Project Initiation Document

MODELING WASTE FROM SPACE

| SYNTHESIS PROJECT 2020 |

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1 Introduction

Around the world more than 2 billion tonnes of municipal solid waste (MSW) are produced every year, one third of which ends up in illegal open dumps. The occurrence of open dumping is more prevalent in developing countries where proper waste management systems are not present. The lack of accessibility to waste management facilities may contribute to the disposing of waste in these open dumps that can cause public health and environmental issues. (Ferronato & Torretta, 2019; Kaza et al., 2018). Considering the high population and economic growth in developing countries, which results in an increased consumption and thereby an increase in the waste production, it is important that these countries improve their waste management systems in order to cope with the current and future amount of waste (de Souza Melaré et al., 2017; Kaza et al., 2018).

The waste management problems that many developing countries face are also present in Mexico, where more than 54 million tonnes of MSW is produced every year. It is expected that this will increase to almost 70 million tonnes in 2030 due to population and economic growth (Kaza et al., 2018). Although Mexico is an upper middle-income country, the waste management services are not equally administered and organised among different states and cities. Waste management services are only adequate in the capital, Mexico City, and certain other large cities. In these cities, 90 - 100 % of the total amount of MSW produced yearly is collected.(Kaza et al., 2018). In cities with less than 10000 inhabitants only 23 % of the MSW is collected. 143 cities do not have any waste management services (Semarnat, 2019). The cities with low or no coverage are primarily located in the poorest states, in the south of Mexico (Semarnat, 2019). According to the World Bank 21 % of all MSW in Mexico ends up in open dump sites (Kaza et al., 2018). However, the former Mexican Secretary of Environment estimated that the percentage of open dumping is around 70 % (MexicoNewsDaily, 2017). It can be concluded that the issues of the waste management system in Mexico are complex and not well reported.

As part of their commitment towards a sustainable environment the FEMSA Foundation asked the company 52impact to help them to comprehend issues regarding open dumping and waste management in Mexico. 52impact will provide them with a method to understand the complex dynamics of waste in this country. We will contribute to this method with our research project where the focus will be on the accessibility to waste management facilities and potential locations for investment in new waste facilities in Mexico. The aim of this project initiation document is to provide information for 52impact on the execution of the research project.

The project initiation document consists of six main sections: section two introduces the contributors to the research project, this includes the team itself and their supervisors. The problem definition will be discussed in section three, in which we will define the research question and the sub-questions. Section four will elaborate on the methodology of the research. The project planning will described in section five. Section six concludes the report with the Rich Picture of the research project.

2 Contributors

The team of this project consists of six TU Delft students from the MSc in Geomatics. The project is executed in cooperation with the company 52impact, who will also supervise us during the process. Furthermore, we have two supervisors from the TU Delft, Edward Verbree and Bastiaan van Loenen. In this section, the team members and client will be introduced and their separate roles described.

2.1 Team members

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Nationality: Dutch
Email: R.J.K.Ramlakhan@student.tudelft.nl
Background: BSc Clinical Technology (Delft University of Technology, Leiden University, Erasmus University Rotterdam).
Interests: Analysing spatial datasets, developing maps.

Vera Stevers

Nationality: Dutch
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Background: BSc Architecture, Urbanism and Building sciences (TU Delft). Minor as an intern at urban design company Urbis. Minor thesis about sustainability in urban planning and education.
Interests: Sustainability, environmental issues, GIS and cartography.

Nur An Nisa Milyana

Nationality: Indonesian
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Background: B.Eng Urban and Regional Planning (Gadjah Mada University, Indonesia)
Interests: Spatial planning and analysis, Spatial Decision Support System, Map visualization and design.

Ellie Roy

Nationality: British
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Background: BSc in Applied Earth Sciences (TU Delft). Minor abroad at ETH Zürich (Department of Earth Sciences).
Interests: Working with open-source data sets, developing automated workflows

Jialun Wu

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Background: Geographic Information Science graduate (China University Of Geosciences). Has completed a BSc thesis on spatial pattern of Relative Bearing Capacity of Jinan.
Interests: Visualization, GIS and cartography, Secondary development.

Quynh Doan

Nationality: Vietnamese
Email: DoanTrucQuynh@student.tudelft.nl
Background: BA Regional and Urban Planning (Ho Chi Minh City University of Architecture, Vietnam), MSc Sustainable Urban Development (TU Darmstadt, Germany)
Interests: Spatial analysis, Planning support system

2.2 Roles

In order to make the process of the project more organised and to spread the workload of the project more evenly we have defined roles for all of the team members. The roles are meant to give someone the responsibility to give directions and keep an overview of a certain part of the project. All parts of the project will be worked on with the whole team collaboratively, not just the team member in charge of that part.

- **Project manager:** Rohit Ramlakhan
  The project manager is in charge of leading meetings, keeping an overview of the work plan and making the agenda for meetings. Furthermore this person holds the other team members accountable to do their tasks and make sure they are finished in time.
- **Communication manager:** Vera Stevers
  The secretary takes care of contact with the client, supervisors and possible contact between members. The secretary writes notes of all the meetings, makes sure the notes are available to all members and puts all the planned appointments in the shared agenda.

- **Quality and process manager:** Nur An-Nisa Milyana
  The quality manager defines the desired quality of the results and reviews this during the project. Furthermore, as the process manager, they are in charge of the process of the project to make sure the desired result is achieved in time.

- **Report manager:** Ellie Roy
  The report manager defines the report layout and the standards used in the report. They also evaluate the quality of the report and act as the main editor.

- **Technical managers:** Jialun Wu and Quynh Doan
  The technical managers first of all define the the requirements for the data used in the project. They keep a general overview of the data collection and analysis. The second task of the technical managers is to take to define the framework in which the software development takes place. Since this is such broad task we decided to have two technical managers.

2.3 Client

The client of this project is 52impact, a Rotterdam-based company specialised in developing, presenting and commercialising geo-spatial data. The company focuses on sustainability and modelling future scenarios for a number of applications, one of them being waste monitoring (52impact, n.d.). Our supervisors from this company are Maurits Kruisheer and Thijs Perenboom. The supervisors will help us by giving feedback on the products that we create, and help us on the way to get a desired result. Furthermore they will provide us with the necessary data.

The topic of the project is given to us by 52impact who have been commissioned by the FEMSA Foundation. This foundation is established by FEMSA, a multinational beverage and retail company in Mexico which is also the largest franchise bottler of Coca Cola. The company has locations all over Latin America but their most important market is Mexico. The FEMSA Foundation has launched a long term commitment to tackle the problem of waste and reduce their impact on the environment. (FEMSA, n.d.).

3 Problem definition

The limited accessibility to waste management facilities in Mexico, may contribute to the disposing of waste in open dumps which can result in health and environmental issues. In order to develop solutions for these problems, our first objective is: *to research the accessibility of sanitary landfills and the prevalence of open dumps in Mexico.*

Considering the population and economic growth in Mexico, which results in an increase in waste production, it is important that Mexico improves their waste management system in order to cope with the current and future amount of waste. Investing in new waste management facilities can realise such an improvement. This leads us to the second objective: *determining potential locations for new waste facilities.*

3.1 Research- and sub-questions

The objectives will be achieved by answering the following research question:

Does the accessibility of sanitary landfills relate to the prevalence of open dumps in Mexico, and, based on this, where could investment be made to provide better access to proper waste facilities?

The research question is divided into two groups of sub-questions each corresponding to one of the two objectives of the research project.

For the first objective the following sub-questions will be answered:

- What are the main sources of waste and what are the waste disposal demands?
- What are the waste collection mechanisms in Mexico?
- Which areas have limited access to the current waste infrastructure system and are open dumps prevalent in these areas?
- Which other (spatial) factors could be the cause for open dumps?

For the second objective the following sub-questions will be answered:

- Which areas need investment in new waste facilities (i.e. what are the weak spots in the current waste infrastructure)?
- Which parameters and criteria should be used to identify potential locations for new waste facilities?
- What method should be used for the decision making mechanism to locate potential waste facilities?
- What is the degree of applicability and robustness of the model?

The approach used to answer these research questions will consist of a number of different aspects including: literature studies, data collection, data processing, spatial analysis and software development. The research methodology is explained in further detail in section 4.

3.2 Relevant courses from the MSc Geomatics program

The objectives stated in this section are relevant to certain courses in MSc Geomatics program. The courses GEO1001 and GEO1002 taught us what geo-spatial data is and how to access, interpret and analyse this data. We will be able to use this knowledge to achieve the first and second objective. During the courses of GEO1002, GEO1000, GEO1004 and GEO1015, GIS software and

Python were used. The experience and knowledge gained from using the software will be used to achieve the first and second objective and thereby to create the final product. In the course of GEO1009 we wrote a scientific paper. This experience will be helpful in writing the scientific report for this assignment.

4 Methodology

4.1 Research approaches

We have developed a number of research approaches in order to answer the research question and sub-questions. These approaches are explained in the following sub-sections and outlined in further detail in tables 1 and 2 for each objective respectively.

Research objective 1: To research the accessibility of sanitary landfills and the prevalence of open dumps in Mexico

- **What are the main sources of waste and what are the waste disposal demands?**
  For this project, we consider domestic waste from human settlements (both in urban and rural areas) as the main source of waste disposal. Industrial waste is hence out of scope. Our first task is thus to define where human settlements are located. By conducting some basic observations, we learn that it would not be reasonable to solely utilise administrative units as the input for spatial analysis. We should also consider the human settlement footprints (built-up areas) in parallel because, as shown in figure 1, the settlement footprints account for only a small portion of an administrative unit. Furthermore, it could be the case that a cluster of settlements belongs to more than one administrative unit (e.g. metropolitan) or that the domestic waste from the settlements of one administrative unit could be dumped in another area.

  The next step is to estimate the annual waste disposal demands from these human settlements. This output is a basis for further analysis on the capacity of the waste facilities. Our approach is to incorporate the data on population (by administrative units), the average waste disposal per person in Mexico and the settlement areas.

- **What are the waste collection mechanisms in Mexico?**
  The waste collection mechanism in Mexico plays an essential role in determining the nature of waste dumping. Through a literature review, we aim to determine whether organised waste collection is present at the household/neighbourhood level, via which domestic waste is transferred to waste facilities. Such services are often provided for urban areas but not always for rural areas. This means that individuals have to drive to the waste facilities to dump the waste themselves. Such an element, hence, will affect the later study in the relationship between travel time and the occurrence of open dumps.

- **Which areas have limited access to the current waste infrastructure system and are open dumps prevalent in these areas?**
  We will assess the spatial distribution of sanitary landfills and open dumps within a distance from the human settlement footprints to find out if the sanitary landfills meet the demands from the settlements and if the occurrence of open dumps is related to such a deficiency. We will also develop a travel time algorithm to quantify the accessibility of sanitary landfills. This will form the basis for identifying weak points which require investment in new waste facilities (further investigated in the second objective).

- **Which other (spatial) factors could be the cause for open dumps?**
  In order to provide a comprehensive approach towards the status of waste management in Mexico, we also look for other elements that could be the cause of open dumps by means of literature review and further exploration on the acquired data.

Table 1: Research approaches of first objective

Research problems	**Research approaches**	**In details**
Source of domestic waste disposal: human settlements	Define human settlement areas	If the data is not available, we can detect settlement footprints by mean of remote sensing.
	Define the demand for waste disposal	Using GIS to incorporate data on population, average waste disposal per person, and the settlement areas.
Waste collection mechanism in Mexico	Identify the way trash is being collected from households or buildings and transferred to waste facilities.	Literature review.
Accessibility to waste facilities	Identify the sanitary landfills and open dumps within a distance from the settlements.	Using GIS, create buffer-zones from settlement areas and define the waste infrastructure within.
	Study the distribution of sanitary landfills and open dumps.	Using spatial analysis tools, study the distribution according to number and sizes, according to directions (i.e. North, South from the settlement), according to settlement patterns (centralised urban patterns, decentralised urban patterns), and according to restricted areas (e.g. natural reserve areas, water bodies).
	Identify driving time/distance to the sanitary landfill and to the open dumps	Develop a travel time algorithm in Python and use the transportation network from Open Street Map (OSM) for estimation.
The relationship between human settlements and the waste facilities	The capacity of sanitary landfills and the demand from the settlements	Estimation of waste disposal compared to the quantity and the capacity of the sanitary landfills to identify if the underdeveloped landfills are causing open dumps.
	The distribution and the travel distance to sanitary landfills and the occurrence of open dumps	Using GIS, overlay the distribution and the travel zones to identify if open dumps occur in the directions that do not have sanitary landfills or the sanitary landfill located far away.

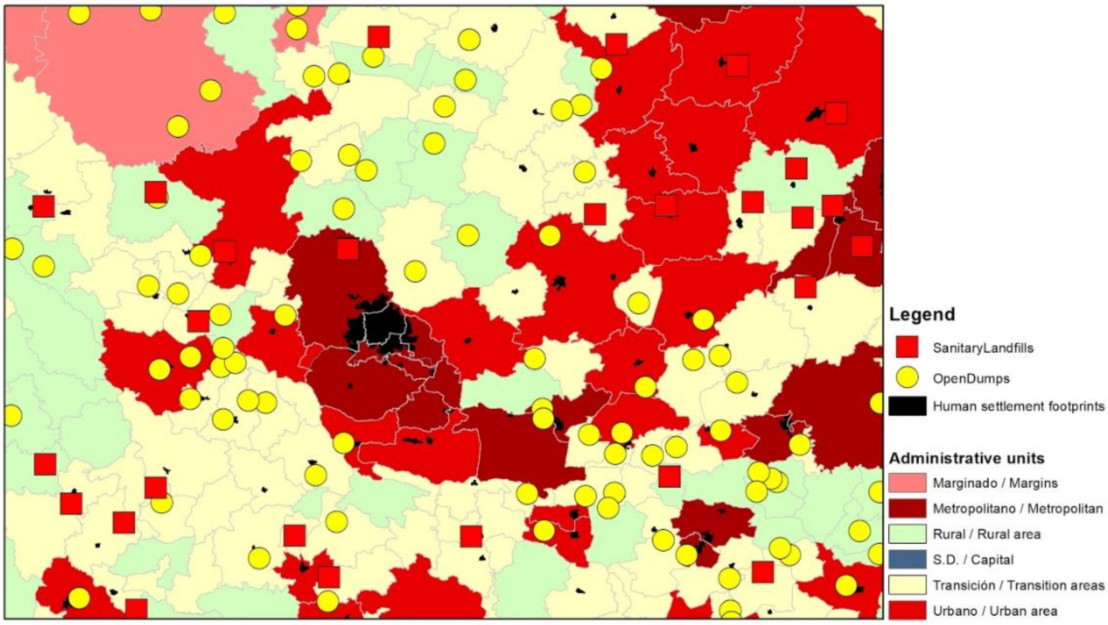

Figure 1: Example map of human settlement footprints, waste facilities, open dumps and administrative units in Mexico

Research objective 2: Determining potential locations for new waste facilities.

- **Which areas need investment in new waste facilities (i.e. what are the weak spots in the current waste infrastructure)?**
  The results from the first research objective already points out the areas in need of investment in waste facilities. However, development in infrastructure cannot be widely carried out, so a strategic investment development plan is needed. Therefore, we rank the areas that are in need of waste facilities regarding: (1) number and size of open dumps (the more open dumps, the more important it is to invest in waste facilities), (2) deficiency of sanitary landfills (the lower the capacity, the higher the level of importance), (3) the population growth rate and (4) the urbanisation rate (the higher the rate, the higher the level of importance).

- **Which parameters and criteria should be used to identify potential locations for new waste facilities?**
  To determine potential locations for new waste facilities, different environmental, social, and economic aspects should be taken into account. For example, groundwater at the waste facility site should be below a certain depth so that potential leakage from waste cannot affect the quality of the water. In addition, waste facilities should be located far enough from human settlements and not stand along a wind path towards urban areas. However, the waste facilities should not be located too far away from the waste sources, so that transportation costs are minimised and the sites remain accessible. Therefore, we will develop a set of criteria that guide the site selection in the latter steps based on literature reviews.

- **What method should be used for the decision making mechanism to locate potential waste facilities?**
  We will develop a spatial decision support system that first assigns weights for the criteria, then assesses the spatial condition based on the criteria, and finally incorporates different assessments to get the final results of the potential sites for waste facilities. We base our spatial decision support system on AHP (Analytical Hierarchy Process) approach, which is explained in further detail in step 5 of section 3). The methodology will be automated by combining Python scripting with QGIS (to potentially create a QGIS plugin).

- **What is the degree of applicability and robustness of the model?**
  In the end, we will assess our model in terms of its robustness and applicability. This will allow us to determine whether the result is still reliable with changes to the inputs, and to see if the research approach can be reused in another country context. For the robustness, we will employ a robustness test for a quantitative model. We will determine how to perform the robustness test from a literature review. For the applicability, we perform qualitative analysis on some other scenarios in other countries to see which aspects often need to be adapted.

Table 2: Research approaches of second objective

Research problems	**Research approaches**	**In details**
Weak spots	Locate areas that need investment in sanitary landfills with ranking (level of importance)	Using GIS and spatial analysis tools, produce a heat-map at the end.
Criteria/parameters for the potential locations	Develop criteria according to the regulation and guidelines from the Mexican government. Develop criteria according to researchers from the scientific community. Our own criteria according the findings from the previous step	Literature reviews
Process the criteria	Assign weight for the criteria	We'll try to find references for the weight. If it is not sufficient, we will employ the role playing decision-making game with 6 members of our group (or if possible with the clients and the mentors) to define the weight.
	Assess the spatial condition according to the criteria. Economical and social criteria are also transformed to spatially related criteria as much as possible.	Using GIS and spatial analysis tools. The product of this step would be a raster map for each criteria, that denotes suitable locations and unsuitable locations. The maps should have the same sizes and resolutions.
Define the locations of the new waste infrastructure with ranking.	Overlay the raster maps with weight produce in the previous step to get the final result.	Using GIS and the Analytical Hierarchy Process (AHP). For this step, we intend to develop a QGIS plugin that takes raster maps and the weight (per criteria) as inputs, and outputs a raster map of potential location.

4.2 Research methodologies

In this section, we explain in details the research methodologies mentioned in the research approach.

1. Literature reviews

To get a more in-depth understanding of the research topic and the situation of the research area, it is necessary to perform a literature study. This helps us to gain more insights and obtain important knowledge to support the research. Here are the main topics of literature that we will study:

- Overview on waste management, with a focus on the practices and challenges of waste management in developing countries.
- The current status and legal framework of waste management, with a focus on waste collection, waste disposal and waste treatment in Mexico.
- The parameters/criteria that needed to be considered when location a new waste facilities, and their level of importance.
- The GIS-based decision support system that incorporate the set of parameters/criteria/weight to identify the final location for waste facilities.
- Geo-spatial analysis and modelling in research and in practice.
- Python scripting for QGIS plugins.

The detailed list of literature can be found in the appendix (section 7.1).

2. List of tools

The main tools required for our research approach are listed in the table below.

Table 3: List of software

Demands	**Software**
System for processing spatial data	FME
Spatial analysis software	QGIS, ArcGIS
Application for computation and analysis	Python 3.7
Data analysis and producing graphs and charts	Excel

3. Data acquisition

In parallel with literature review, we establish a list of data need to be collected for (spatial) data analysis. The list is developed based on three main topics: basemaps, social-economy and environment. Then, we can explore these main topics into more detailed list of data (see appendix, section 7.2).

4. Data pre-processing

Before performing analysis, we need to implement the data pre-processing to make the data in a standardised format for analysis (e.g. same resolution). We will make sure the data are all in the same period and spatial extent. For example, we will clip the OpenStreetMap based on the extent of the datasets. Also, we will check the attribute of each point(the location/name/duration of use) and delete some points that are not satisfied with our data standard (i.e. we regard them as outliers).

5. Data analysis

5.1. Geo-spatial analysis

After data pre-processing, we need to conduct spatial analysis on the data. The current distribution of waste facilities can be analysed using basic geo-processing tools (buffering, intersecting, etc.) and spatial queries. For example, we use GIS software to create buffer-zones from settlement areas and define the waste infrastructure within. With more spatial analysis tools we can study the distribution patterns. Then we overlay the travel isochrones with the distribution area to see the Boolean operation (e.g. intersection) results by using spatial analysis tools.

The accessibility of sanitary facilities will be assessed by calculating the travel time from the data point (open dumps or sanitary landfills) to any location on the map. To achieve this, we will code in Python to calculate an isochrone map (travel time map) for every data point. A travel time algorithm will be developed in Python.

1. Create a street network graph and visualise it. We can use OSMnx Python library for street networks.

2. Determine travel time contours (isochrones) We define our data points as points of interest and select them as the start point of the travel. We set the distance and travel speed as user defined parameters.

5.2. Site selection

Using GIS and the AHP method (which is commonly used in site selection issues), we assign weights to our criteria for helping decision making. We define the criteria based on several factors that can impact the results, for example land use, soil type, etc. For different categories of data sets (economic/environmental), we will transform them into spatially related data to perform spatial analysis.

Regarding the AHP method, to combine all the impact factors together, we need to select the areas that are weak spots for lacking sanitary landfills. The Analytical Hierarchy Process (AHP) is selected among other multi-criteria decision-making processes because it provides the possibility to formulate the criteria in a hierarchical model. We will start by giving weights to the criteria through a pairwise comparison method to see which factor or criteria is more important than the other. Based on a scale of importance developed by (Saaty, 1987), we give a rating scale of 1-9 to form a decision hierarchy (see appendix, section 7.3). The weights are calculated by normalising the eigenvector associated with the maximum eigenvalue of the matrix. The sum of weights from all criteria should equal to 1. After this, we check the consistency ratio from the rating, and CR $< 0{,}1$ is considered as a reasonable rating of criteria, meaning that the weight has been assigned reasonably.

Based on this weight, we process our data into a rasterised map and also combine with the index overlay method to classify the condition in terms of the suitability for the landfill location (less suitable, moderate suitable, highly suitable). For example: we can create the index from the surface water network, the closer it is to the water then the location is less suitable. However, we recognise that the situation is different in urban areas and rural areas, so we will take this into account in the development of our algorithm. Moreover, we will automate the process by combining Python scripting with QGIS and potentially develop a QGIS plugin if time permits.

6. Product design

Finally, we will visualise the potential spots for new sanitary landfills based on the analysis. The final product consists of two parts:

- Main product:
  As per requirement from the client, the main product would consist of a written report and a package of intermediate products and the final map of potential locations for investment in new waste facilities. For the report, we will describe our approach towards the problem

in detail, explain the steps we took to conduct the spatial analysis for each subject and the decision making process using the AHP method (as explicitly as possible by means of workflows and descriptive text). For the intermediate products, we will deliver all spatial analysis maps, data analysis results in Excel worksheets and relevant Python scripts. The deliverable should be clear so that the client could reproduce the approach without further research.

- Automation of main product:
  If time permits, we will first try to automate the process of site selection in QGIS, and then try to further improve the process with a software using Python scripting. This software would consist of a spatial decision support system (SDSS) developed using QtCreator and Python. In other words, a processing tool to determine the suitable location of new sanitary landfills/or waste facilities. The automation software would take thematic raster maps as inputs (each raster map represent a criteria), and users can specify the weight for the criteria (we will also provide default parameters). For that, we can build a user-friendly GUI to help users interact with the software. The output are the map product that indicates the potential spots of new waste facilities. We hope to develop the software in the form of a QGIS plugin, which can be useful for future research.

4.3 Quality assurance

The quality assurance is done in two processes: during the analysis and after all information has been processed. During the analysis, there are several conditions that we check, such as:

- Check whether the data that we want to process meet the specification, for example: for the connectivity check requires a geometric network with connectivity rules.
- Check whether the final weight for each criteria meets the standard
- Check whether there are any spatial problems during the process of overlaying each criteria dataset.

After all the information has been processed, an accuracy adjustment should be tested to ensure the precision of the result. To do this, the modeling results are compared with the actual field situations based on satellite images and current issues of waste management in Mexico. From the actual situation, we should be able to indicate that the selected location will be acceptable with some percentage of error. We also analyze the limitations to see the replicability and the reproducibility of our final product by considering to what extent the process of the product design will still be valid or not.

5 Project planning

5.1 Work plan

In order to provide direction to the project, we have formulated a preliminary work plan. This work plan specifies the main phases of the project, the team member(s) leading each phase and the breakdown into smaller work packages. The phase leaders were chosen to correspond with the roles outlined in subsection 2.2. The role of the phase leaders is simply to provide direction to each phase of the project and to avoid the majority of responsibility being assigned to the project manager. All aspects of the project will be worked on collaboratively with the whole team, however some overlapping work packages may be divided between different group members to improve efficiency. Overall, all members of the team should dedicate 280 hours to the project, corresponding to 10 ECTS.

As shown in the Gantt diagram in figure 2, we have split the project into four main phases and assigned each work package an estimated duration and scheduled working period. Our plan is to complete the first objective of the project by the midterm review, so that we can focus on the second objective in the second half of the project. This will also allow us to define the depth of our approach for the second objective based on the feedback received for our intermediate progress. A brief description of each work phase is presented below:

Organisation phase

Phase leader: Ellie

- Setting up an online working environment to allow the team to work together despite all being at home. This included: (1) setting up a Google Drive to store meeting notes, references, data sets, etc; (2) creating a Discord server in which online group meetings can be held and (3) sharing an online repository on GitHub in which all code can be managed.
- Team and client meetings to define the scope of the research.
- Team meetings to discuss the overall plan for the project (e.g. the role of each member, the main objectives, outline of the research approach, work plan, etc).
- Scheduling of regular team and client meetings for the duration of the project.
- Creation of a project initiation document to provide an overview of the entire project, which will form the foundation for the project approach.

Research phase

Phase leaders: Vera and Asa

- Literature research based on information provided by the client and other relevant sources found online. The main topics covered by the literature review are: (1) general background on waste disposal in Mexico, (2) the methodology of similar research projects, (3) parameters and criteria that could be used to identify potential locations for new waste facilities.
- Technical research into (1) the structure and requirements of a spatial decision support system (SDSS) and (2) the use of Python scripting in combination with QGIS in order to automate the site selection process within a SDDS.
- Collection of data required for the spatial analysis and construction of maps (e.g. settlement footprints, administrative data on waste demands, road network from OpenStreetMap, data sets relevant for the site selection process such as soil type, land use, etc).

- Brainstorming and developing a framework for the methodology based on the literature research into the approach used by similar research projects.

Data processing and analysis phase

Phase leaders: Quynh and Jialun

- Pre-processing of data collected in the research phase to create raster maps with the same resolution.
- Construction of overlay maps for each site selection parameter (e.g. soil type, land use, groundwater depth, etc)
- Spatial analysis to determine the accessibility of sanitary landfills and the relation to the occurrence of open dumps (e.g. using buffer zones, spatial analysis tools and travel time algorithms). We will use this analysis to establish if there is any spatial correlation present and identify weak points in the waste infrastructure system.
- Preparation of a PowerPoint presentation and progress report for the midterm review.
- Development of the site selection process for investment in new waste facilities. The process will initially be developed manually in QGIS.
- Automation of the site selection process using Python in combination with QGIS to develop a spatial decision support system.
- Analysis of the results and assessment of the model developed (in terms of applicability and robustness).

Presentation of results

Phase leaders: Rohit and Ellie

- Writing the final report with the results and conclusions gained from the research conducted.
- Creating a presentation that displays the key points of the project (perhaps in video format).
- Presenting the project online.

5.2 Communication plan

For the project to be successful under the current circumstances, a good communication plan is essential. The project manager and communication manager are the main team members responsible for maintaining a good communication plan. However, all team members have a combined responsibility to be transparent in their communication and share their progress/any issues encountered with the rest of the group.

Online meetings

Team meetings will take place every Monday and Friday on Discord to discuss the individual tasks for the week and assess the intermediate progress. Furthermore, every Wednesday we will meet with our supervisors and the client via the SURF video conferencing platform. In these meetings we will present our progress and provide an overview of the tasks that we will be working on next. We will also discuss any challenges that we have faced, so that our supervisors can provide feedback and guidance. The project manager will compose an agenda for each meeting, which will be shared with all participants, including the supervisors, beforehand. This means that everyone

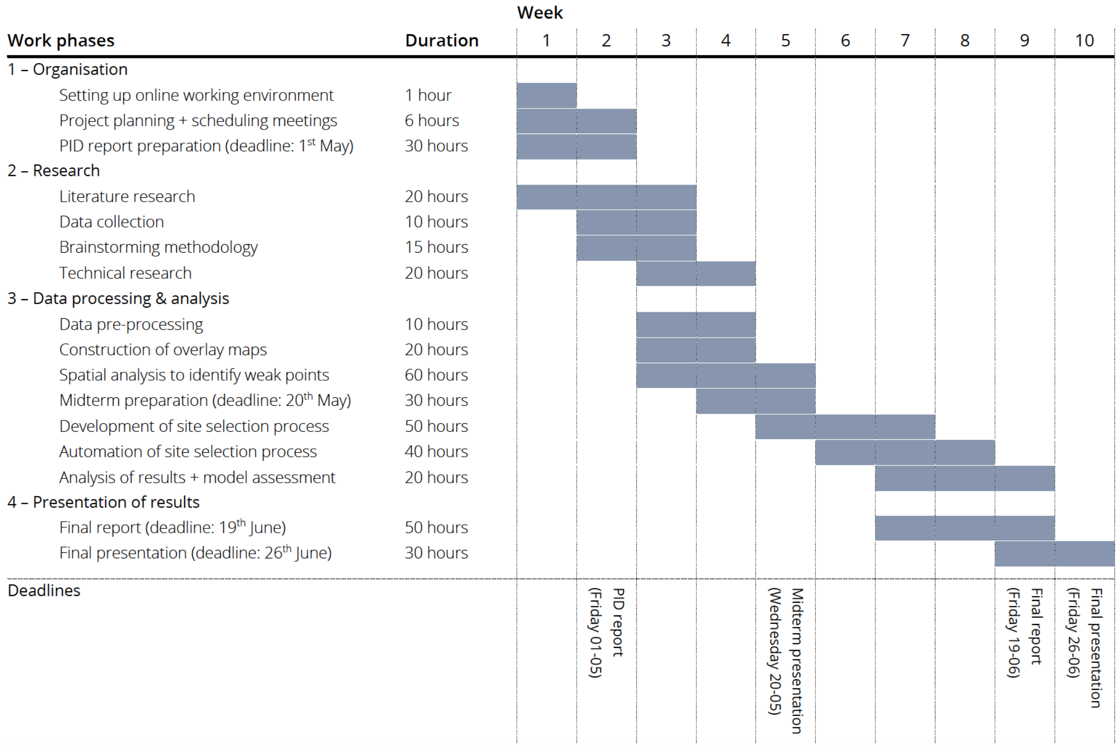

Figure 2: Gantt diagram of project work plan

has an overview of what will be discussed prior to the meeting and can provide suggestions for additional topics if necessary. Meetings are scheduled using a shared calendar so that all team members are kept up to date on when meeting will take place each week. In addition, during each meeting the communication manager will keep notes and track the current to-do's. The to-do's of each meeting will be discussed at the start of the next group meeting, so that we can easily assess our progress. The notes are shared with all team members via Google Drive (and, if necessary, with the supervisors via email). This ensures that everyone has a good overview of what was discussed and what their tasks are.

Other online communication

Aside from scheduling weekly online meetings, we have also set up other mechanisms to ensure good online communication. Firstly, a shared log file has been made to track all content added to the Google Drive (e.g. data sets, literature references, etc). This is mostly important for the research phase, so that everyone can keep track of the relevant literature and data sets collected by other team members. Secondly, the work plan has been converted into a shared spreadsheet so that we can refine the planning as the project progresses, incorporate new work packages, assign responsibilities and assess the status of each main task in a dynamic format (click here to view).

5.3 Overview of risks

As part of the project planning, it is important for us to be aware of the risk factors that may cause a delay or partial failing of the project, and to agree on a risk mitigation approach. The risks can be roughly subdivided into 3 main categories: those dependent on our research approach, internal and external factors.

1. **Based on research approach**

   - The parameter selection for the algorithm may lead to different potential locations for new waste facilities.

     Solved by: We will try different parameters and compare the results. Also, we look for scientific support for the selection of parameters to give a good result.

   - The selection of possible locations for new waste management facilities is influenced by many factors. It is difficult to define the degree of influence, the weight, the different factors have on the result.

     Solved by: We will analyse the weight (influence) of different influencing factors and build a scoring model to make the final choice

2. **Internal factors**

   - Drop out of team members due to for example illness during the Corona virus period.

     Solved by: We will follow the instructions of Dutch government and try to ensure personal safety. Also, everybody is involved in the tasks and we regularly assess the progress of the project as a group so, in case of illness, we could take over each other's tasks

   - Hard to communicate with clients, supervisors and group-mates during the current circumstances.

     Solved by: We create several chat groups for meetings and have well organised agenda for every week's meeting.

   - Computer limits and crashes.

     Solved by: We divide the work so that each person is responsible for processing data in different areas, split big mass of data-sets.

External factors

- Lack of data (with national coverage).

  Solved by: Look for smaller data-sets (cities, blocks) that have more data.

- Language barriers (Spanish).

  Solved by: We will use translators (e.g. Google Translate) to help us to read the literature and the website of Mexico. We will also consult some friends and teachers for helping.

6 Rich picture

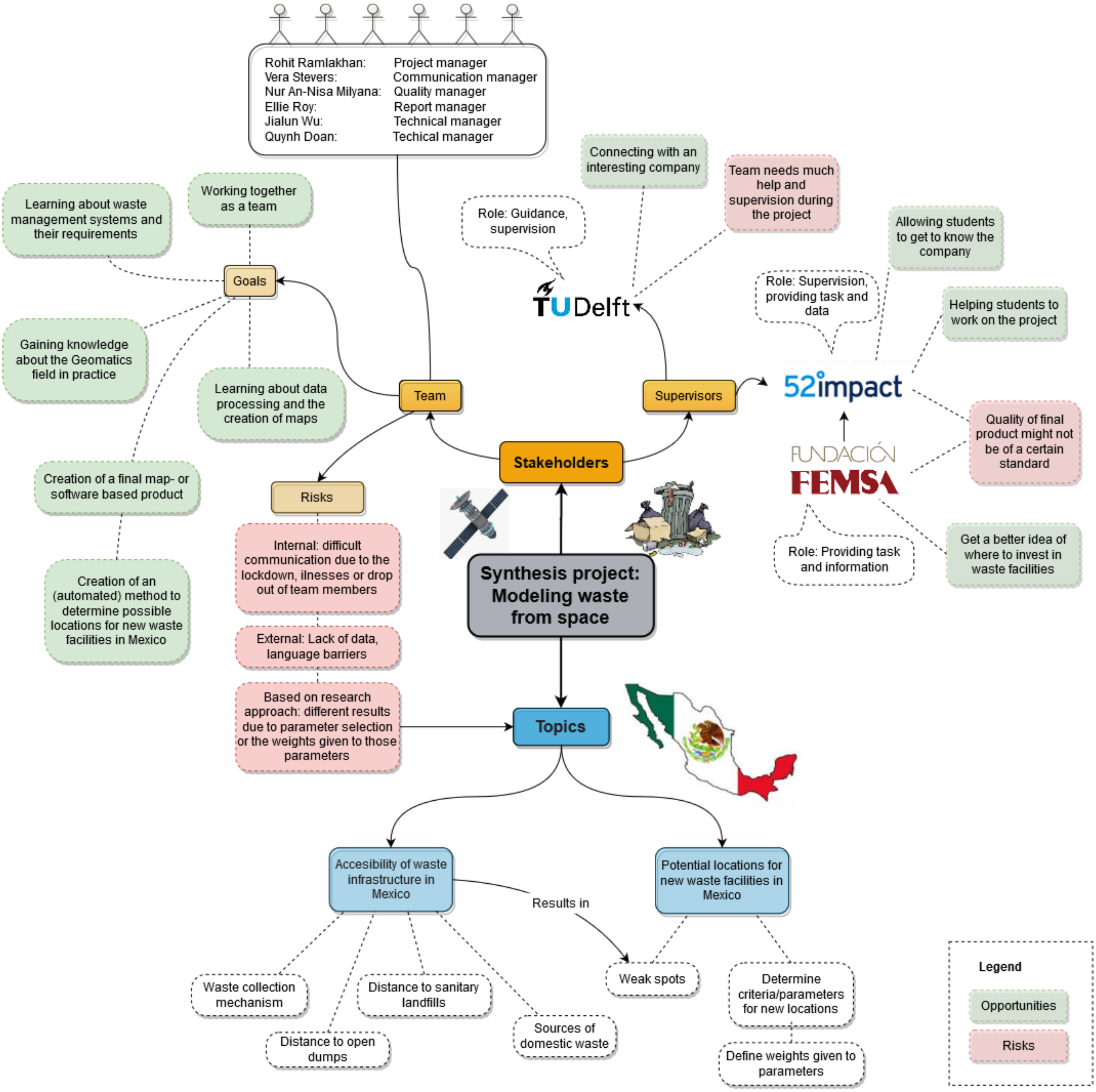

Figure 3: Rich picture

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7 Appendix

7.1 Appendix 1: Literature lists

Literature lists	Fields
Waste management system in Mexico : history , state of the art and trends(Ojeda-Benítez & Quintanilla Montoya, 2006)	General background on Mexico
Ley general para la prevención y gestión integral de los residous (Semarnat, 2013)	Regulation for criteria detection
Sustainable solid waste collection and management (Pires et al., 2018)	Waste management
Future scenarios of global plastic waste generation and disposal', Palgrave Communications (Lebreton & Andrady, 2019)	Waste management
Use of a geographic information system to find areas for locating of municipal solid waste management facilities (Colvero et al., 2018)	Spatial Analysis
GIS-based multicriteria municipal solid waste landfill suitability analysis: A review of the methodologies performed and criteria implemented (Demesouka et al., 2014)	GIS-based decision support system

7.2 Appendix 2: List of data

Data	Source
Location of open dumps and sanitary landfills	INEGI
Human settlement footprint	INEGI
Administrative boundaries	Geoportal of Mexico
Transportation network	Geoportal of Mexico
Natural reserve areas	Geoportal of Mexico
Surface water networks	Geoportal of Mexico
Groundwater depth	Geoportal of Mexico
Land elevation	Geoportal of Mexico
Soil Type	Geoportal of Mexico, INEGI
Land use	Geoportal of Mexico
Wind direction	(Not yet found)
Aerial imagery	INEGI
Population per administrative units	Geoportal of Mexico, INEGI
Population growth rate per administrative units	Geoportal of Mexico, INEGI
Urbanization rate per administrative units	(Not yet found)
National development plans (which areas are the focus for future developments)	(Not yet found)
Legal documents regarding waste management in Mexico	Government of Mexico - Website

7.3 Appendix 3: Scale of Importance

Intensity of importance	Definition
1	Equal importance
3	Weak importance of one over another
5	Essential or strong importance
7	Demonstrated importance
9	Absolute importance
2, 4, 6, 8	Intermediate values between the two adjacent judgements