternally grateful to be in a group with responsible members. Each of the members handled their work efficiently and on time. Even without verbal communication, face-to-face contact, and also different time zones, we managed to finish the assignment smoothly. At the same time, I am happy to help out my group members wherever I can, for example coming up with a method to find the proximity of alignments in ArcGIS Pro. Thanks to Tiffany and Hester for leading us throughout this project, and also Marcus for providing different perspectives that helped us come up with great ideas. I would also like to thank the tutors for helping us throughout the assignment patiently, giving us guidance as they can.