GEOG*4480 Final Report

Using Multiple Criteria Evaluation to Assess the Suitability, Location and Course of a Formula One Track in Grand Casablanca, Morocco

Prepared For:
Professor Ben DeVries
Department of Geography, Environment, and Geomatics
University of Guelph

Prepared By:
Group 1 - JAM

Marina Coric	1092498
Jacky Liang	1054829
Annaliese Schropp	1013472

April 17, 2023

Table of Contents

Acknowledgements

We would like to thank Dr. Ben DeVries, Yannan Wang, and Jacob Mardian for their support and encouragement regarding this research. We would also like to thank Adam Bonnycastle for his assistance regarding the creation of the track and knowledge of GIS tools. Special thanks to all of them for providing such insightful feedback that helped make this project a success. Special thanks goes to Sahibjeet Babbrah for being an honourary team member. Finally, we wish Fernando Alonso all the best in his fight for title this season, he inspires us every day.

Abstract

With the rise in Formula One's (F1) global popularity comes the inherent need for accessibility and representation in order to promote inclusivity and expand into untapped markets. Underrepresented locations, such as Africa, are being overlooked despite the financial benefits it would provide to both the region and Federation Internationale de l'Automobile (FIA), the organisation that oversees F1 events. The aim of this study was to bridge this gap by identifying the most suitable location within Grand Casablanca, Morocco using a multiple criteria evaluation (MCE), designing a regulation circuit layout within that space using least-cost pathways, and analyzing existing track land suitability against it. Based on research regarding mega-sporting events and F1 circuit regulations, factors concerning slope, land use, distance from water bodies, healthcare, transportation, and housing were considered when identifying appropriate regions. Proximity to roads and healthcare were prioritised to ensure accessibility and safety for attendees involved in the event. Using a ten-point scale, where ten was the most suitable, a parcel of land with a maximum suitability score of 9.6 was found, located in the western portion of Grand Casablanca. It contains an area of approximately 1.93 km^2, from a defined input range of 1.5 - 3 km^2. The average features of highly efficient circuits were considered in addition to the surrounding slope of the selected region, resulting in a track design that contained a lap distance of 4.9 km and an area of 0.71 km^2. Not only does the location provide the best possible proximity to tourism accommodations but it also minimises social disruptions to current residents. By comparison, existing circuits including Suzuka Circuit, Circuit of the Americas, and Hungaroring, ranged from a score of 7.2 to 9.2 using this model. The contrast between these suitability results and the identified space showcases the potential for a successful event should the track be constructed. To conclude, the use of a model similar to this should be applied when determining future locations for permanent F1 circuits due to its considerations of core aspects for hosting mega-sporting events and the potential for reusability.

Keywords: formula one, multi-criteria evaluation, Casablanca, suitability, least-cost pathway

1. Introduction

Beginning after World War II, F1 made its grand debut on the world stage. Its inaugural season first hosted seven races, six of which were held across Europe and the sport quickly expanded from there (Formula One Art & Genius, 2018). The advent of streaming services and production of reality television shows such as Netflix's *Drive to Survive*, allowed for even more global recognition to arise (Serra, 2022). This boom in popularity can be credited with additional tracks being added to the race calendar, but there is still a distinct lack of representation of all locations (Formula 1, 2022). In particular, the 2023 race calendar (Table 1) features races on every populated continent except Africa, despite the growing fanbase (Muchinjo, 2022). In particular, Morocco is overlooked as a potential race candidate, having hosted major events like the Dakar Rally, and the Moroccan Grand Prix (Formula E, 2016; Formula 1, n.d.). Being a historic landmark for motorsport history showcases the potential for FIA to expand into these markets, and for the country to capitalise on the commercial opportunities hosting an F1 event provides (Subak-Sharpe, 2022).

Table 1: Breakdown of all Formula One Grand Prix races being hosted in the 2023 season by continent.

Continent	Number of Races
Africa	0
Asia	7
Australia	1
Europe	9
North America	5
South America	1

With the lack of races in Africa, the aim of this project was to locate the most suitable track location within the region of Grand Casablanca using an MCE, designing a regulation circuit layout within that space using least-cost pathways, and analyzing existing track land suitability against it to assess the model. The method of conducting an MCE model has likely not yet been applied to F1 for site identification, and overall, there is limited publicly available research about locations and track layout in the industry, allowing for transparency within this subject to be exhibited.

This research is an inherently spatial problem as it pertains to determining the most suitable locations for an F1 track. Therefore, Geographic Information System (GIS) technologies, such as a weighted MCE, are critical to accomplish this accurately. The area identification process requires many factors with large quantities of data regarding both the physical geographies and tourism accommodations, thus these tools can reliably pinpoint the most desirable location by managing them all at once. MCEs have been used in determining other mega-sporting event suitability like the Olympics (Karaca, 2017) with success and for that reason, it is believed that this type of weighted spatial model can assist in determining a suitable region for a F1 event in Grand Casablanca.

2. Research Objectives

The goal of this research was to evaluate and determine the suitability of potential F1 track locations in Grand Casablanca. Using this evaluation, this study designed a regulation circuit to fit the identified space. These goals were accomplished by following the research objectives below:

1. Identify criteria that would contribute or detract from the suitability of potential locations. This may include proximity to hospitals, hotels, food, and transportation. Other constraints may be related to land cover, such as elevation, drainage, flood vulnerability, and land use.
2. Develop a model using multiple criteria evaluation to assess the suitability of the location for the circuit.
3. Extend the model to determine the optimal path given how suitable the location is to produce an ideal layout of a theoretical circuit. The track layout should satisfy all required safety regulations while being engaging for drivers, constructors, and fans alike.
4. Evaluate the model by running it against current F1 track locations and assessing the resulting suitability scores.

3. Study Area

The focus of this study centers around Africa, the only populated continent absent from the calendar, specifically in Morocco. Its geospatial location in North Africa makes Morocco an ideal candidate for a track as it provides convenience and accessibility to the dominant European fanbase.

Of all the regions in Morocco, Grand Casablanca (Figure 1) is home to the country's largest city, Casablanca, with approximately 4.2 million residents (Haut Commissariat du Plan, 2016). Grand Casablanca was selected for the study area as opposed to other Moroccan regions due to several factors related to its physical and human geography. Hosting a mega-sporting event such as an F1 race requires easy access to lodging accommodations for all prospective attendees. Good connections to transportation, and electricity are also required, therefore being in close proximity to a city that is able to account for an influx of tourism is essential. Casablanca is well equipped to handle said incursion as it has the largest airport facilities, highest number of accessible hospitals, and an ever-increasing volume of tourist accommodations (Oxford Business Group, 2022). The area is relatively flat with minimal water bodies, allowing for ease of construction and flood prevention. The northern and northeastern regions of Morocco, such as Tangier and Saidia, were not considered because they are vulnerable to floods (Snoussi, 2009; Aitali, 2020). Similarly, the interior of Morocco is mountainous and thus was also not considered.

The presence of these characteristics are requirements to uphold safety regulation of the track itself, which is why the regional scale was selected for this evaluation model. It allows for the model to consider suitable land with criteria related to city features but outside the city limits to reduce local disturbances. On average, venues for permanent tracks use approximately 1.29 km^2 of space, a figure obtained by using Google Earth to determine site boundaries (Table 9). Therefore, the final size of the selected parcel of land was required to be between 1.5 and 3 km^2 to account for the area required for temporary construction sites, buildings, seating locations, and the track itself.

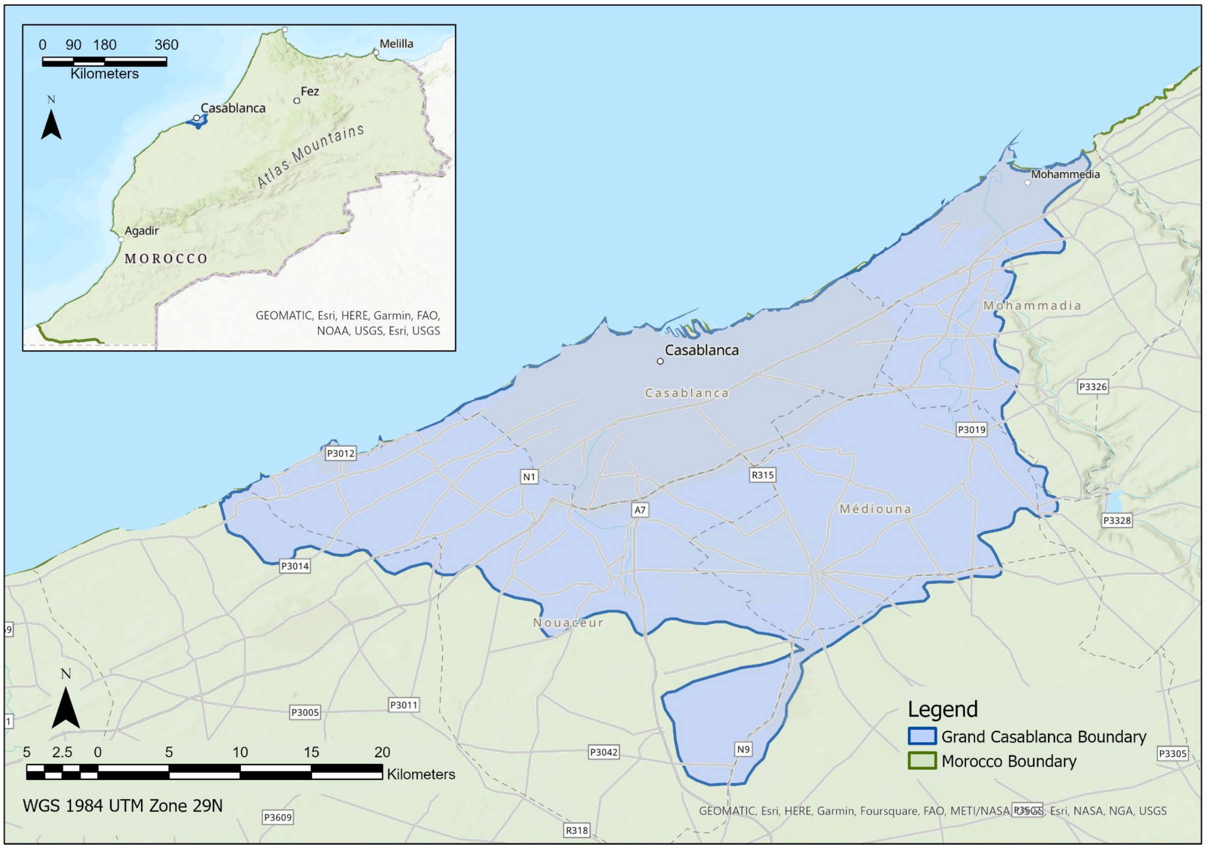

Figure 1: Regional boundary map of Grand Casablanca, Morocco

4. Methods

Minimising the amount of social disturbances to the current population is paramount. As such, only the construction of a permanent track was considered. The alternative, a street circuit, is essentially a temporary track through a city. This would require blocking access to a portion of Casablanca's streets for construction and tear down efforts with each edition of the event, unavoidably causing large disturbances.

For the purposes of addressing the research objectives, GIS techniques were used to develop a suitability model, upon which a suitable site was selected, and analysis was conducted. The techniques will be discussed in detail below.

4.1 Objective 1 - Variables Chosen

In order to produce a sufficient MCE, criteria and constraints selected must have effectively produced the necessary limitations for this research. Criteria are variables that either contribute or detract from an area's suitability, while constraints are limiting factors to the area. Selecting these variables was determined through identifying characteristics related to the circuit regulations (FIA, 2022) as well as logistics regarding hosting a mega-sporting event.

The selected variables will be processed in order to isolate or transform the data to fit the model specifications in Table 2.

4.1.1 Data Preprocessing

All relevant data layers were reprojected to WGS 1984 UTM Zone 29N, followed by clipping to the study area to ensure that all data was described in the same area and way.

Table 2: Summary description of data variables regarding factors, workflows, and reasonings which will be utilized within the MCE.

Variables	Type	Components	Geomatic Workflows	Rationale
Water Systems	Constraint	Rivers, large water bodies	Distance Accumulation Reclassify	Distance masks of 250 m, 500 m and 1 km to minimise flood risk and construction costs
Land Cover	Constraint	Grasslands, Shrubland and Farmland	Extract by Attribute	Relatively clear and flat, non-urban land covers considered, assists in slope requirement and minimises construction costs to clear
Slope	Constraint	Grade in degrees	Slope Reclassify	Slope range of 0 - 5°, decreases construction efforts while still allowing drainage
Roads	Constraint & Criteria	Road Network	Distance Accumulation Exponential Transformation	Ensuring that location does not overlap permanent roads; ease of access for transport for people and equipment
Railways & Rail Stops	Constraint & Criteria	Rail Tracks Passenger railway stations	Distance Accumulation Small Transformation	Ensuring that location does not overlap train tracks; convenient accessibility for attendees
Bus Stops	Criteria	Bus Stops	Distance Accumulation Small Transformation	Convenient accessibility for attendees

Table 2 Continued: Summary description of data variables regarding factors, workflows, and reasonings which will be utilized within the MCE.

Variables	Type	Components	Geomatic Workflows	Rationale
Airports	Criteria	Airport facilities	Distance Accumulation Small Transformation	Accessible transport of people and equipment to and from track
Hotels	Criteria	Hotel locations	Distance Accumulation Small Transformation	Convenient accessibility from attendees' lodging
Health Centres	Criteria	Hospitals and Clinics	Select by Attribute Distance Accumulation Exponential Transformation	Ensure easy access to medical centers for those in need
Study Area	Other	The region of Grand Casablanca	Clip to Grand Casablanca	Overall area under consideration

4.2 Objective 2 - Developing the MCE Model

The selected model for this research was an MCE because it is often used for spatial decision analysis with great accuracy (Masoudi, 2021). A weighted MCE allows criteria to be standardised and through the use of pairwise comparisons.

Weightings can be applied to obtain results based on their relative importance to one another, with the objective of introducing as little bias as possible (DeVries, 2021). Standardisation of criteria was required to ensure that all comparisons are made on an identical scale, allowing conclusions to be drawn based on the final score output. Weightings essentially influence the criteria they are attached to by modifying their relative importance amongst all other criteria - a higher perceived importance leads to a higher criteria weight, and vice versa.

All “criteria” in Table 2 except roads and health centres were rescaled using a small transformation function to achieve standardisation. Under this scheme, smaller distance values were given a higher suitability score (ESRI, n.d.-b). Road and health centre factors used an exponential transformation function to reach standardisation. With this transformation, the suitability score and the factor value follow a positive correlation. These rapid increases resulted in large suitability score inflations (ESRI, n.d.-b).

The scale used to determine suitability was defined as 0 for not suitable at all (i.e., limited by a constraint) to 10 for high suitability. For the purposes of this study, a score of 7.5 or higher was deemed to be sufficiently high to make a piece of land suitable. After experimentation, this threshold range was found to yield the most continuous suitable pieces of land while remaining at a high enough value to be considered a suitable score. Stricter ranges resulted in large holes inside suitable regions, proving to be too limiting.

Other models and methods, such as network analysis, were considered. However, these were deemed unsuitable as they typically involved consideration of street circuits, defeating the motivation of keeping disturbances to a minimum. Conversely, a permanent track instead favoured the use of an MCE in order to identify suitable parcels of land.

4.2.1 Determining Weights of Criteria

To aid in determining weights for the criteria, Saaty’s Pairwise Comparison Matrix was used. Three weighting sets were created (Tables 6-8) for each time the model was run. By doing this, the level of sensitivity between the factors was explored to identify the most commonly suitable areas.

4.2.2 Creation of Model

The creation of the MCE model is described within the flowchart visualization of Figures 2-5. When the weights were finalized, they were input into an equation to determine the suitability of a particular section of land for the construction of an F1 circuit (Figure 4).

$$S = \sum_{i=1}^{n} w_i f_i \prod_{i=1}^{m} c_i$$

Where, w_i represents the weight of a particular factor, f_i is the standardised factor value and c_i represents a particular constraint (DeVries, 2021).

Nine continuous suitability rasters were generated to identify suitable regions based on the three weighting and three water body distances (Figure 11-13).

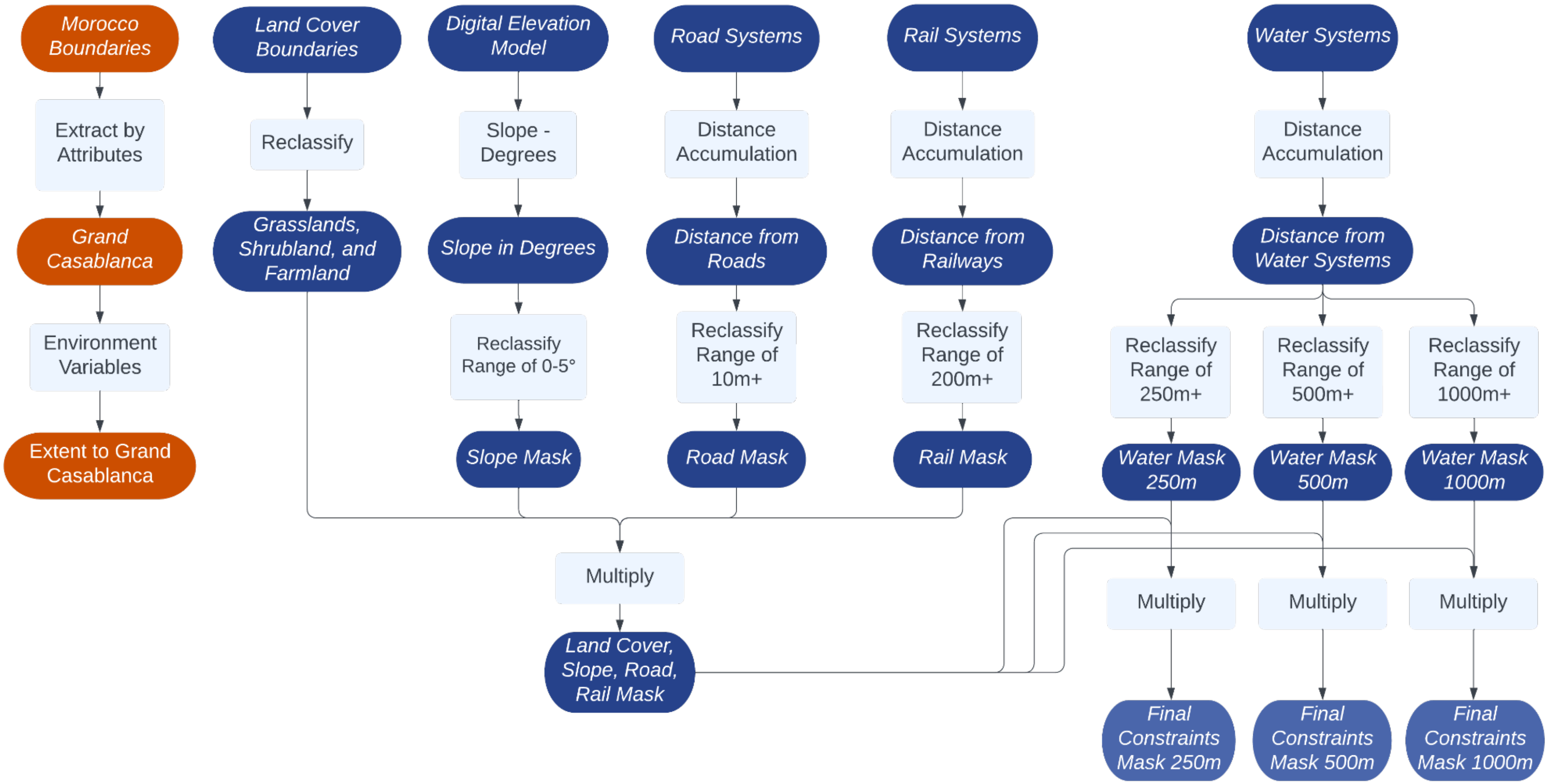

Figure 2: Procedure to preprocess the constraints and create final masks containing variable water distance thresholds

Figure 3: Procedure to preprocess criteria including hospitals, roads, rail stops, bus stops, airports, and hotels

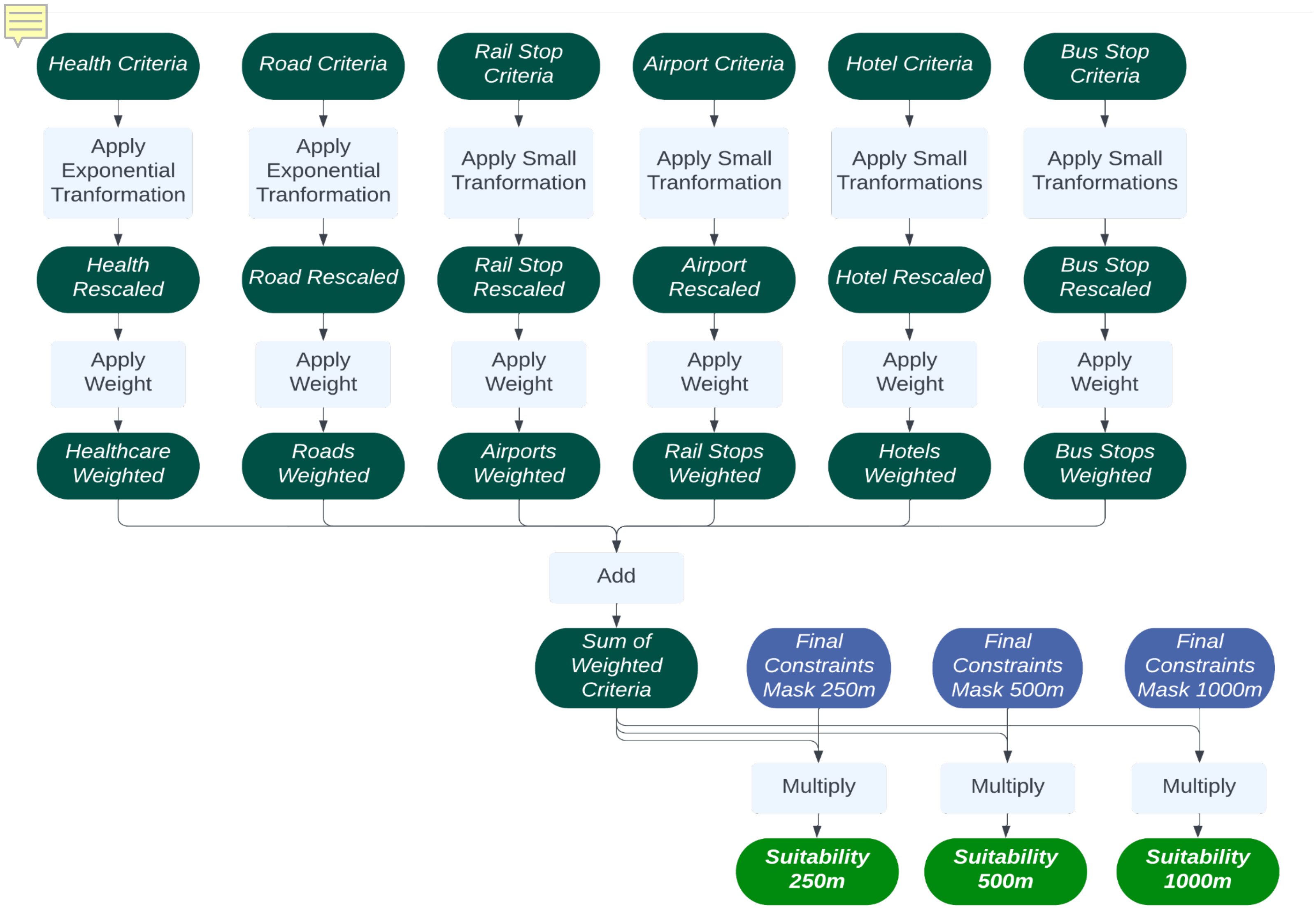

Figure 4: Procedure for MCE calculation including applying the masks and criteria to raster calculation, adding the weights, and applying transformations to obtain the suitability map.

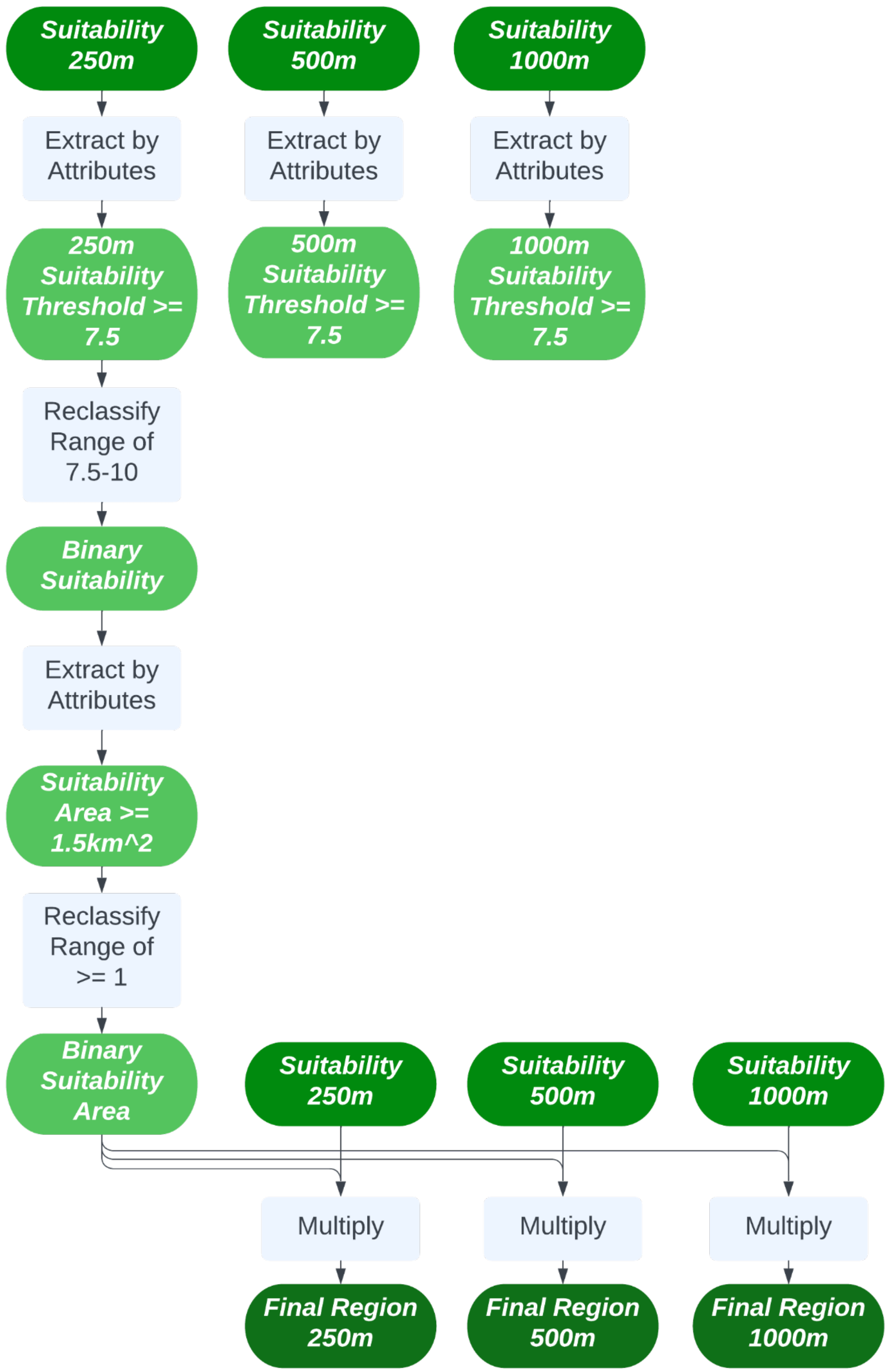

Figure 5: Procedure to identify the most suitable region that is at least 1.5 km².

4.3 Objective 3 - Creation of Circuit Layout

4.3.1 Track Criteria

In order to host an F1 race, the track must meet the highest standard licence, referred to as Grade 1 status. While the licence encompasses all aspects of the event, such as stocked medication, the focus was on track related criteria. All other aspects have not been considered as they would not influence the layout of the track heavily or at all (Fairman, 2021).

Designing the shape of the circuit is unrestricted however, in order to achieve Grade 1 status, there are a number of regulations that must be met. A typical closed-circuit track has a minimum length of 3.5 kilometres and a recommended maximum of 7 kilometres. The first turn cannot be less than 250 metres away from the start and must be at least a 45-degree directional change. The number of turns within a circuit varies, however straights cannot exceed 2 kilometres in length (Motosports, 2021; FIA, 2022).

The efficiency of the track to be created was considered regarding the layout as this is a key factor for the longevity of the sport. A study was conducted to benchmark F1 circuits based on their length, turn count, car performance and safety to identify this (Gutiérrez, 2018). The tracks with the highest efficiency, found in Table 3, were used as guidelines to determine common features within highly performant circuits (Gutiérrez, 2018). A rough sketch of a track layout that uses pieces of these efficient tracks and combining them into one design was created and used as input data for track creation (Figure 16).

4.3.2 Track Creation

Given the above criteria, there were limited algorithm-based choices freely available to design a track in the way specified by FIA. As a result, the track was created using a combination of manual input and least-cost path tool. The tool provided the ability to create a connected line between two points that was the most efficient pathway. A backlink raster retraces a route towards the source that is the least costly based on specified criteria (ESRI, n.d.-a). For this model, the input surface cost was the slope using a standard deviation stretch type and dynamic range adjustment statistic. An outline of key points on the rough track layout was placed over the selected suitable region (Figure 17). The least-cost path tool was then used to provide suggestions for the final theoretical layout. Corners were designed and connected with help from the tool, pursuant to the goal of creating corners efficiently. Straights on the track were manually drawn as there is only one way to connect two points in a straight line, rendering the tool redundant. Once the layout was determined (Figure 18), the lines created as suggestions were smoothed manually to ensure the track met the safety regulations and was drivable at high speeds.

4.4 Objective 4 - Model Evaluation

The applicability of the MCE model was assessed to evaluate its performance against existing track locations on the 2023 race calendar. Three permanent circuits were randomly selected (Table 3). Some changes were made to the model to account for the testing of already existing circuits as opposed to evaluating the possible locations for a circuit. The land mask constraint, which was previously Grassland, Shrubland, and Farmland was changed to Artificial Surfaces which the existing tracks were classified as. The model was also tested with only one water body constraint (250 m) as there were not many natural water bodies near the track, and tested only using weight set 2 as it yielded the highest scores.

Table 3: Selected circuits and their hosted events used to assess model performance.

Track Name	Grand Prix Hosted
Suzuka Circuit	Japanese Grand Prix
Circuit of the Americas (COTA)	United States Grand Prix
Hungaroring	Hungarian Grand Prix

Table 4: Characteristics of the most efficient Formula One circuits and their average values including circuit type, the total distance of one lap, the distance of the longest straight, the number of total turns, the number of chicanes turns, the number of hairpin turns, and orientation. Features were derived from FIA's official circuit layouts (FIA, 2019).

Circuit	Type	Lap Distance (km)	Longest Straight (m)	Total # of Turns	# Chicane Turns	# Hairpin Turns	Orientation
Albert Park	Street	5.287	750	16	4	0	Clockwise
Circuit of the Americas	Permanent	5.513	1100	20	1	1	Counter-clockwise
Istanbul	Permanent	5.338	700	14	1	1	Counter-clockwise
Monaco	Street	3.34	470	12	3	1	Clockwise
Montreal	Hybrid	4.361	670	14	3	1	Clockwise
Monza	Permanent	5.793	1120	11	2	0	Clockwise
Nürburgring	Permanent	5.148	850	15	3	2	Clockwise
Red Bull Ring	Permanent	4.318	650	10	1	0	Clockwise
Sepang	Permanent	5.543	900	15	3	2	Clockwise
Shanghai	Permanent	5.451	1200	16	2	3	Clockwise
Silverstone	Permanent	5.891	750	18	2	1	Clockwise
Yas Marina	Hybrid	5.281	1200	16	1	2	Counter-clockwise
Average	Permanent	≅ 5.105	≅ 863	15	2	1	Clockwise

5. Data

Table 5: Data used within the suitability model including its source, scale, and last modified date.

Data	Data Source	Date of Modification	Scale
Digital Elevation Model	Producer: Jeffery Neal and Lawrence Hawker, University of Bristol (Neal & Hawker, 2023)	January 18, 2023	30 m resolution
Land Cover	Producer: GlobeLand30 (Chen et al., 2021)	August 17, 2020	30 m resolution
Water Network	Producer: OpenStreetMap (OpenStreetMap, 2021d)	July 3, 2020	National
Study Area Boundary	Producer: QGIS, Khaoula Ajbal (Ajbal, 2019)	March 18, 2019	Regional
Roads	Producer: OpenStreetMap (OpenStreetMap, 2021c)	July 3, 2020	National
Railways Lines	Producer: OpenStreetMap (OpenStreetMap, 2021b)	July 3, 2020	National
Railway Stops	Producer: OpenStreetMap (Geofabrik, 2023d)	March 16, 2023	Regional
Bus Stops	Producer: Geofabrik (Geofabrik, 2023c)	March 16, 2023	Regional
Airports	Producer: OpenStreetMap (OpenStreetMap, 2020)	July 3, 2020	National
Medical Centers	Producer: OpenStreetMap (OpenStreetMap, 2021a)	July 3, 2020	National
Hotels	Producer: OpenStreetMap (OpenStreetMap, 2023)	February 13, 2023	Regional

6. Results and Discussions

6.1 Suitability MCE Output

From the candidate regions, a parcel common to all three weight sets and water body constraints was selected (Figures 6). The total area of the region was 1.92 km^2, was located approximately 4 kilometres away from the main core of the city, and already has easy access to bus stops. This region, based on weight set 2 as it yielded the highest suitability, had a maximum suitability score of 9.6, compared to other regions which had maximum scores ranging from approximately 8.5 to 9.2. The minimum score drops only to 8.0 compared to other candidate regions which all had a minimum score of 7.5. Much of this area has a slope of less than 1.72°, with a small subsection of the bottom raised to between 1.72 and 3.43. It is between 5 and 6 kilometres from the nearest water bodies and train tracks and does not overlap any permanent roads while still remaining close (edges are less than 30 metres from roads) allowing for ease of construction.

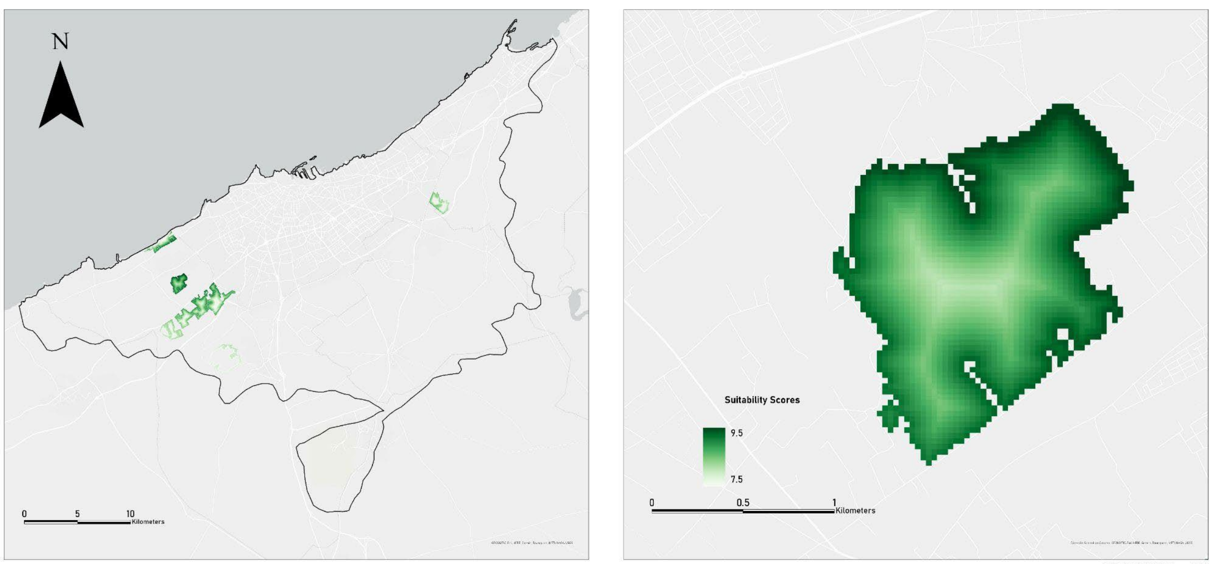

Figure 6: Left: The final candidate regions identified in all Grand Casablanca using weight set 2. Right: Final region identified with the highest suitability score (9.6) and area of at least 1.5 km^2.

6.2 Track Creation

The final layout included 15 turns total, including two hairpin turns and two chicane turns (Figure 7). The track runs through relatively flat terrain for most of the length. In total the track is 4.9 kilometres in length, featuring a straight that is 830 m in length, and it takes up a total of 0.71 km^2. This leaves 1.21 km^2 of area for other Grand Prix needs, which includes the paddock and pit lane, grandstands, medical facilities, bathrooms, and areas for food and rest (Fairman, 2021).

Figure 7: Left: Final circuit layout show with permanent roads that were considered in the model. Right: Final circuit layout shows with final selected region.

6.3 Model Evaluation

To assess the performance of the model, three random permanent tracks on the 2023 F1 race calendar were selected, and the model was run to score the areas of the track, with the chosen locations listed in Table 3. The three locations had a score of 8.5, 7.2, and 9.0, respectively (Figure 8).

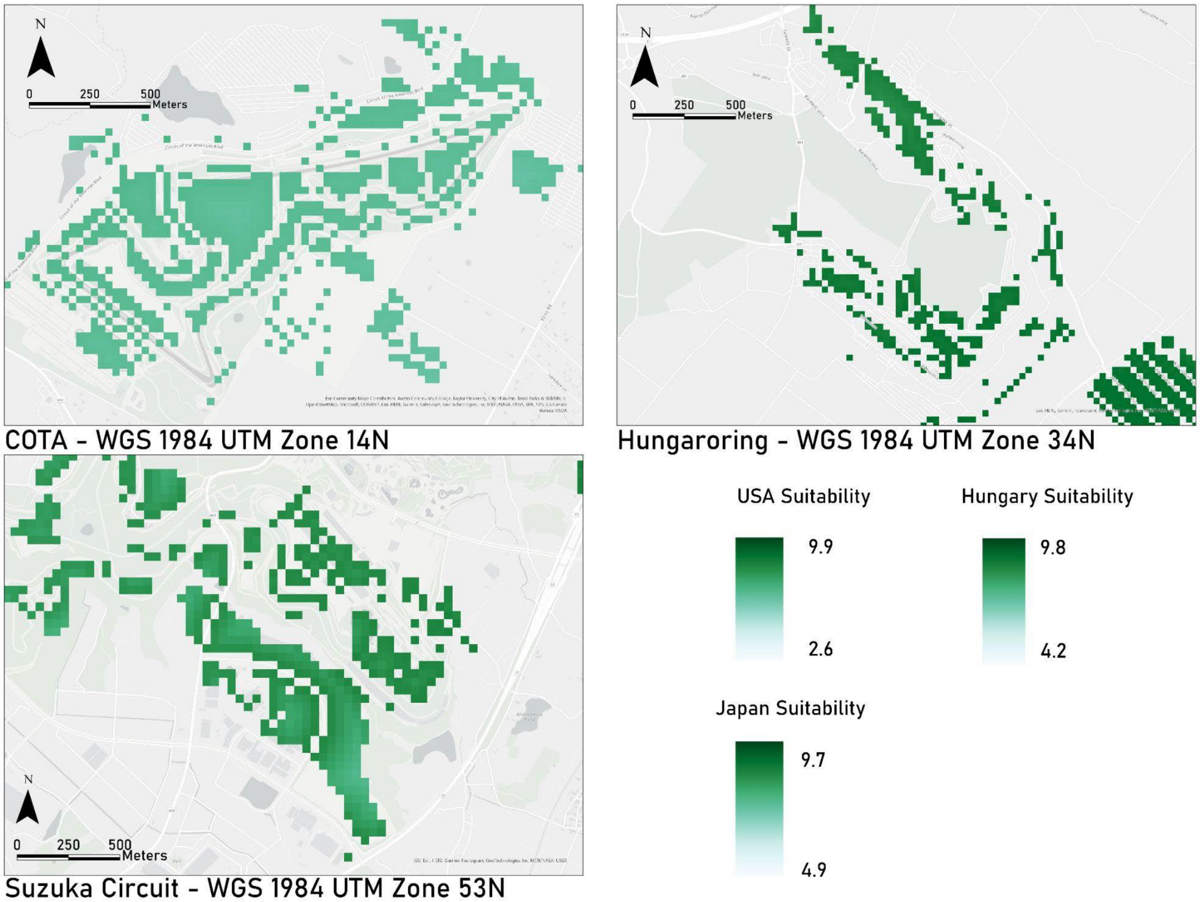

Figure 8: Suitability maps of Circuit of the Americas, Hungaroring, and Suzuka Circuit using the created MCE workflow.

6.4 Discussion

The high suitability score and relative closeness to the city centre identifies it as an ideal candidate for hosting a F1 race, however this is only one aspect of the event. Hosting an event of this calibre can come at the risk of not sustaining a sufficient profit and can sometimes be difficult for the government to evaluate the benefits of doing so (Kim et al., 2017). Using the Chinese Grand Prix as a case study, it was found that there were both benefits and restrictions. The event brought in an influx of money for the local government through services such as transportation, lodging, and retail. However, the actual organisers of the event announced that no profit was made. This indicated that hosting an event of this magnitude requires a large amount of support from the local government. It also found that 5.77% of attendees were international tourists, which would likely increase with Casablanca, and thus increasing local spending (Kim et al., 2017). In Casablanca, tourism increased 5.2% from 2018-2019 due to increased air links from Europe to Mohammed V Airport (Guerraoui, 2020). Although Casablanca does not have as high of a developed tourism industry, hosting this event may mean an increased number of tourists in the city every year (Moroccan World News, 2019).

There are strengths and limitations involved with assessing the model against other current tracks. Suzuka and Hungaroring both yielded great results, while COTA had a lower score. This can be derived from the fact that the circuit is located about 18 kilometres away from the nearest health clinic and about 21 kilometres away from the nearest hospital. It is likely that the proximity to clinics and hospitals were not a large priority when building the track, as the FIA requires all circuits to have a medical centre on the grounds (Fairman, 2021). However, it felt that a large emphasis on health facilities was needed in the model, due to recent indices such as Jules Bianchi's incident in 2014, and Romain Grosjean's in 2020, which both required fast acting medical care and hospitalizations (Ryan, 2021; CNN, 2014). As well, events of this calibre can have spectators upwards of 100,000, meaning that the location of the track should be located close to health centres in case of an incident occurring during the race weekend. As well, the location of Austin itself does not prove ideal compared to other tracks on the calendar. The track is located a significant distance away from downtown Austin, at 30 kilometres (Grand Prix Experience, 2022). Additionally, spectators from recent races have complained about the traffic getting to and from the track, as well as the lack of food options available around the track (346jear, 2021; P4521TQstephenf; 2021). Overall, although the model produced very low scores against one of the tracks, based on poor experiences travelling to and from the track and the emphasis on health in our model, it is advisable that future locations are selected using similar criteria and weightings.

6.4.1 Limitations

The output of a GIS-based process is only as good as the data inputted, so it was important to remark that there are certain missing factors with regards to data sourced from OpenStreetMap that was used in selecting criteria. In particular, there was a lack of data regarding private accommodations available in the study area in the form of Airbnb or similar accommodations. These types of accommodations can be attractive alternatives when compared to conventional hotels. Further analysis with certain residential areas included to account for Airbnb-type accommodations may yield different results with regards to balancing accessibility and noise abatement near residential areas.

Additionally, OpenStreetMap relies on user provided data, which may not necessarily be completely accurate, whether due to intentional sabotage or input error. This has been partially mitigated by performing visual spot checks on relevant data, but any existing errors will remain in OpenStreetMap's data sets until discovered by relevant parties who can remove these errors.

There was a significant amount of subjectivity regarding MCEs due to selection of factor weights being left to the model builders. This can introduce bias as the model may be missing certain variables entirely or be built in such a way that it only reflects the builders' worldviews, rather than using an impartial stance (DeVries, 2021).

It should also be remarked that the final track layout designed was not truly 'least cost', as there still had to be some consideration of actual features in an F1 circuit, such as chicanes, and the number of turns in a circuit. Had the circuit followed every suggestion made by the least cost path tool, it would have a large number of turns, and little opportunity for an exciting race.

Some other limitations include that sometimes the criteria were located outside the region of study. The majority of hotels in Hungary were located in Budapest, while the closest airport in Japan was located in the neighbouring prefecture. To circumvent this, distance accumulation was performed across the entire country, then clipped to the study region.

7. Conclusions

When determining a new location for an F1 venue, there are many factors related to both the infrastructure and physical landforms of the area that would influence the potential for suitable sites. The nature of hosting a mega-sporting event required aspects including distance from health centers and lodging, as well as transportation such as roads, bus stops, and railways to be considered carefully. To ensure F1 track regulations were met, the physical criteria focused on were slope, land use, and distance from water bodies. Using this data, the goal of this research was to showcase a reusable methodology for identifying a suitable region based on the criteria, which could be used in determining future sites for motorsport events.

Three MCEs were generated of varying weights to examine the level of sensitivity within the model, resulting in a final suitability map containing a parcel of land with a score of 9.6. The final site and average characteristics of existing designs were used in the creation of a regulation F1 circuit to demonstrate the potential utilization of the land. Using the model, scores ranging from 7.2 to 9.2 were found using existing tracks, showcasing that COTA did not have easy access to factors that were deemed necessities while the other tracks did. These results indicated the potential need for a higher focus with regards to healthcare and tourism accommodations when determining future sites.

While the application of this research was geared towards F1, identification of other mega-sporting event location suitabilities could utilize this model when looking for potential venues. This model would set a precedent for standardising the identification of land suitability regarding hosting events. Having a standardised methodology is an effective tool for both the prospective host and FIA, since it provides the ability to explore different avenues repeatedly and quickly while ensuring criteria are met accurately.

F1 lends itself well to research using geomatics, as seen with the model, however, there is a significant research gap with constructing track layouts. Using emerging technology, research can be conducted in this area using the likes of artificial intelligence and machine learning. Different algorithms can then be derived to produce safe but exhilarating road courses for future F1 races, and indeed can extend to other fields as well.

8. References

346jear. (October, 2021). Traffic control was a nightmare [Review of the F1 - United States Grand Prix]. https://www.tripadvisor.ca/ShowUserReviews-g30196-d8820218-r816147238-F1_United_States_Grand_Prix-Austin_Texas.html

Aitali, R., Snoussi, M., & Kasmi, S. (2020). *Coastal development and risks of flooding in Morocco: The cases of Tahaddart and Saidia coasts.* Journal of African Earth Sciences, *164*. https://doi.org/10.1016/j.jafrearsci.2020.103771

American Formula 1 2023 (Austin, USA). Grand Prix Experience. (2022, November 16). Retrieved April 15, 2023, from https://grandprixexperience.com/f1-race/usa-austin/

Appendix O to the International Sporting Code. FIA. (2022, September 30). Retrieved February 17, 2023, from https://www.fia.com/sites/default/files/appendix_h_2022_published_29.08.2022.pdf

Breaking: Las Vegas to host formula 1 night race from 2023: Formula 1®. Formula 1. (2022, March 31). Retrieved February 16, 2023, from https://www.formula1.com/en/latest/article.breaking-las-vegas-to-host-formula-1-night-race-from-2023.69O9nKLwKraqAhR5rr8TQg.html

CNN. (2014, October 8). *Bianchi family reveal F1 driver has suffered 'diffuse axonal injury'*. CNN. Retrieved March 31, 2023, from http://edition.cnn.com/2014/10/07/sport/motorsport/motorsport-bianchi-injury-family-update/index.html

DeVries, B. (2021, February 10). *GEOG*3480-W21 GIS AND SPATIAL ANALYSIS UNIT 4: MULTI CRITERIA EVALUATION (PART 3)* [PowerPoint slides]. Department of Geography, Environment & Geomatics, University of Guelph. Guelph, Ontario, Canada.

ESRI. (n.d.-a). *Creating the least-cost path*. Creating the least-cost path. ArcGIS Pro Documentation. Retrieved March 29, 2023, from https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/creating-the-least-cost-path.htm

ESRI. (n.d.-b). *The transformation functions available for rescale by function*. ArcGIS Pro Documentation. Retrieved February 17, 2023, from https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/the-transformation-functions-available-for-rescale-by-function.htm

Fairman, K. (2021, June 1). *What does it take to be an FIA 'grade 1' circuit?* WTF1. Retrieved February 17, 2023, from https://wtf1.com/post/what-does-it-take-to-be-an-fia-grade-1-circuit/

FIA Circuit List of 2019. Fédération Internationale de l'Automobile. (2019). Retrieved March 25, 2023, from https://www.fia.com/sites/default/files/fia_circuit_list_template_2019.pdf

FIA track grades: Requirements to hold an F1 race, potential tracks. Motorsport.com: F1 News, MotoGP, NASCAR, Rallying and more. (2021, May 14). Retrieved February 17, 2023, from https://www.motorsport.com/f1/news/fia-track-grades-requirements-f1-potential/6508330

Formula 1. (n.d). *1958 Morocco Grand Prix - RACE RESULT*. Formula 1. Retrieved March 29, 2023, from https://www.formula1.com/en/results.html/1958/races/168/morocco/race-result.html

Formula 1. (2022, March 31). *Breaking: Las Vegas to host formula 1 night race from 2023: Formula 1®*. Formula 1. Retrieved February 17, 2023, from https://www.formula1.com/en/latest/article.breaking-las-vegas-to-host-formula-1-night-race-from-2023.69O9nKLwKraqAhR5rr8TQg.html

Gutiérrez, E., & Lozano, S. (2018). Benchmarking formula one auto racing circuits: A two stage DEA approach. Operational Research, 20(4), 2059–2083. https://doi.org/10.1007/s12351-018-0416-z

Haut Commissariat du Plan (2016, October 25). *RGPH 2014 (population par régions(16 régions) et provinces).* Morocco Data Portal. Retrieved February 17, 2023, from https://morocco.opendataforafrica.org/uesftqc/rgph-2014-population-par-r%C3%A9gions-16-r%C3%A9gions-et-provinces?regions=1000480-grand-casablanca

Insight: The history of racing in Morocco. The Official Home of Formula E. (2016, November 8). Retrieved January 26, 2023, from https://www.fiaformulae.com/fr/news/6482/insight-the-history-of-racing-in-morocco

Karaca, C. (2017). *Analysis of the Optimal Olympic Place Choice in Turkey by Multi Criteria Decision Making Methods*. Bolu Abant Izzet Baysal University. Retrieved from https://www.researchgate.net/publication/322012427_Analysis_of_the_Optimal_Olympic_Place_Choice_in_Turkey_by_Multi_Criteria_Decision_Making_Methods.

Kim, M. K., Kim, S.-K., Park, J.-A., Carroll, M., Yu, J.-G., & Na, K. (2017). Measuring the economic impacts of major sports events: the case of Formula One Grand Prix (F1). Asia Pacific Journal of Tourism Research, 22(1), 64–73. https://doi-org.subzero.lib.uoguelph.ca/10.1080/10941665.2016.1176061

Masoudi, M., Centeri, C., Jakab, G., Nel, L., & Mojtahedi, M. (2021). GIS-based multi-criteria and multi-objective evaluation for Sustainable Land-Use Planning (Case Study: Qaleh Ganj County, Iran) "landuse planning using MCE and Mola." *International Journal of Environmental Research*, *15*(3), 457–474. https://doi.org/10.1007/s41742-021-00326-0

McKenzie-Kennedy, S. (2021, July 13). *What makes a good F1 track?* Everything F1. Retrieved February 17, 2023, from https://www.everythingf1.com/what-makes-a-good-f1-track/

Morocco World News. (2019, May 12). Tourist arrivals in Morocco rose by 4.1% in March 2019. https://www.moroccoworldnews.com/. Retrieved April 15, 2023, from https://www.moroccoworldnews.com/2019/05/272864/tourism-observatory-tourist-arrivals-in-morocco/

Muchinjo, E. (2022, May 7). *Africa: Popularity rising for motorsport in Africa, but African market remains untapped*. allAfrica. Retrieved January 26, 2023, from https://allafrica.com/stories/202205070009.html

Oxford Business Group. *Tourism sector in Morocco emphasises diversification and improved air connectivity - africa 2016*. Oxford Business Group. (2022, November 16). Retrieved March 16, 2023, from https://oxfordbusinessgroup.com/reports/morocco/2016-report/economy/a-regional-leader-the-sector-plan-emphasises-diversification-of-the-offering-improved-air-connectivity-and-investment-in-promotion

P4521TQstephenf. (October, 2021). It's a marathon, and then it's an obstacle course [Review of the F1 - United States Grand Prix]. https://www.tripadvisor.ca/ShowUserReviews-g30196-d8820218-r816025318-F1_United_States_Grand_Prix-Austin_Texas.html

Ryan, N. (2021, March 6). *Romain Grosjean Bahrain crash report released with details of impact, fire*. MotorSportsTalk | NBC Sports. Retrieved March 31, 2023, from https://motorsports.nbcsports.com/2021/03/06/romain-grosjean-crash-report-f1-bahrain

Guerraoui, S. (2020, February 9). Record year for morocco tourism with 13 million visitors. Arab News. Retrieved April 15, 2023, from https://www.arabnews.com/node/1623446/middle-east

Serra, C. (2022, February 10). *How a Netflix docuseries set off a rise in F1 popularity*. Audiense. Retrieved January 26, 2023, from https://resources.audiense.com/blog/the-netflix-effect-how-an-f1-docuseries-set-off-a-meteoric-rise-in-popularity-in-the-us

Snoussi, M., Ouchani, T., Khouakhi, A., & Niang-Diop, I. (2009). *Impacts of sea-level rise on the Moroccan coastal zone: Quantifying coastal erosion and flooding in the Tangier Bay.* Geomorphology, *107*(1-2), 32–40. https://doi.org/10.1016/j.geomorph.2006.07.043

Subak-Sharpe, T. (2022, November 9). *What a formula 1 return to Africa could mean for the sport and the continent*. Sportcal. Retrieved from https://www.sportcal.com/comment/what-a-formula-1-return-to-africa-could-mean-for-the-sport-and-the-continent/

The Early Years. Formula One Art & Genius. (2018, May 5). Retrieved March 16, 2023, from http://www.f1-grandprix.com/?page_id=272

The World Bank. (2013). *Building Morocco's Resilience*. Retrieved February 3, 2023, from https://documents.worldbank.org/curated/en/703601468060288949/pdf/837820WP0REVIS00Box382112B00PUBLIC0.pdf

Appendix A

Data Sources

Ajbal, K. (2019). *Morocco Regional Boundaries.* [Data set]. figshare. https://doi.org/10.6084/m9.figshare.7857002.v1

Chen J., Ban Y., Li S. (2021). *Open Access to Earth Land-Cover Map.* [Data set]. GlobeLand30. https://doi.org/10.1038/514434c

Geofabrik. (2023a). *Chubu, Japan (Suzuka Circuit)*. [Data set]. Geofabrik. https://download.geofabrik.de/asia/japan/chubu.html

Geofabrik. (2023b). *Hungary (Hungaroring).* [Data set]. Geofabrik. https://download.geofabrik.de/europe/hungary.html

Geofabrik. (2023c). *Morocco (Bus Stops).* [Data set]. Geofabrik. https://download.geofabrik.de/africa/morocco.html

Geofabrik. (2023d). *Morocco (Railway Stops).* [Data set]. Geofabrik. https://download.geofabrik.de/africa/morocco.html

Geofabrik. (2023e). *United States of America, South USA (Circuit of the Americas).* [Data set]. Geofabrik. https://download.geofabrik.de/north-america/us-south.html

Neal, J., and Hawker, L. (2023, January 18). *FABDEM V1-2*. [Data set]. University of Bristol. https://doi.org/10.5523/bris.s5hqmjcdj8yo2ibzi9b4ew3sn

OpenStreetMap. (2020). *HOTOSM Morocco Airports*. [Data set]. Humanitarian Data Exchange. https://data.humdata.org/dataset/hotosm_mar_airports

OpenStreetMap. (2021a). *HOTOSM Morocco Health Facilities*. [Data set]. Humanitarian Data Exchange. https://data.humdata.org/dataset/hotosm_mar_health_facilities

OpenStreetMap. (2021b). *HOTOSM Morocco Railways*. [Data set]. Humanitarian Data Exchange. https://data.humdata.org/dataset/hotosm_mar_railways

OpenStreetMap. (2021c). *HOTOSM Morocco Roads*. [Data set]. Humanitarian Data Exchange. https://data.humdata.org/dataset/hotosm_mar_roads

OpenStreetMap. (2021d). *HOTOSM Morocco Waterways*. [Data set]. Humanitarian Data Exchange. https://data.humdata.org/dataset/hotosm_mar_waterways

OpenStreetMap. (2023, February 13). *Hotels in Casablanca*. [Data set]. HOT Export Tool. https://export.hotosm.org/en/v3/exports/c9bc065c-05c8-4abe-8537-6ccd2cf3ccc4

Pairwise Rankings and Individual Weights

Table 6: Weight set 1 of pairwise rankings and individual weights for criteria of health centers, roads, hotels, bus stops, airports, and rail stops in order of priority

Pairwise Ranking							Individual Weights						Total Weights	
	Health	Roads	Hotels	Bus Stops	Airports	Rail Stops	Health	Roads	Hotels	Bus Stops	Airports	Rail Stops	Fraction	Decimal
Health	1	1	5	3	3	7	1/3	5/16	15/38	15/46	9/34	7/26	1/3	0.32
Roads	1	1	5	3	3	7	1/3	5/16	15/38	15/46	9/34	7/26	1/3	0.32
Hotels	1/5	1/5	1	1	3	3	1/15	1/16	3/38	5/46	9/34	3/26	1/9	0.12
Bus Stops	1/3	1/3	1	1	1	5	1/9	5/48	3/38	5/46	3/34	5/26	1/9	0.11
Airports	1/3	1/3	1/3	1	1	3	1/9	5/48	1/38	5/46	3/34	3/26	6/65	0.09
Rail Stops	1/7	1/3	1/3	1/5	1/3	1	1/21	5/48	1/38	1/46	1/34	1/26	2/45	0.04
Sum	3	3 1/5	12 2/3	9 1/5	11 1/3	26	1	1	1	1	1	1	1	1

Table 7: Weight set 2 of pairwise rankings and individual weights for criteria of health centers, roads, hotels, bus stops, airports, and rail stops in order of priority. This version produced a suitability of 9.6.

Pairwise Ranking							Individual Weights						Total Weights	
	Health	Roads	Hotels	Bus Stops	Airports	Rail Stops	Health	Roads	Hotels	Bus Stops	Airports	Rail Stops	Fraction	Decimal
Health	1	1	6	3	2	6	1/3	6/23	5/14	18/47	3/14	1/4	2/7	0.30
Roads	1	1	6	2	1	6	1/3	6/23	5/14	12/47	3/28	1/4	1/4	0.25
Hotels	1/6	1/6	1	1	3	5	1/15	1/123	5/84	6/47	9/28	5/24	1/7	0.14
Bus Stops	1/3	1/2	3	1	2	3	1/9	3/23	5/28	6/47	3/14	1/8	1/7	0.14
Airports	1/2	1	1/2	1/2	1	3	1/6	6/23	2/67	3/47	3/28	1/8	1/8	0.13
Rail Stops	1/6	1/6	1/3	1/3	1/3	1	1/21	1/23	1/50	2/47	1/28	1/24	1/26	0.04
Sum	3 1/6	3 5/6	16 5/6	7 5/6	9 1/3	24	1	1	1	1	1	1	1	1

Table 8: Weight set 3 of pairwise rankings and individual weights for criteria of health centers, roads, hotels, bus stops, airports, and rail stops in order of priority

Pairwise Ranking							Individual Weights						Total Weights	
	Health	Roads	Hotels	Bus Stops	Airports	Rail Stops	Health	Roads	Hotels	Bus Stops	Airports	Rail Stops	Fraction	Decimal
Health	1	3	5	5	5	5	1/2	36/65	30/71	3/8	30/61	5/19	3/7	0.43
Roads	1/3	1	3	2	3	4	1/6	12/65	18/71	3/20	18/61	4/19	1/5	0.21
Hotels	1/5	1/3	1	2	1/2	3	1/15	4/65	6/71	3/20	3/61	3/19	66/695	0.10
Bus Stops	1/5	1/2	1/2	1	1/3	3	0	6/65	3/71	3/40	2/61	3/19	48/583	0.08
Airports	1/5	1/3	2	3	1	3	0	4/65	12/71	9/40	6/61	3/19	9/67	0.14
Rail Stops	1/5	1/4	1/3	1/3	1/3	1	1/21	3/65	2/71	1/40	2/61	1/19	1/26	0.04
Sum	2 2/15	5 5/12	11 5/6	13 1/3	10 1/6	19	1	1	1	1	1	1	1	1

Table 9: Approximate venue areas of permanent or hybrid circuits from Table 3, calculated using Google Earth's measurement tool.

Circuit	Venue Area (km^2)
Circuit of the Americas	1.62
Istanbul	1.62
Montreal	0.69
Monza	1.99
Nürburgring	1.25
Red Bull Ring	0.79
Sepang	0.81
Shanghai	1.14
Silverstone	1.94
Yas Marina	1.04
Average	$\cong$ 1.29

Appendix B

Suitability Model Script: https://github.com/annalieseschropp/GEOG4480_Suitability

Appendix C

Intermediate Maps from Suitability Workflow

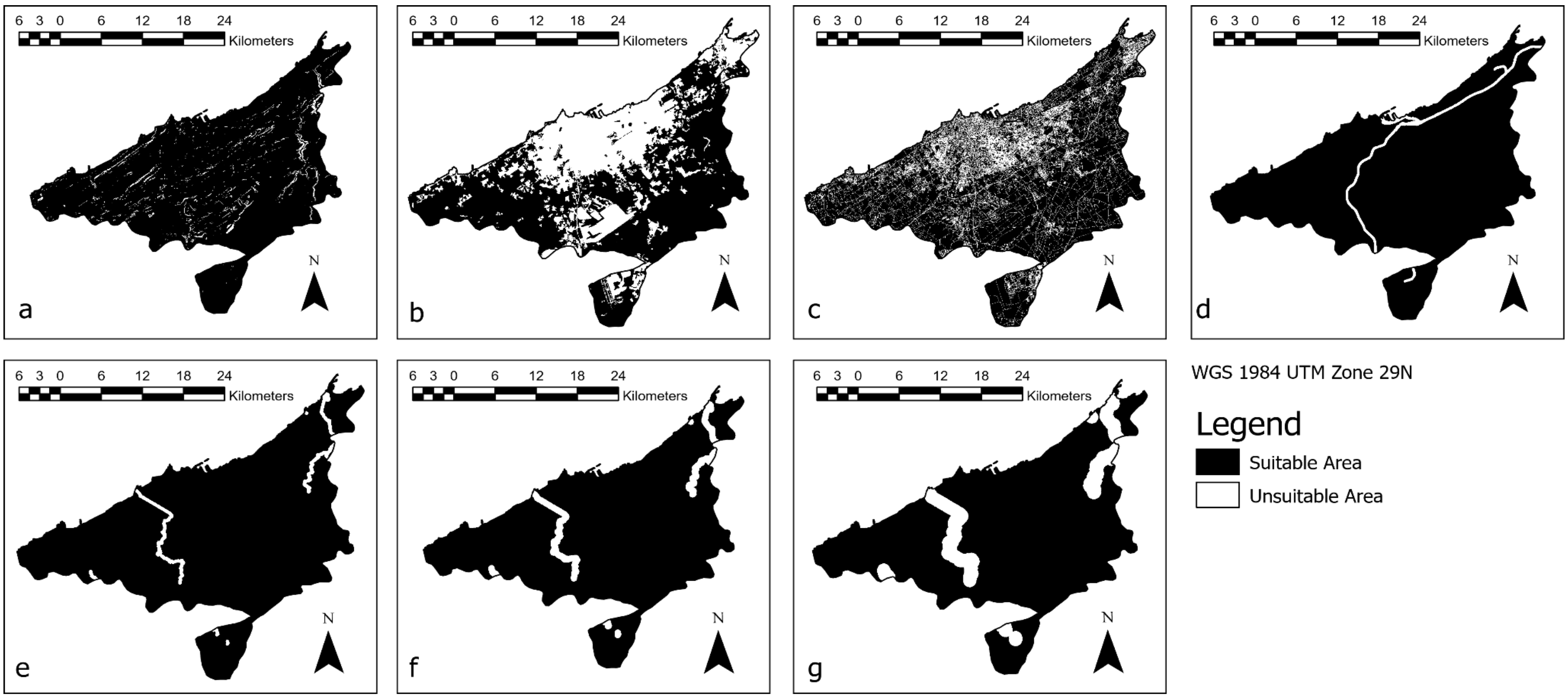

Figure 9: Map of constraints indicating which areas are suitable including a) slope of 0-5 degrees, b) grasslands, shrubland, and farmland land use c) roads, d) railways e) water body distance of 250 m, f) water body distance of 500 m, g) water body distance of 1000 m.

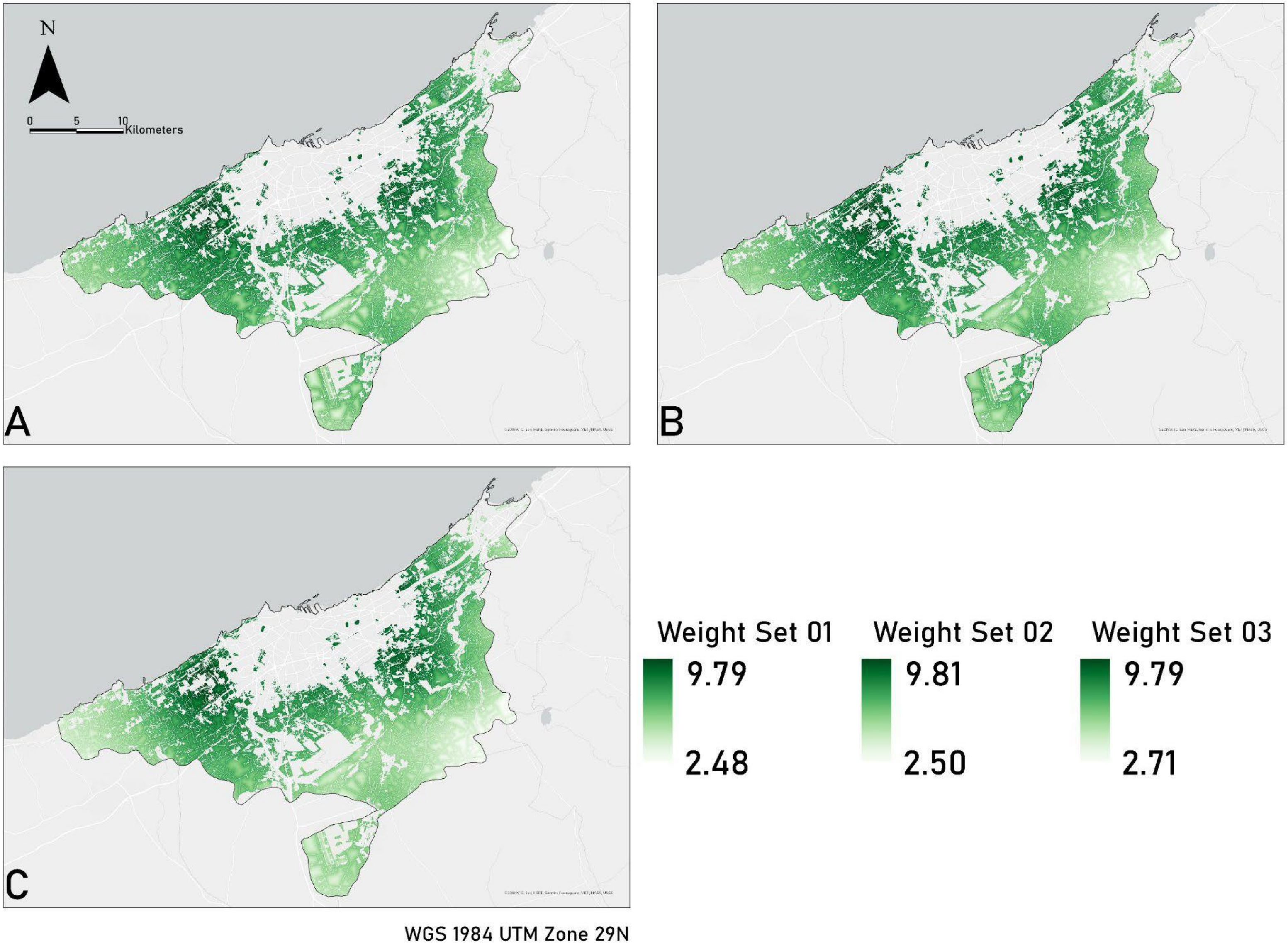

Figure 10: Suitability map after combining criteria and weighted transformed constraints. a) weight set 1 suitability, b) weight set 2 suitability, c) weight set 3 suitability

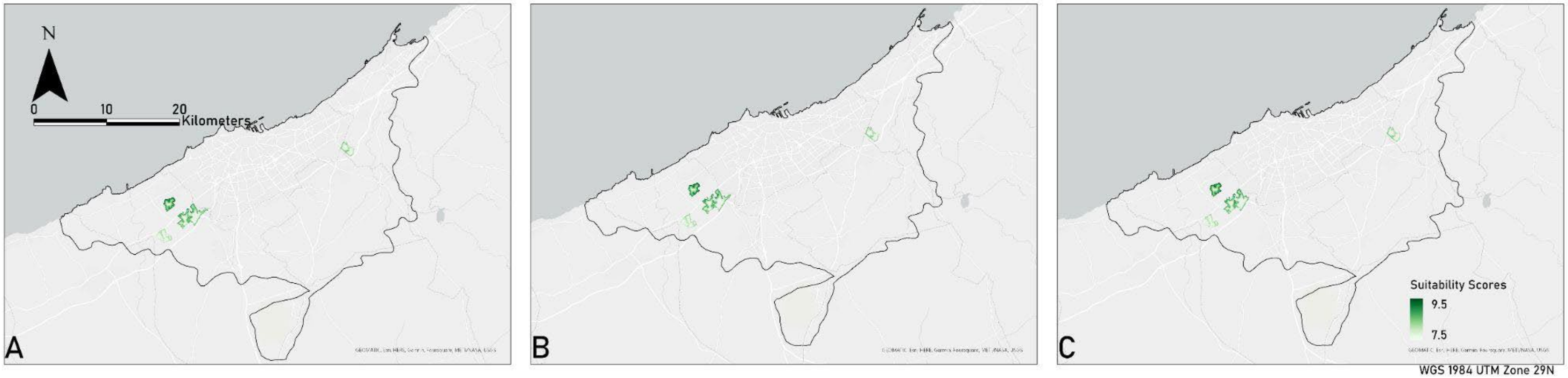

Figure 11: Suitability score regions of at least area 1.5km^2 of weight set 1 using each water body distance including a) weight set 1, 250 m, c) weight set 1, 500 m, d) weight set 1, 1000 m.

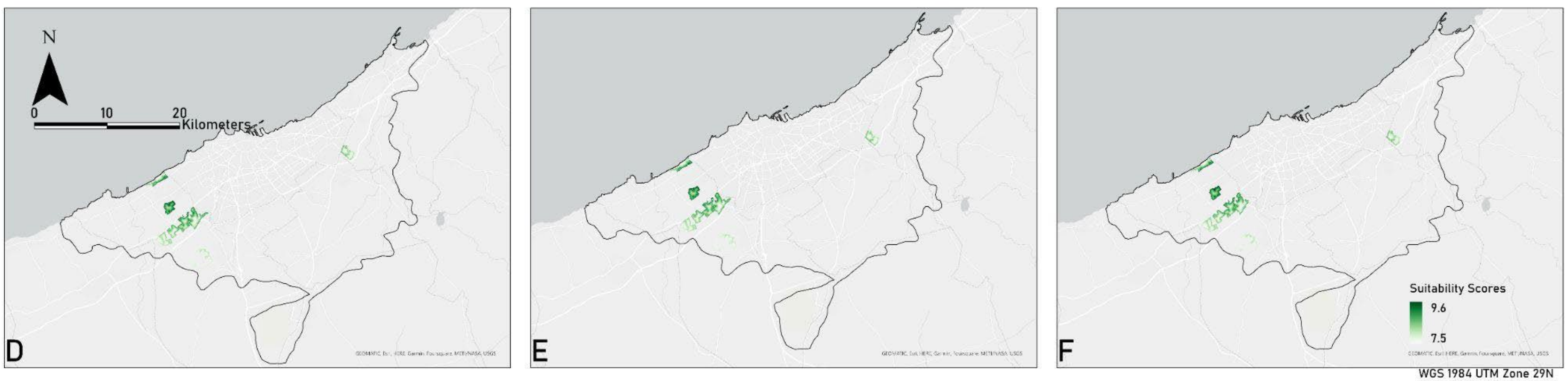

Figure 12: Suitability score regions of at least area 1.5km^2 of weight set 2 using each water body distance including d) weight set 2, 250 m, e) weight set 2, 500 m, f) weight set 2, 1000 m.

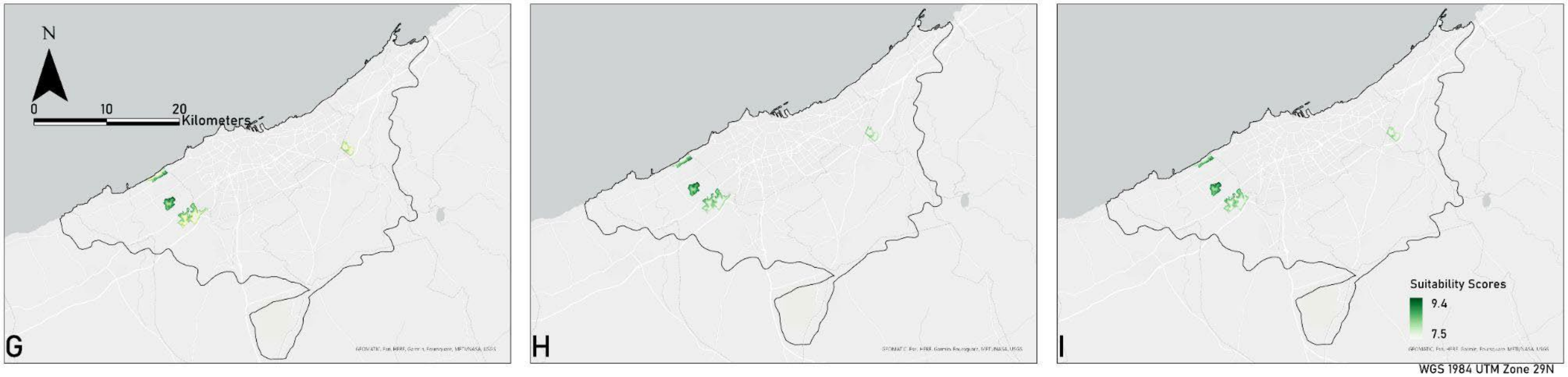

Figure 13: Suitability score regions of at least area 1.5km^2 of weight set 3 using each water body distance including g) weight set 3, 250 m, h) weight set 3, 500 m, i) weight set 3, 1000 m.

Intermediate Maps from Track Creation

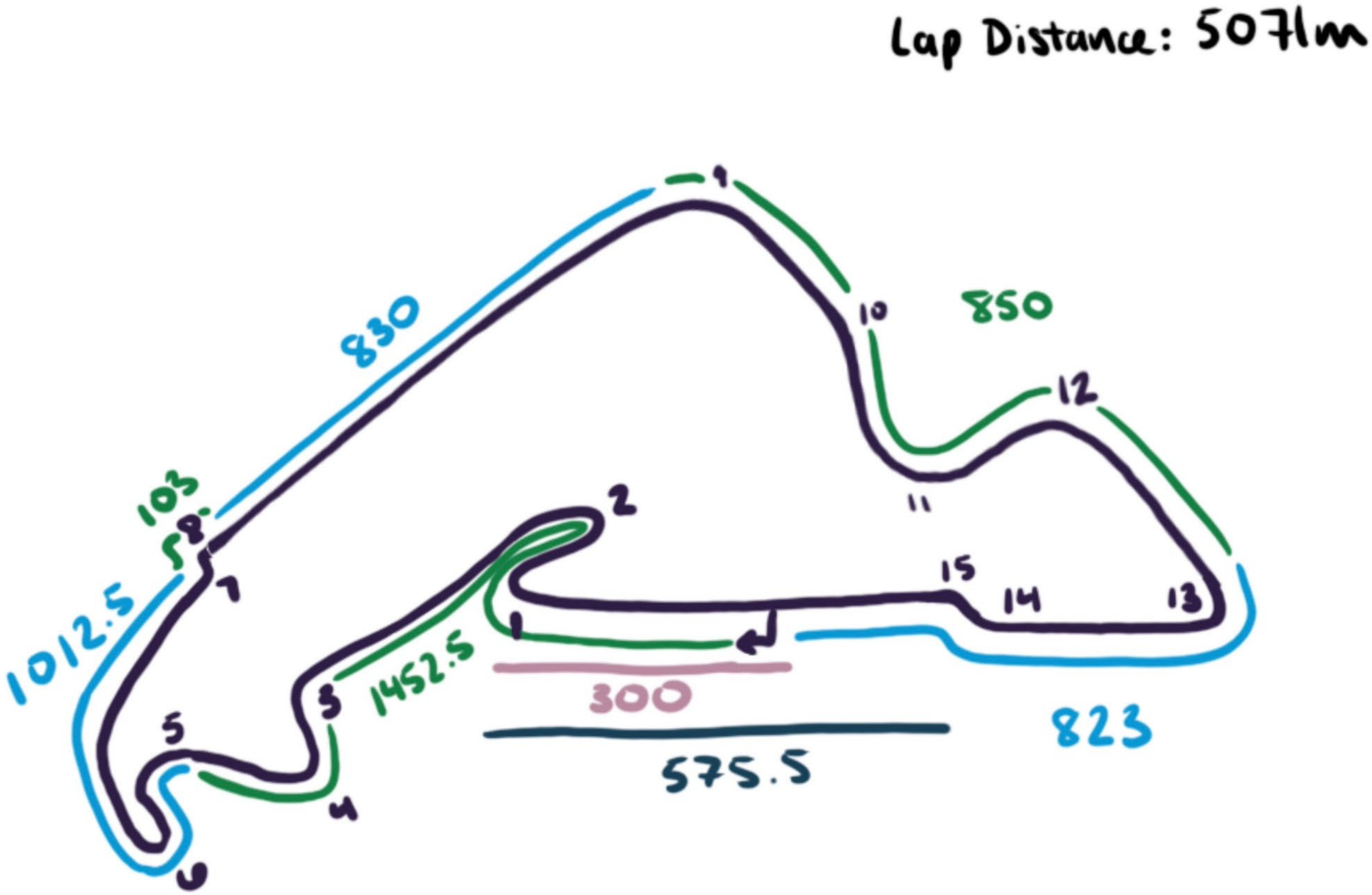

Figure 14: Rough circuit design following averages and turns of circuits from Table 3

Figure 15: Points indicating track layout that were input into the least cost path tool to generate Figure 16

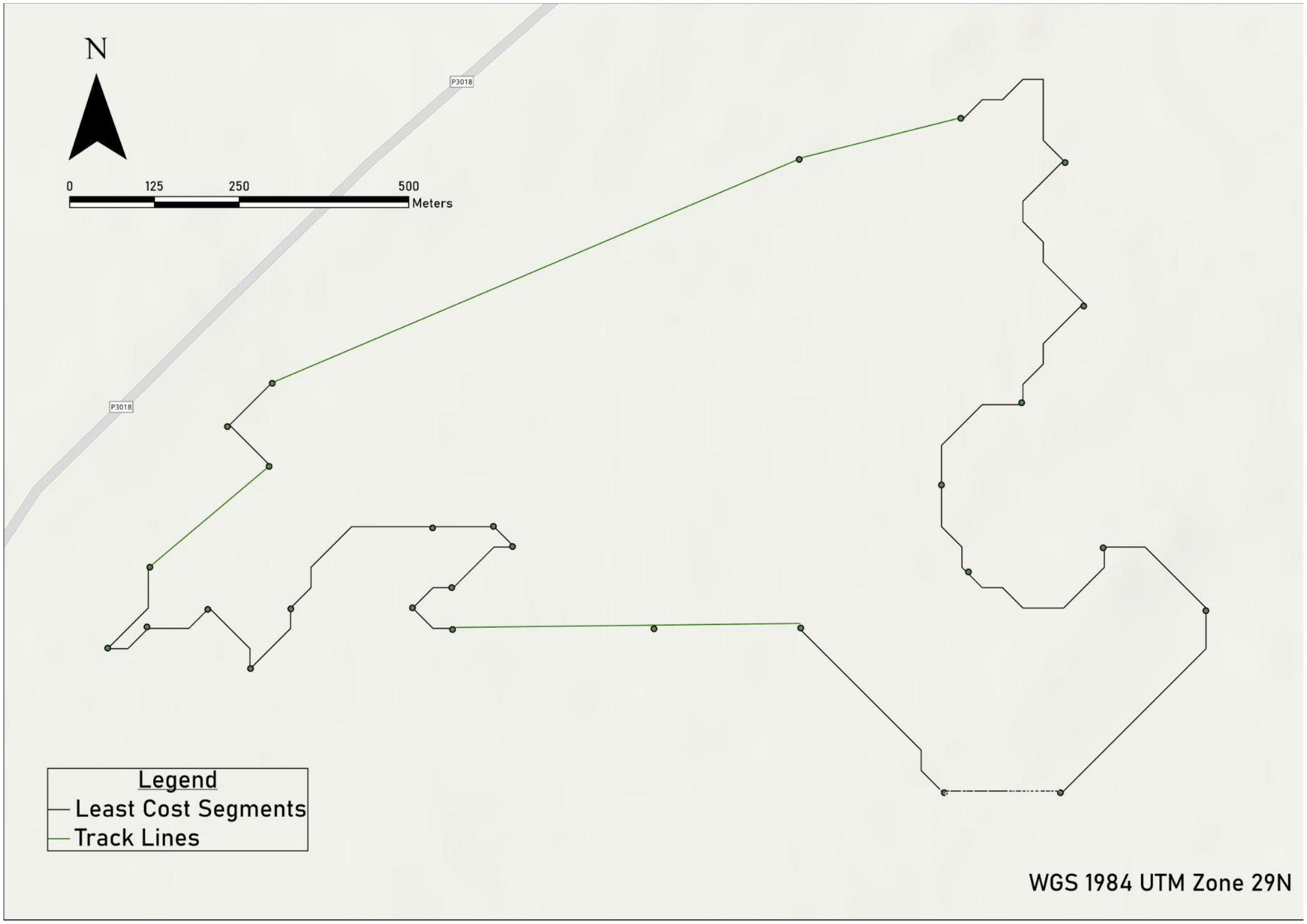

Figure 16: Track layout using least cost path tool to connect points using the most efficient path based on slope.