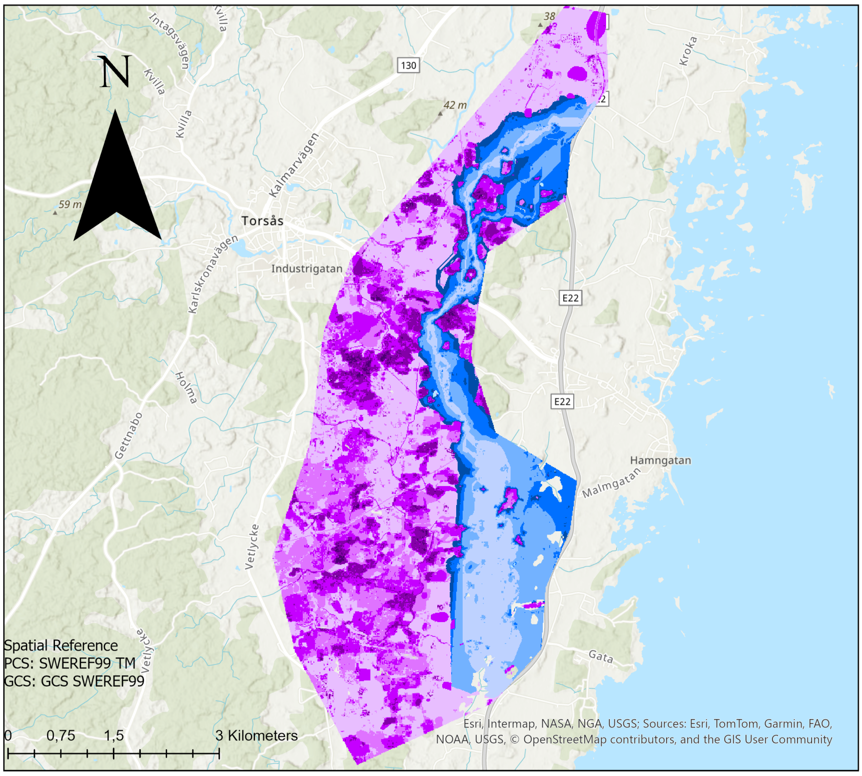

Enhancing geospatial tools through integration of climate data

A path toward more sustainable infrastructure planning and decision-making

Master's thesis in Master Programme Industrial Ecology

MIA ROSTÉN
VENDELA LÖNKVIST

DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2025
www.chalmers.se

Master's thesis 2025

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Supervisor: Ida Storm, Department of Digitization, Norconsult
Supervisor: Maud Lanau, Department of Architecture and Civil Engineering
Examiner: Holger Wallbaum, Department of Architecture and Civil Engineering

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Department of Architecture and Civil Engineering
Division of Infrastructure and Environmental Technology
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Cover: Result of weighting in Georaptor

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Department of Architecture and Civil Engineering
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Abstract

Climate impact is an important dimension in today's urban planning since the construction of new roads contributes to large emissions of greenhouse gases as well as environmental impacts on the ecosystem. One approach, part of the strategies from the action plan developed by governmental initiative Fossilfritt Sverige, to mitigate climate impact relates to increased use of digital tools of which includes different types of geo tools. The objective of this thesis is to investigate if climate data can be effectively integrated into a Geo tool and to evaluate its role in mitigating climate impacts in infrastructure projects. Furthermore, to analyze to what extent geo tools can support and streamline decision-making during the early design phase in infrastructure projects.

This study examines a route analysis planning tool named Georaptor using a weighting method called AHP. To determine whether the weighting method is effective in drawing conclusions based on climate data, a case study was conducted in the area around Bergkvara, Kalmar County. In addition, perspectives from previous projects, expert opinions, and comparisons between different weightings were analyzed. The result reveals that the tool is useful for analyzing where to construct a road in a given area, taking climate impacts into account. By identifying areas with high ecological value, it is possible to avoid sensitive areas and thereby reduce the road's carbon footprint and preserve important natural values. The tool helps streamline the decision-making process by quickly generating multiple corridor alternatives during the design phase, which can later be manually evaluated. This minimizes the workload and provides transparency, as both good and less favorable alternatives are compared.

Keywords: Digitalization, Geo tool, Sustainability, Environmental Engineering, Georaptor, Infrastructure planning, Climate data.

Förbättring av geospatiala verktyg genom integration av klimatdata
En väg mot mer hållbar infrastrukturplanering och beslutsfattande
Mia Rostén & Vendela Lönkvist
Institutionen för Arkitektur och Samhällsbyggnad
Chalmers tekniska högskola

Sammanfattning

Klimatpåverkan är en viktig dimension i dagens stadsplanering eftersom ny vägbyggnation bidrar till stora utsläpp av växthusgaser samt påverkar ekosystemet negativt. En av strategierna i handlingsplanen som utvecklats av det statliga initiativet Fossilfritt Sverige för att minska klimatpåverkan är att öka användningen av digitala verktyg, däribland olika typer av geoverktyg. Syftet med detta examensarbete är att undersöka om klimatdata kan effektivt integreras i ett geoverktyg samt att utvärdera dess roll i att minska klimatpåverkan i infrastrukturprojekt. Vidare analyserad i vilken utsträckning geoverktyg kan stödja och effektivisera beslutsfattande i de tidiga skedena av planerings- och designfasen i infrastrukturprojekt.

Denna studie undersöker ett ruttanalysverktyg kallat Georaptor, som använder en viktmetod kallad AHP. För att avgöra om viktmetoden är effektiv för att dra slutsatser baserade på klimatdata genomfördes en fallstudie i området kring Bergkvara i Kalmar län. Dessutom analyserades erfarenheter från tidigare projekt, expertutlåtanden och jämförelser mellan olika viktningar. Resultatet visar att verktyget är användbart för att analysera var en väg bör byggas inom ett visst område med hänsyn till klimatpåverkan. Genom att identifiera områden med höga ekologiska värden är det möjligt att undvika känsliga områden och därigenom minska vägens koldioxidavtryck samt bevara viktiga naturvärden. Verktyget bidrar till att effektivisera beslutsprocessen genom att snabbt generera flera korridoralternativ i designfasen, vilka sedan kan utvärderas manuellt. Detta minskar arbetsbördan och skapar transparens, då både bra och mindre lämpliga alternativ jämförs

Nyckelord: Digitalisering, Geoverktyg, Hållbarhet, Miljöteknik, Georaptor, Infrastrukturplanering, Klimatdata

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At Chalmers University of Technology, we thank our peers and our supervisor Maud Lanau who have provided us with excellent guidance and feedback. We also thank Holger Wallbaum for accepting the responsibility of being our examiner and for his valuable feedback.

Mia Rostén & Vendela Lönkvist, Gothenburg, June 2025

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

AF	Airborne Fraction
AHP	Analytic Hierarchy Process
BIM	Building information modeling
DOM	Dead Organic Matter
EIA	Environmental impact assessment
GIS	Geographical information system
IPCC	Intergovernmental panel on Climate change
MCA	Multi criteria analysis
MFA	Material flow analysis
SIC	Soil inorganic carbon
SLU	Swedish university of agricultural science
SOC	Soil organic carbon

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1
Introduction

The infrastructure sector faces challenges globally due to rapid urbanization, shifts in the geopolitical situation, evolving social priorities and climate change [17]. In Sweden the building and construction industry stands for 22% of the total emissions yearly which corresponds to 11,1 ton CO2 equivalents yearly and for which 12% comes from the infrastructure sector. There is an action plan developed by a group of different actors in the profession on the governmental initiative Fossilfritt Sverige of the construction and civil engineering sector. According to the action plan, reducing the impact of the climate in the building and construction sector, standardizing the use of digital tools and methods to increase transparency is essential to meet the goals of mitigating climate impact. Digital tools furthermore enables sharing knowledge and data between different actors and more specifically streamlines for example the use of different climate data bases and climate declarations. Meanwhile there are great opportunities to implement and increase the level of digital tools and routines in every part of the building phase, from start to the final stage, the planning and design phase has much potential of creating prerequisites to reduce climate effect during the rest of the life cycle of a construction. Including use of resources, streamlining the amount of transports, and potential errors that prolongs and incriminates the following phases.

Geographic Information Systems (GIS) and other Geospatial Tools (Geo tools) are digital instruments which can be used for studying the environment and help visualize, analyze, and understand spatial data[24]. Therefore, Geo tools are useful when it comes to functions such as interactive mapping and data visualization since the tools are useful for identifying trends, assessing risks, improve decision making and adapt to climate change. Developing Geo tools technology further is crucial so that researchers, professionals in infrastructure, and authorities like the Swedish transport administration (Trafikverket) can streamline their work and process data effectively. This development can also support more climate- and environmentally-friendly decision-making, enabling greater consideration of areas that store large amounts of carbon or are important for biodiversity. Today, tools that are used in this sense are for example Geokalkyl that is used by Trafikverket (the Swedish transport administration) for primarily analyzing masses for economical or environmental purposes. However, further development is crucial for enhancing the usage of Geo tools for sustainable infrastructure that can effectively tackle the challenges caused by climate changes and to reach environmental goals.

1.1 Background

Between the years of 1850-1900 and 2011-2020 the measured global surface temperature has increased with 1.09°C [8]. During the most recent 50-year period the global surface temperature has increased faster than any other period. Intergovernmental panel on Climate change (IPCC) has mapped out 2021 that the global warming will exceed 1.5°C during the 21st century and make it harder to limit warming below 2°C. Approximately 41.6 billion tonnes carbon dioxide was emitted 2024, there has been an increase of 2.4 % from last year [53]. Climate change is already affecting many weather and climate extremes in every region across the globe [8]. Between year 1901 and 2018 the global water level has increased 20 cm in average. Extreme weather events such as heat waves, heavy rains, droughts and hurricanes has increased and affects all regions of the world. The climate change affects vulnerable and poor groups the most. Today, approximately 3.3 to 3.6 billion people live in regions vulnerable to climate change. The IPCC report shows that global emissions need to be reduced significantly to avoid 1.5°C warming compared to pre-industrial times. Once this threshold is crossed, the risk of irreversible changes such as melting ice caps and rising sea levels and loss of ecosystems such as rain forests and coral reefs increases.

In the year of 2015 the world leaders agreed on the United Nations 17 global goals with purpose to reduce the climate impact globally [19]. The aim of these goals is to contribute to social, economical and ecological sustainable development. Some of these are relevant for the development of infrastructure for example goal 9 and goal 13. Goal 9 is focused to sustainable industry, innovation and infrastructure of which the aim is to build resilient infrastructure, promoting inclusive industrialization and encouraging new innovations. Goal 13 means to combat climate change where the aim is to take urgent action to mitigate climate change and its impacts. Furthermore, there is the Paris Agreement which is another goal that 196 of the world's countries are participating in [37]. The agreement states that the global temperature increase should be kept below 2°C and that efforts should be made to limit it to 1.5°C. The agreement includes strategies to increase the ability to adapt to negative effects and be able to take care of the damage and losses caused by climate change. Sweden adopted to a climate policy framework 2017 that include a climate law, climate targets and a climate policy council. At a national level, Sweden adopted a climate policy framework in 2017, which includes a climate law, climate targets and a climate policy council [44]. In addition, Sweden has set a goal of having net emissions of greenhouse gases into the atmosphere by 2045. This goal is furthermore divided into sub-goals, for example, that emissions in 2030 should be 63 percent lower than emissions in 1990 and in 2040, emissions should be 75 percent lower than emissions in 1990.

The emissions from Europe consist of mostly carbon dioxide (80 %) and methane (12 %) [15]. The infrastructure sector stands for about 22 percent of the total emissions of carbon dioxide due to its high demand of material usage, energy consumption and waste generation[17]. The action plan from the initiative of Fossilfritt Sverige, aims to reduce Sweden's climate emissions and presents several goals. By 2030, greenhouse gas emissions should be reduced by 50 percent and by 2040, greenhouse gas emissions should be reduced by 75 percent. By 2045, the construction and civil engineering sector should achieve net zero greenhouse gas emissions. To achieve these goals, some key factors have been identified. For example, continuing to increase knowledge of climate changes and continuing to work on technical development and innovation in order to achieve net zero emissions. Another key factor is to increase the digital information exchange about material and energy between the different actors in the sector.

Trafikverket has the responsibility for the construction, operation and maintenance of state roads and railways [2]. In 2022, Trafikverket's operations emitted approximately 1.5 million tonnes of carbon dioxide equivalents. Approximately half of the emissions from Trafikverket come from new investments, while the remaining comes from operation and maintenance and re-investments. There are opportunities to reduce climate impact in every part of the life cycle of infrastructure projects. The design phase offers the greatest opportunities, where measures to mitigate climate impact can be taken by conscious decisions of type of materials, volumes of material use, amounts of circular materials by evaluating possibilities of recycling and reuse of materials. Within infrastructure projects, decisions can be made such as carefully investigating the location for new constructions so that the climate impact is minimal. This can be done by avoiding areas such as peat and wetlands that store a high amount of carbon, but also by choosing a location where the amount of carbon from biomass and carbon from soil is low. It is also beneficial to consider locations with respect to potential amounts of additional filling materials, such as avoiding water passages and unstable soil.

1.1.1 Geo tools and technical frameworks

The technology of Geospatial tools (from now on called Geo tools) has been developed throughout the history from conventional maps and photographic interpretations to a big variety of instruments, thanks to the technical development of satellites and computers, including remote sensing, Geographic information systems (GIS), Global positioning systems (GPS) and internet mapping technologies such as Google Earth [1]. From mostly evolving within military use such as during the cold war, the last decade has brought rapid development for using Geo tools in a big variety of fields such as industrial engineering, biodiversity and agricultural monitoring. Most importantly, today there are large-scale climate datasets and API climate data which are available to public usage through Copernicus Climate Data Store, Climate Change Service (CCCS), Boverket, and the Swedish forest agency (Skogsstyrelsen) to name a few.

In recent years building information modeling (BIM) together with frameworks such as Life cycle analysis (LCA) and Environmental impact assessment (EIA) have increased as part of the strategies to reach the global and national goals of reducing emissions [10]. BIM which combines visualization through virtual and digital modeling systems with coordination between different interests is an effective strategy to acknowledge challenges early on in the project phase as well as presenting an early cost model of the material usage. While LCA is quite a complex framework EIA is a structured process which involves data collection of environmental conditions, consultation with local land use owners, municipalities and other communities to get a detailed view of consequences of any proposed project. Using BIM together with EIA means to visualize the project scenarios in virtual models which can help identify and calculate the risks. One technical method is to use GIS and other Geo tools to achieve the result. Geo tools can enhance the effects of a proposed project when environmental data is integrated and be helpful in decision making of material, methodology as well as different costs in terms of economical, social and environmental.

1.1.2 Environmental aspects

An important aspect of environmental sustainable development revolves around weighting different values, for an example considering natural values as a part of mitigating climate change. Carbon sinks are one of many natural values and it is defined as anything which absorbs more carbon from the atmosphere than it releases. Carbon sinks are important and should be carefully considered since they contribute to balance the climate of Earth [12]. Carbon sinks can for example be found in the oceans, soils, forests and fungi. Therefore, when planning for sustainable infrastructure, it becomes essential to consider this type of natural factors and to keep them intact to maintain the natural uptake of carbon in order to contribute to the continuous work of achieving climate goals, especially to keep global warming below the 2°C target. BIM, tools such as geo tools, modeling systems as well as frameworks such as environmental impact assessments can help streamline decision making processes that contributes to sustainable development and to reduce global emissions. Looking into different solutions of how to efficiently develop these tools is therefore vital in the sector of infrastructure.

1.2 Aim

This thesis aims to integrate climate and environmental data into a Geo tool and evaluate its role in supporting decision making to reduce climate impacts in infrastructure projects.

By developing data sets with layers that include climate and environmental data using GIS technology, this research will support companies involved in the profession of infrastructure to visualize and analyze climate and environmental aspects. The tool will enable users to access and interpret climate data without advanced technical skills. It provides a solution for people in the industry of infrastructure to better understand the environmental impact of their designs and decisions. Stakeholders such as clients, investors, and contractors can access the information and use it to make more sustainable choices in their projects. Leading to greater consideration of the climate and increased sustainable practices in the infrastructure industry.

1.3 Research questions

This thesis focuses on investigating aspects of the program Georaptor and suitable solutions for enhancing the perspective of climate and environmental data while excluding economic value and material usage. The report focuses primarily on Swedish infrastructure development with regulations and data from authorities, companies and earlier projects all based in Sweden. To reach the aim of this thesis the following questions were set to be answered:

- How can climate data be effectively integrated into a Geo tool for infrastructure development?
- How do geotools contribute to mitigation of climate impacts in infrastructure projects?
- How effectively do geo tools support and streamline the decision-making process to reduce climate impacts in infrastructure projects

Furthermore the report discusses how geo tools can be developed in the future and how they can continue to contribute mitigation the climate impact of infrastructure projects.

2

Theoretical Background

This chapter presents the theoretical foundation needed to execute this thesis. Background information about the relevant systems, tools and road building is brought up as well as the multi criteria weighting process which is used in this study. Georaptor, which is the main program used in this thesis, is described along with an example of how it has been used in previous projects.

2.1 Geo tools

This section briefly introduces the available Geo tools on the market to highlight strengths and weaknesses in order to clarify why GeoRaptor specifically has potential of making a difference in future infrastructure projects.

2.1.1 Trimble Quantm

Trimble Quantm is developed by Trimble and designed to find the most efficient alignment of roads, railways and other infrastructure projects from one location to another [51]. The tool is particularly valuable in the initial phases of infrastructure projects, as it offers rapid analysis that can guide later adjustments. Trimble Quantm combines GIS data, unit costs, and geometric parameters to be able to analyze the existing situation. It is focused to base its analysis of cost efficiency, environmental impact and resource usage. The tool calculates all the alternative routes in the ongoing project and compares different alignment alternatives in order to find the most optimal route. The tool has a CO2 calculator that forecasts carbon emissions from moving materials, preparing land, and building infrastructure projects along each proposed alignment. Furthermore, another advantage is the possibility of forecasting the CO2 emission from vehicles that will traffic the new infrastructure by calculating the flow of traffic, average speed and fuel consumption. Morover, there are indicators for noise that will affect surrounding communities.

2.1.2 Geokalkyl

Geokalkyl is a geo tool that was created together by ÅF (Afry) and Sweco on behalf of the Trafikverket[46]. The tool works as a complementary tool in early stages in the design and planning phase within infrastructure projects. The objective is to be able to compare alternative routes of infrastructure objects like roads and railways with a focus on geotechnical ground reinforcement and efficient earthworks management. The result of using the program is, at an early stage and without major preparatory work, a generated calculation with quantities and mass balance for the management of soil and rock. Furthermore a 3D facility model and soil layers showing land requirements and information on where additional geotechnical investigations needs to be carried out. Finally, a construction cost estimate is obtained where economic cost and climate impact are calculated from the inputs of materials and machines that will be used.

The advantage of Geokalkyl is that several alternative corridors can be compared and it becomes possible to identify where the greatest costs for earthworks and geotechnical reinforcement measurements arise [46]. This information opens up for improvements and the possibility of justifying the profile or for example to move the route horizontally to even out the mass balance and possibly minimize economic cost, energy use and carbon emissions. The tool also provides comprehensive information on where additional geotechnical investigations need to be carried out.

2.2 GeoRaptor

Route Analysis Planning tool and representation (GeoRaptor) is a geo tool developed by Norconsult which is used in infrastructure planning to provide information about route analysis for example roads, pipelines, power lines and fiber networks [36]. The focus is to determine the most optimal path between two points in a specific area and thereby finding the best solution to place new infrastructure. This is done along with the a large amount of geospatial input data which is up to the user to decide which to use.

GeoRaptor relies on a weighting method called analytical hierarchical process (AHP) which is a multi-criteria analysis (MCA) method and it is described in section 2.3 below [36]. By weighting different criteria based on, for example, environmental impact, cost and social impacts, the tool can create different alternative corridors where a road could be constructed. These different corridors can later be used in the design and construction phase to justify and make decisions about where to build a road. The input data is chosen by the user. Either it comes from Norconsults geodata catalog Geopangea or either local data or other geospatial data from other sources like authorities, which is specific for e.g., nature values, cultural values etc. The Geopangea catalog is continuously updated with data, therefore it works as a good base source. For the weighting process it is possible to weight different layers pairwise in datasets differently each time a new project will be conducted with GeoRaptor, which makes the output of most optimal route adjusted to whatever weighting criteria that any involved profession has decided for.

2.3 Analytical hierarchical process (AHP)

Analytical hierarchy process (AHP) is a multi-criteria method developed Thomas L. Saaty during 1970s for military use [6]. The purpose of the method is to simplify the process to decide on an alternative by creating a methodology to evaluate and compare different alternatives. It is widely used in different industries to solve complex problem and make decision-making more efficient.

The process can be divided into three processes, the first process is to create the hierarchical structure[6]. This is done by first defining the goal, it can for example be to find the best place for a new road. The criteria that are relevant to meet this goal are then decided for and placed in a hierarchical structure that has multiple levels. Higher-level criteria are subdivided into more detailed sub-criteria see figure 2.1. This structure helps to organize and understand the importance of each criteria. The second process is to assign each criteria a value from a scale from 0 to 1, where every level has a total number of 1. This is done by doing pairwise comparisons, each criteria is evaluated against each other to decide how much more important one criterion is compared to another. Comparisons are made at each level, but they are also compared with the other global criteria, which means that subcriteria 1 and 2 is first compared and then criteria 1 and 2 see figure 2.1. The result is a weighted number for each criterion that shows the importance of the criterion. The last and third process is to compare different alternatives to find the alternative that meets the goal the best, which in this case of Georaptor can be to find the best place for a new road. Two alternatives one in red and one in blue are shown in figure 2.1. Each alternative is evaluated against the sub-criteria through pairwise comparisons. The goal is to decide how good each alternative performs on each criteria with a number from 0 to 1. The weighting for each criterion together with the weighting for each alternative creates an overall score that shows which alternative best meets the end goal. The final result can be shown in different formats, for example as a list that ranks the different options or it can be a visualization that, for example, shows different options where to plan a route.

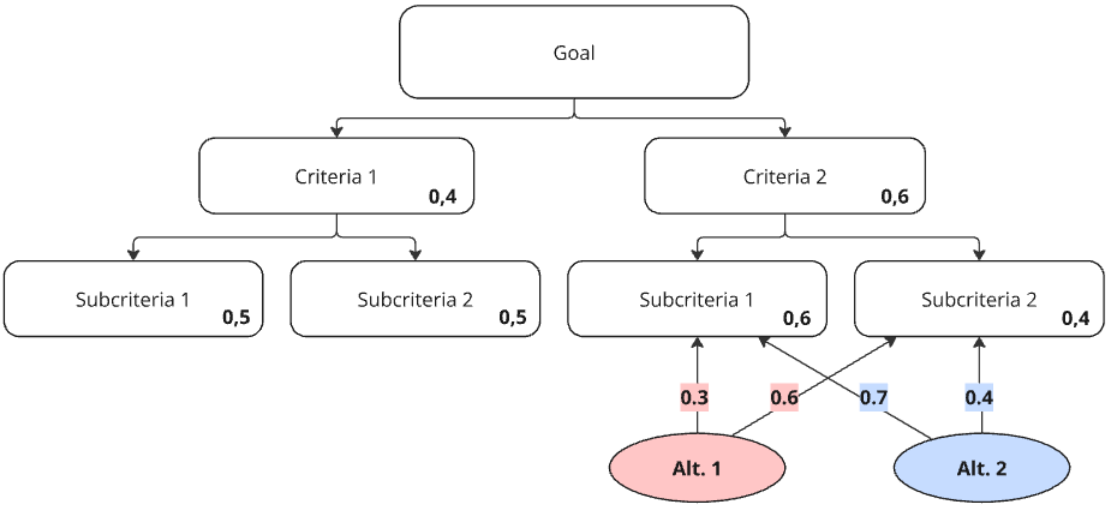

Figure 2.1: The figure is a simple example of how to subdivide different criteria that are included in the AHP and that will be weighted against each other.

This methodology helps decision-makers to do well-informed choices but also speeds up and simplifies the decision-process [6]. One of the most difficult challenges in defining criteria structures is avoiding contradictions. These can arise when comparing many different criteria with each other. For example economy can be valued the highest followed by climate impact and then nature value, see the figure 2.1. If contradiction arise it is important to reconsider the criteria structures.

2.4 Example study

To better illustrate how Georaptor can be used, a study is presented in this section. The study was carried out in the area of Riksväg 19, Härlöv – Karpalund [54]. Figure 2.4 illustrates the workflow, which began with acquiring data from the Geopangea database, along with complementary data from sources such as municipalities and clients. The next step involved selecting the most relevant data for the study. The data were then weighted and processed using GeoRaptor, which generated rasters showing visual representations, such as the location of areas, corridors, and route suggestions.

The weighting was done according to Analytical Hierarchical Process (AHP), explained in section 2.4 . The first step was to identify the most important criteria for the area such as soil depth or land use [54]. In this study the criteria were divided into 7 global criterion that has up to ten subcriteria. Thereafter, the criteria were weighted to each other pairwise to decide the relative importance of the criteria. Each criterion was assigned a number from 0 to 100, with the total weight of all criteria in each set summing up to 100. In this study, the weighting was emerged from several weighting workshops in which technical managers and experts in road design, environmental fields and permitting processes participated. They based the weighting on factors such as availability, feasibility and progress in the given area.

The weight criteria were then combined, creating a merged data raster. The raster consisted of pixels that are 1*1 m where the values of the weight criteria were shown. A low value means that the pixels are more suitable for construction and a high value shows that the pixels are less suitable for construction.

The resulting merged data raster was then possible to be used for locating areas, show alternative routes and create corridors, see figure 2.2 [54]. Locating areas means finding an area with as low cost as possible. (Cost refers to the same as weight criteria and is based on as before factors such as availability, feasibility and progress in the given area). When Georaptor determines a corridor, the pixels are merged into one continuous length and in this way different corridors can be created. The cost is calculated for all the possible corridor options and Georaptor present the corridor within twenty percent from the lowest cost.

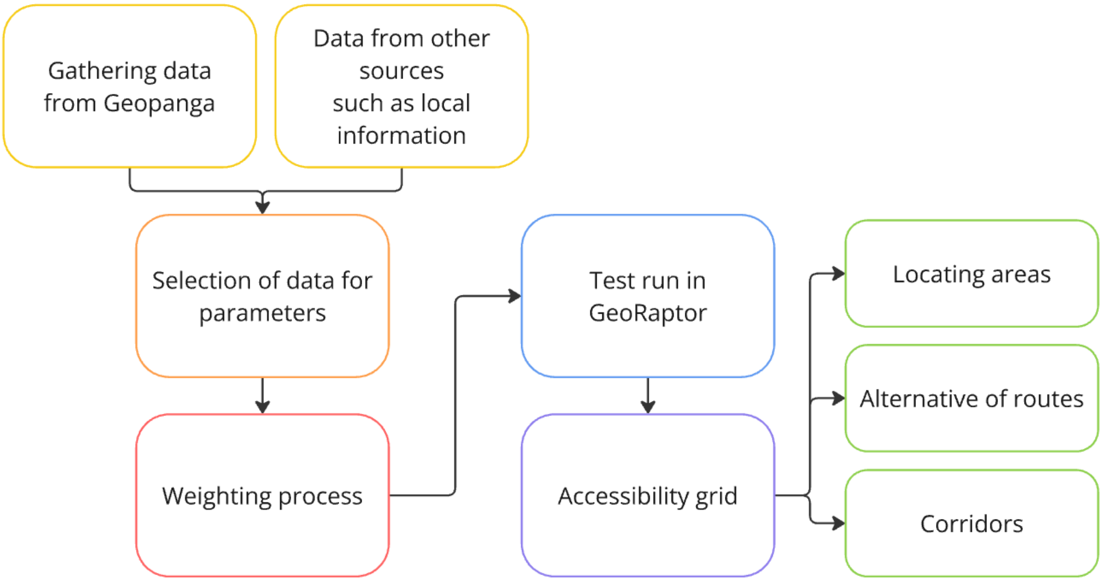

Figure 2.2: The figure shows the workflow of the study conducted in the area of Riksväg 19, Härlöv – Karpalund.

2.4.1 Weighting process in Georaptor

The weighting process in Georaptor is, as earlier disclosed for, formed as an AHP. Data of interest is uploaded and datasets will be created of the different data layers. The layers must then be weighted which is structured as follows. The global criteria, local criteria and sub criteria are selected by preference of the user. Georaptor also includes a feature called NOGO. The term "No go" is used as the term to describe where the corridor wouldn't be able to cross meaning that specifying a criterion as NOGO, Georaptor is prohibited from cross the criterions pixels and create a corridor through these pixels. A NOGO object could be a house, a wind turbine, or a protected area. All the different hierarchy levels of criteria are weighted against each other separately except from the NOGO criterion. This process is performed through answering how to weight subcriteria against each other which Georaptor asks for. Figure 2.3 presents an example of what the alternatives might look like and furthermore the user must answer the same questions for each and every hierarchy level of criteria, meaning the number of alternatives also will vary with how many layers which are chosen as subcriteria. The program provides a question as following, "Are roads more suitable for construction than powerlines?" and several options appear in order, and the user should pick the alternative which suits the situation the best.

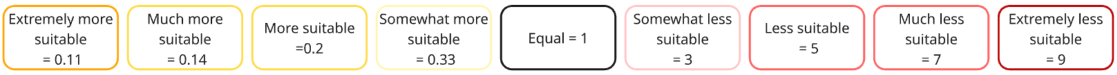

Figure 2.3: The figure presents the alternatives the user can choose between in the weighting process.

2.5 Road design and building

This thesis investigates Georaptor with regards to the planning and design phase in the process of construction of infrastructure due to support the decision making which can be done earlier to avoid different costs. Therefore, this process and a description of important aspects to consider while constructing a road is explained in this chapter. Figure 2.4 shows an overview of the different processes in general.

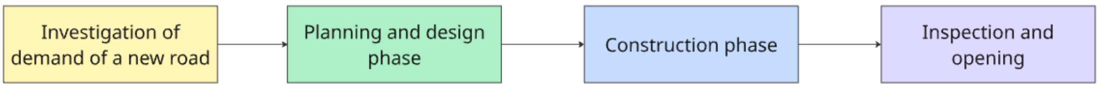

Figure 2.4: The figure show an overview how the process of constructing a road can look like.

2.5.1 Analyze of current situation

Trafikverket is responsible for the planning, building and maintenance of governmental and public roads in Sweden [47]. To reach agreement on what should be built, when, and where, a lot of communication has to be run by different municipalities, the county administration, public transport services, local communities, and other authorities. Depending on the demand the responsible actor, they can decide to choose to make a smaller change which consists of adapting the current situation to a more optimal solution which could cover measures like streamlining the existing infrastructure or smaller reconstructions. However, sometimes a complete new construction is inevitable to meet the demand of a growing population, transport system or to meet safety measures.

2.5.2 Planning & design

The fundamental information which is needed to start planning for a new road covers environmental, social, technical and legal aspects [48]. This includes a complete survey of the area which is of concern which normally is concluded of parameters such as geotechnical (soil type, soil depth, type of vegetation, rocks, watercourses etc.), traffic load (e.g., annual average daily traffic), local interests (cultural, social functions, natural values etc.), current situation of infrastructure (buildings, power lines, power plants, railroad etc.) and nature (red listed species, protected areas and vegetation etc.). All of the aspects are important since it relates to the corridor of where to place a road. In general, this type of information can be provided by for example municipalities or the county administration board (Länstyrelsen). However, sometimes further investigations are needed to examine the area through for example an EIA.

The different characteristics will affect the corridor of the new construction [48]. Depending on local circumstances the possibility to construct nearby or in the same exact location might vary in terms of safety, protected species and areas as well as legal and economical aspects. Buildings, forests, water courses, existing infrastructure, arable land etc. are all aspects of the land use that will be affected by a new construction. There are different challenges that follows the new construction which regards permission to build, ability to construct, different land owners and costs in terms of removing existing construction, ground and vegetation.

The measures regarding the ground for road construction is dependent on the type of soil. A simple classification can be found in descriptions of requirements by Trafikverket where there are 6 different where 1 is the best alternative and 6 is the worst [49]. These classes identify the different measures that need to be taken during construction due to variations in grain size and material type, which will lead to different levels of settlement. The division of classes can be interpreted as follows: 1 - rock, 2 - gravel, 3 - moraine, 4 - clay, 5 - silty clay, 6 - silt and organic material. Organic material decomposes quickly and therefore leads to settlements beneath the construction, which is undesirable. In contrast, rock provides a stable base and does not cause such settlements. The varying ground conditions require different measures such as thickness of layers in the embankment including filling material, bearing and non bearing materials, reinforcements etc.

Cultural and natural values need to be considered early in the project phase. Cultural values for example may hold great historical values and may require permission from Länsstyrelsen or Riksantikvariet to be moved or when placing constructions nearby[27]. Natural values such as water protected areas, protected species, and other areas which have cause to be preserved also needs consideration or if possible to be avoided. Specific local attributes like areas of Natura 2000 or contaminated areas might exist in the area of interest. Natura 2000 consists of areas which are protected by chapter 4 and 7 in Miljöbalken. Contaminated areas demands for testing the ground and for potential sanitation of the area, this could be areas close to e.g., factories, sawmills or hospitals.

In general, the planning process demands for a lot of cooperation between experts on many fields which can be architecture, water and sewerage, landscaping, electricity and lighting, construction etc. [50]. Effective communication is essential for the involved considered components such as bridges, tunnels, pavements, service pockets, passing places, wildlife crossings, ditches, natural habitats and road furniture like fence or barriers. Helpful strategies and tools are key for the interplay so that arising issues can be accommodated such as Building information systems like Autodesk Civil 3D, modeling programs like CAD or Geographical information systems like ArcGIS or QGIS [10]. The planning phase usually consists of the common goal to present legal documents which is directorial when it comes to function, building materials, property negotiations and safety during building phase etc. [50]. In some cases there might be necessary to seek permission for some of the measures that will be made. For example infringement on private properties or protected areas .

2.5.3 Construction, inspection and opening

The building phase includes parts such as demolition, deforestation, blasting works, removing earth, building the new embankment, terracing the construction and additional constructional work. Depending on the conditions of the area different measures are needed to construct the road [50]. In addition, measures must be taken to ensure compliance with environmental regulations, construction safety, and constructional requirements from the entrepreneur and the client such as Trafikverket. [47]. Regular controls must be performed to ensure the requirements are met as well as finding anything to report such as unexpected leaks of chemicals, deficiencies in the construction, dangerous conditions, failures of machines etc. Furthermore, the finishing part of the construction consists of the equipment for the road which includes road painting, road signs or traffic lights etc. as well as restoring of the area such as vegetation and surfaces. When the construction phase is complete inspections of stability, deficiencies in the construction (such as cracks in the paving or damaged components) are executed [50]. Whenever the inspections are ready and necessary fixes have been made and the client has given its approval, the road is ready for opening.

2.6 Carbon stock and flows on earth

As earlier stated in section 1.1 approximately 41.6 billion tonnes carbon dioxide was emitted 2024, which means an increase of 2.4 % from last year [53]. To deal with the increasing amount of carbon dioxide in the atmosphere, carbon sinks such as biomass, soil and water play a crucial role. To further investigate the relationship in terms of human activity and the natural processes, the following section is clarifying carbon flows on Earth and where carbon can be stored and more specifically the existence of carbon in forests since the selected area in the case study are rich in forested areas. This furthermore demands for an understanding of inventories of carbon which is executed annually with multiple inventories that takes into account the carbon stocks in the ground and in vegetation. The process is described in section 2.6.2 and 2.6.3. The carbon stocks can be divided into carbon in biomass and soil carbon that include both Dead organic matter (DOM) and Soil carbon.

2.6.1 The carbon cycle

The carbon cycle describes how carbon circulates between carbon stocks in the atmosphere, biosphere, hydrosphere and geosphere. Figure 2.5 shows a simplified overview of the carbon flows and stocks on earth where the circles represent different carbon stocks and the rectangular shapes represent processes where the carbon is transformed through different chemical processes between the carbon stocks. The carbon cycle is a closed system, meaning that the total amount of carbon on Earth always remains the same, even though it is transformed through various chemical processes [9]. However, human impacts are disturbing of this balance. For instance, according to Canadell 2007, Carbon released 155 years ago through deforestation to convert land for agriculture could yet be present in the atmosphere or stored in the ocean.

On the left in 2.5, the important exchange of carbon, water, glucose, oxygen and energy occurs through the interaction between photosynthesis and cellular respiration [52]. This specific process is essential because carbon is captured from the atmosphere and is stored in the biosphere by living organisms which together form biomass [34]. When the biomass dies, it becomes dead organic matter (DOM), which then decomposes in the soil and carbon stocks in soil (SOC) is created. SOC is stored and compacted over long periods of time, eventually forming geological carbon reserves. The stored carbon can later be released through human actions such as oil extraction or natural events such as volcanic eruptions or changes in land use that contributes to the release of carbon dioxide into the atmosphere [33]. Human activity affects the carbon cycle in various other ways as well. For example through changes in land use or deforestation in order to create new landscapes or for the production of building materials and products. Materials and products in its end of life phase are in turn, incinerated which releases carbon into the atmosphere. However, recycling of carbon within products and materials slows down the use of carbon which is illustrated on the right in the figure.

Human activity that contributes to carbon dioxide emissions creates imbalances in the carbon cycle, causing more carbon to end up in the atmosphere than natural carbon stores can absorb. In the recent years the fossil fuels in the atmosphere have increased which can be seen through analyzing the airborne fraction (AF) which is defined as atmospheric carbon dioxide divided by total carbon emission from fossil fuels and changes in land use[3]. From 1959 to 2021 the AF has increased from 0.42 to 0.48 which indicates for an increased amount of carbon in the atmosphere. Meanwhile the AF has only increased 6 %, the increase in AF have been suggested to be explained by the fact that sequestration by the sea and atmosphere might have turned less effective. Therefore, counteracting an increase in the AF and hence global warming it is important to lower emissions of carbon but also to keep natural carbon sinks like forests intact [9]. Globally since 1850, an estimated 31% of fossil

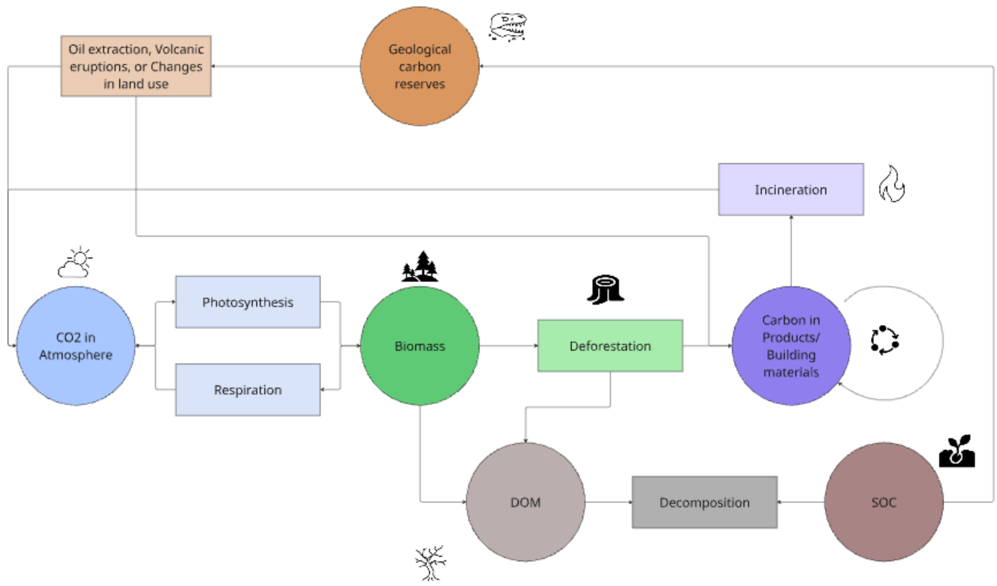

Figure 2.5: A simplified overview of the carbon flows and stocks on earth

fuels emissions have been stored in the terrestrial carbon sink [18].
Forests are considered important carbon sinks since they absorb and store carbon in both vegetation and soil. The total volume of trees in the different areas is a measure of how much carbon dioxide the trees have absorbed, as well as an indicator of the amount they are expected to absorb in the future. The amount of carbon which is stored is however somewhat challenging to determine, see section 2.6.3 and 2.6.4. Approximately 45-60 % of forest carbon stocks are stored in the soils according to Swedish University of Agricultural Sciences (SLU) [45]. However, according to Skogsstyrelsen the soil stores two thirds of the total carbon stocks in forest [40]. These slightly different numbers can be explained by variation in composition of biomass [55]. A realistic range of distribution would be somewhere in between 35-55% in aboveground living biomass and 45-65% in soil carbon. Methods to calculate for the carbon in forests and to make inventories for the carbon in soils are compiled in the chapters below.

2.6.2 Carbon stocks in biomass

The Swedish University of Agricultural Sciences (SLU) conducts riksskogstaxering, which means that they measures the forest and land use across Sweden periodically every fifth year[13]. Riksskogstaxering is carried out by Lantmäteriet (the national mapping, cadastral and land registration authority in Sweden) that uses laser scanning on forest lands with aircraft, and with help from SLU's sample data, various data can be estimated in the area such as the volume of forest per hectare or the biomass tons of dry matter per hectare. The carbon data from the inventory are later presented by Skogstyrelsen and are displayed as maps with raster of size

10*10m [39]. The data which represent the forest volume includes the entire trunk of trees above normal stump height as well as the top as bark in the unit m^3/ha. Branches, stumps and roots are not included. The forest volume varies from 0 to 830 m^3/ha. On average for Swedish forests, one cubic meter of forest corresponds to a total biomass of 750 kg dry weight, which includes the trunk with bark, branches, needles, stumps and roots [4]. 50% of the biomass is assumed to consist of carbon [32].

2.6.3 Carbon stock in soil

Inventories of soil carbon has been done by the SLU on behalf of the nature conservation agency (Naturvårdsverket) of Sweden [29]. The data from the inventories are presented with maps where both dead organic matter (DOM) and soil carbon are included in the pixels which have a resolution of 10×10 meters. The carbon stocks data in mineral-rich soils on natural pastures and in peat soils are obtained from the soil inventory conducted by SLU. [31]) The soil inventory is a sampling program where samples of soil chemistry are analyzed and its carbon content is calculated. The carbon stocks in the soil carbon and organic humus layers of mineral forest soils has been mapped and measured by Hounkpatin et al., [23]. This was performed according to an algorithm by Random Forest together with other types of data describing qualities of the soil and topography as well as geochemical data etc. The carbon stocks that are not covered by Hounkpatin mappings are instead represented by the average values obtained from the soil inventory done by SLU. The data of carbon stocks in the living biomass, dead wood, coarse silt and annual silt is collected from Riksskogstaxeringen. The riksskogstaxering is an inventory program of forests and land use in Sweden and carries out sample inventories across Sweden in a systematic network [38]. In the DOM carbon pool, dead wood, litter, and organic humus layers are included which exist in different land types and areas. For example, humus layers are found on mineral forest soils outside wetland areas. The humus layers consists of organic material in various stages of decomposition. The different substances form a somewhat dark, organic matter in the soil, typically found in the upper horizons of a soil profile, but do not constitute a uniform material group.

How much carbon the soil can store depends on what the land is used for, whether it is forest, peatland, open land or arable land. The average carbon stocks on mineralogical forest soil in organogenic humus layers in Kalmar County goes up to 21,400 kg C ha-1 and in the soil carbon pool 66 386 kg C ha-1 [29]. In total, the soil carbon in forests of the area goes up to 87 786 kg C ha-1. The peat stock is measured to a depth of 50 cm and goes up to 280 433 kg C ha-1 in average. The carbon stock in the grassland is 90 700 kg C ha-1 to the depth of 50 cm. The arable land consist of a carbon stock of 98 328 kg C ha-1 to a depth of 25 m and 40 438 kg C ha-1 between 25-50 cm, which in total adds up to 138 766 C ha-1.

When using different data from inventories of volumes of biomass there can be overlapping in different inventories which makes it difficult to calculate precisely the carbon content in areas [41]. For example Riksskogstaxeringen separates Natural pasture while SLU includes Grassland in Open field lands which are much large areas that includes several types of land use[42]. This represents one of the challenges of calculating carbon stocks.

2.7 Qualities which determine carbon stocks

The forest plays a crucial role in storing carbon as described in section 2.6. How much carbon soil and biomass can store depends on different factors. For soil carbon, influencing factors are for example pH and moisture and for biomass, influencing factors are for example age and wood density. The following section also describes what happens to the carbon in the forest when a road is constructed.

2.7.1 Soil carbon

The soil carbon can be divided into two types, soil organic carbon (SOC) and soil inorganic carbon (SIC)[14]. SOC is defined by carbon stored in soil within organic matter, for example plants, roots, animal waste, microbes and microbial byproducts. Soil inorganic carbon (SIC) is defined by carbon stored in soil within mineral forms as carbonates, for example calcite (CaCO3) or magnesium carbonate (MgCO3). Soil organic carbon has a maximum carbon capacity; when the soil is saturated with carbon, there will be an excess of carbon available for decomposition [26]. The soils ability to store and stabilize organic carbon is dependent on the composition and structure of the soil. A soil that consists of a higher proportion of cations such as Ca^{2+}, Al^{3+} and Fe^{3+} is better at creating strong bonds with organic compounds. Soils that are composed of more limestone, have higher pH and have better conditions to stabilize organic carbon because of calcium ions (Ca^{2+}) that can create bonds between soil particles and organic molecules. Soils that contain more iron ions (Fe^{3+}) and aluminum ions (Al^{3+}) have lower pH, these ions form organo-metallic complexes with organic carbon and in this way carbon is protected from decomposition. This leads to the carbon becoming less available for decomposition. A more stable soil has less carbon degradation. Soil structure that has low porosity, i.e. pores smaller than 5 µm, limits oxygen and microbial emergence and thus decomposition

Furthermore, pH affects how much carbon that is stored in the soil [30]. A pH above 6.2 contributes to increased microbial metabolism, which in turn leads to increased carbon sequestration. This can be explained by the fact that microorganisms use organic material to build up their biomass, which contributes to the formation of more SOC. A pH lower than 6.2 causes microbial metabolism to decrease because they do not thrive in acidic environments. Reduced microbial metabolism contributes to less organic material being broken down, which means increased SOC. In the long term, plant growth decreases with a lower pH, which leads to less supply of organic matter and in turn leads to reduced SOC.

Soil moisture also has an impact on how much SOC is stored. Dry soil inhibits microbiological metabolism, which reduces the decomposition of organic matter and more SOC is stored[20]. In the long run, lack of moisture leads to reduced new organic matter and thus reduces the total long-term SOC. Wet soil lacks oxygen, which inhibits microbiological metabolism and its decomposition of organic matter. This means that much organic matter remains untouched and stores carbon. Moderate soil moisture contributes to increased microbiological metabolism as the conditions for photosynthesis are optimal. More organic material is then broken down and forms more microorganisms, which results in increased biomass and more SOC. In this process also some of the carbon is released as CO_2. The total SOC is dependent on the inputs of organic matter from plants and the losses from microbial respiration. Another factor which is important to note is that peat is a source of methane as it is released through anaerobic decomposition of organic material under oxygen-poor conditions [25] In summary, the long-term positive benefits from carbon dioxide storage exceed the methane emissions that are formed as a by-product of peat formation.

Soil inorganic carbon (SIC) is stored in the soil primarily in the form of calcium carbonates such as calcite (CaCO3) or magnesium carbonate (MgCO3) [16] Carbonate formation is a balanced storage form and is more common in drier areas. The carbonates neutralize acids and thus raise the pH value in the soil. In short, SIC is found in drier soils with higher pH around 7-9.

2.7.2 Biomass carbon

Forest is one of the biggest carbon sinks in the world's land ecosystems. 70-90 % of the total global amount of biomass exists in forests and the rest can be found in for example sunken land and open land [22]. 70-90 % of the biomass in forest is located above ground and the rest is located below ground in the form of roots, microbial, organism or degraded plant matter. The aboveground biomass, and thereby also the aboveground carbon stocks, is much more sensitive to disturbances such as land use change, natural disasters and other landscaping psychological and metabolic changes. This can happen due to human behavior like harvesting forests and natural disasters like fires, storms, diseases etc. Therefore, soil carbon exist in much higher quantity, about 2-3 times more, because of the stable conditions in comparison to aboveground biomass.

How much carbon a forest can store is dependent on tree species and their wood density and life span[11] but also factors like tree composition and age. In general, older and therefore larger trees absorb carbon dioxide at a higher rate than younger and smaller trees. A tree's carbon uptake accelerates year by year and typically reaches its peak after around 25 years. After this point, the rate of carbon sequestration decreases slightly but remains high for many years. As a result, clear-cut areas do not hold the same carbon value as mature forests, since it takes many years before newly planted trees reach their full capacity to sequester carbon [5]. In addition, mature forests that are more intact offer additional ecosystem services, such as greater potential to support biodiversity and regulation of water flow to improve water quality [7].

There is a difference between tree species in terms of their ability to store carbon. This is due to that different tree species use factors like sunlight and nutrients that are crucial for photosynthesis in different ways[11]. Tree species with low wood density often grow faster than a tree with high wood density which enables more rapid early carbon uptake. However, because its wood is less compact, it contains less biomass and therefore less carbon per unit of volume. In contrast, trees with high wood density grow more slowly and live longer, but store more carbon per unit volume due to their denser wood structure. Certain combinations of tree species can store more carbon than others. When combining tree species that grow tall with those that spread out in width allows the forest to capture sunlight more efficiently at different levels, making better use of the available light for photosynthesis. The tree species also affect the amount of carbon in the soil, for example some leaves decompose quickly while other leaves decompose slowly. In addition, different trees have different root systems and thus differ in how much carbon they can store.

2.8 Impact on soil carbon during road construction

Carbon in the soil is more difficult to recreate than biomass that can be replanted. During road construction, vegetation and the top layer of soil are removed and the remaining ground is shaped to fit the road[21]. The changed soil structure, where the top layer that stores the most organic carbon is removed, meaning that the soil's carbon is exposed to oxygen and large amounts of carbon can be oxidized to carbon dioxide. It takes a long time for new organic material to build up under a new road. This can lead to road construction contributing to the long-term loss of soil carbon and thus increased carbon dioxide emissions. A new road construction can change the flow of water through the landscape and change groundwater levels. The new road can also act as a drainage path, which can lead to increased runoff or water saturation in adjacent land. The changed water flow affects ecosystems and can contribute to the drainage of wetlands, the increased oxygen supply accelerates the decomposition of organic carbon, which contributes to the release of carbon dioxide and potentially nitrous oxide[35].

3
Method

To be able to answer research questions of this thesis an analysis of relevant background information, existing studies, similar tools and technical foundation had to be established. This thesis was carried out in different phases which is visualized in figure 3.1 below. First, the purpose and research questions were formulated, then a literature review was made to establish theoretical foundation, understanding and knowledge for the thesis background. For further understanding of the data which is used as input to Georaptor, other GIS programs such as ARCGIS and QGIS was used for analyzing and interpreting data attributes. Furthermore, an external analysis was made to lay foundation for how the Geo tool is used today and for how the process of designing and building infrastructure projects are carried out in the profession. In addition, interviews and a case study was carried out. Interviews were conducted with people in the profession to help uncover specific needs and challenges related to the future of digital Geo tool within infrastructure projects. With deeper insight, design and function can be forwarded to system developers for improvements of Geo tools which can meet with the expectations of future users.

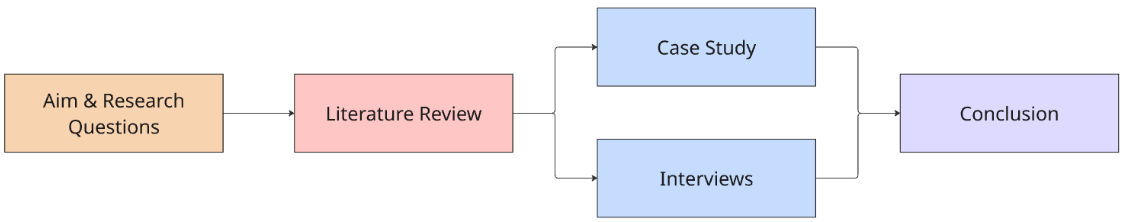

Figure 3.1: Overview of the method of this thesis

3.1 Case study

The case study was conducted in an area in the south part of Kalmar county, where a new road already has been planned for [27]. Trafikverket has conducted a location study to determine where the most preferable location of the new road would be. The area where a road is already planned was chosen because it would offer an interesting viewpoint of comparison. Ultimately, it will be possible to evaluate whether the road had been planned differently when the climate aspect is taken into account.

The road E22, which is one of the major roads that make up the infrastructure network in Sweden, passes through the community of Bergkvara. The speed limit through Bergkvara is 50 km/h, however this specific part of the road represents one of the few remaining sections of road that has been considered to pose a risk to both passing and crossing people, as there are insufficient measures in place to separate passing traffic. This implies for a higher risk of accidents for passing vehicles as well as unprotected road users such as pedestrians and cyclists. Furthermore, the busy road leads to disturbances for residents of Bergkvara in the form of noise and vibrations. Due the current situation, Trafikverket was commissioned to carry out a location study to determine which route is most suitable for a new section of the E22. Trafikverket's study was based on a multi-criteria analysis. Below in the figure 3.2 the result from location study can be seen. The most suitable alternative for the road corridor is shown in yellow.

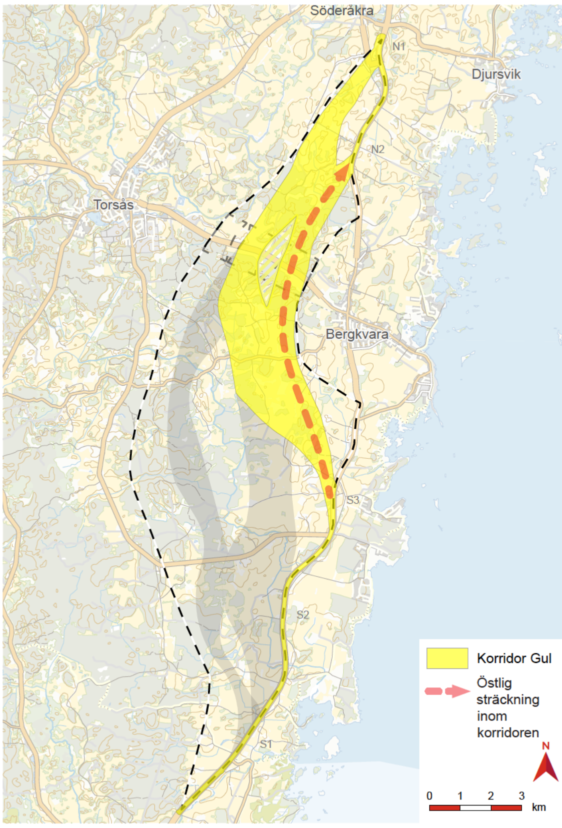

Figure 3.2: The figure was produced for Trafikverket's location study [27]. The yellow corridor shows the most preferred route for the new road section of the E22 and the red dashed line shows the eastern road section within the yellow corridor.

The case study was established through the program Georaptor and the area that was studied was clipped the same as in Trafikverket's study see figure 3.3. The area around Bergkvara consist of two landscape types, Agricultural landscape to the east and mosaic landscape to the west [27]. The agricultural landscape consists mainly of farmland that is divided by tree lines, stone walls and grasslands. The soil type is mainly moraine and sandy moraine, but also smaller amounts of glacial sediment, peat and clay. The mosaic landscape consists of a mixture of woodland, pasture, natural pasture and cultivated grassland. The soil type consists mainly of moraine but also smaller amounts of clay, silt and peat. Within this area, there is a water protection zone. The current section of the E22 road passes through this protected zone, which covers approximately 131 hectares. The water source previously supplied the towns of Bergkvara, Torsås, and Söderåker, but today these towns receive their water from Kalmar. This change was made due to issues with the water's quality and quantity. As a result, the wells have served mainly as backup sources for the past ten years. Moreover, some potential contaminated areas were identified, for example a plant nursery, a textile industry and a sawmill.

There is also a Natura 2000 area near Bergkvara that consist of a traditional hay meadow covering 0.8 hectare. Natura 2000 aims to protect and preserve this valuable natural habitat and its interconnected plant and animal ecosystems, as the hay meadow is one of the few remaining in the region. Moreover, there are two key biotopes in the area, one consisting of protected coniferous trees and one consisting of protected deciduous trees however there is no legal protection. These areas were identified by Skogstyrelsen and hold special importance for the forest's plants and animals. In the area around Berkgvara, a cultural heritage management landscape can be found that shows what economic development looked like from the Iron Age to the present. There is one historic building in the area, an old mill. Several ancient monuments can also be found in the area.

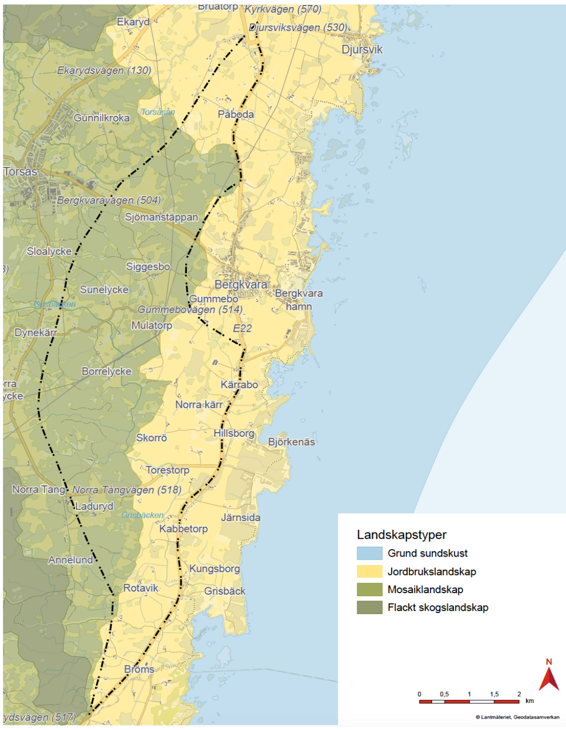

Figure 3.3: The figure is taken from Trafikverket's location study [27]. It shows how the area for the new road section of E22 consist of two landscape types, agricultural landscape in yellow and mosaic landscape in the lightest green. The blue represent shallow coastal strait and the darker green represents flat forest landscape.

The number of global criteria and the weighting were based partly on previous projects that have been done with Georaptor as well as the specific study previously done in the area by Trafikverket. The criterion selected were Land use, Soil type, Natural environmental factors, Cultural environment and NOGO. In addition, to investigate the environmental perspective, a criteria named Climate was included to enhance the result of climate effect when planning for the new road. The global criteria would also be divided into local criteria and sub criteria.

The criteria was later included in the weighting process that is designed as an AHP where the weighting is performed pairwise depending on the qualities that is decided as more or less important when it comes to the situation of the corridor where, potentially, a road will be built. The weighting was performed by the authors of this report. The output from Georaptor is a map where each and every pixel is a result from the weighting, which means that a corridor will be possible to draw through the map. This output allows for comparison of different scenarios and determination of the most favorable location for road construction, taking into account factors such as the highest carbon sink potential or the lowest material use. Finally, a comparison was made where the global criteria were weighted high versus low to broaden the perspective on how the climate criteria affect the corridor.

3.2 Data collection

The criteria requires data from several data sources. Mainly, the corresponding database GeoPangea, which Norconsult has developed, was used for collecting layers of data. The Geopangea database was used for the global criteria Land use, Soil type, Natural environmental factors, Cultural environment and NOGO. Some data was gathered from authorities and companies. Data for biomass carbon was collected from Skogstyrelsen [28] and the data for soil carbon was collected from SLU [43], see section 2.6 and 2.7. Altogether, the collected data which was selected as important for the output of the study was integrated in GeoRaptor. The AHP in Georaptor gives the opportunity to subdivide in three levels. The figure3.4 below illustrates the structure of the Global criteria, Sub criteria and Local criteria.

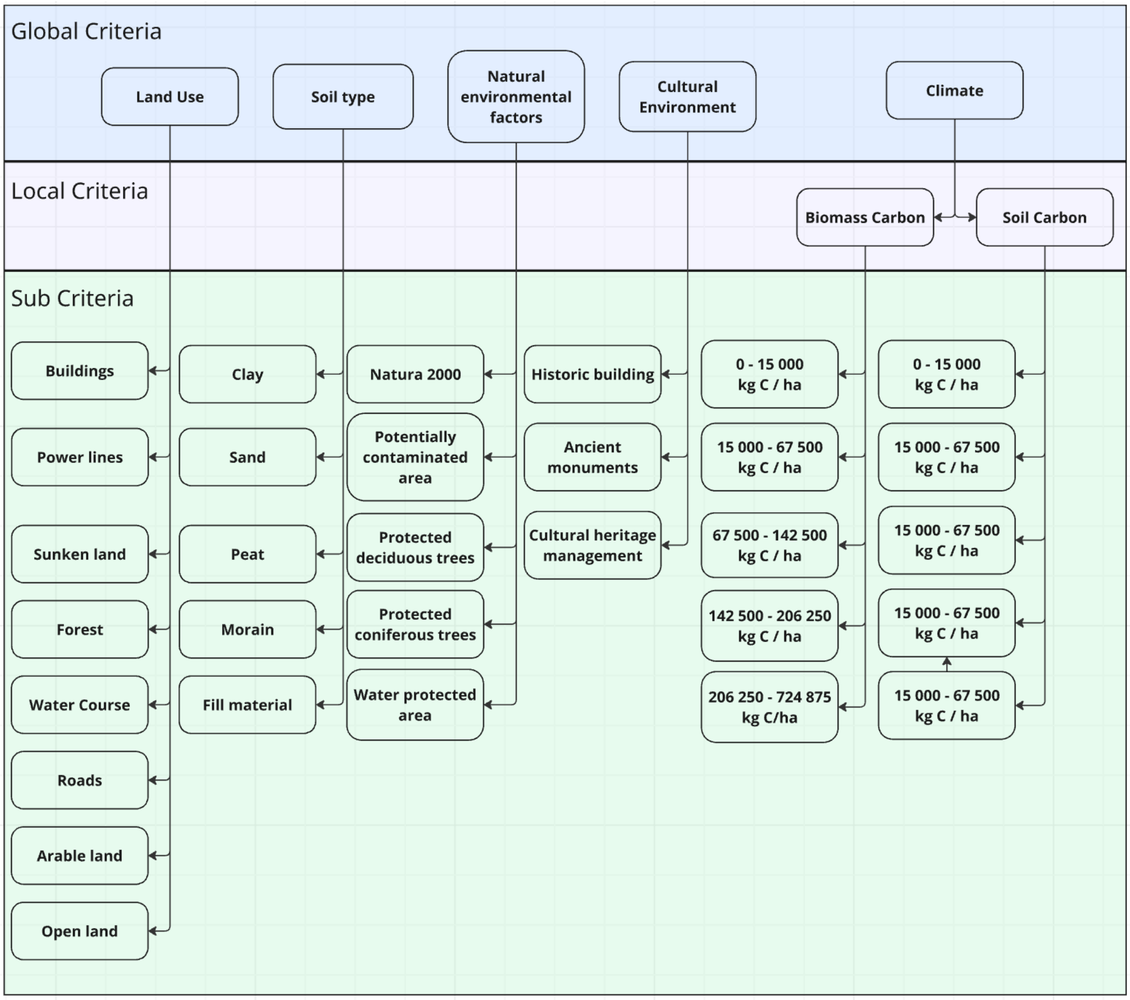

Figure 3.4: The global criteria Land use, Soil type, Natural environmental factors and Cultural Environment have collected data from Geopangea. Data for biomass carbon was collected from Skogstyrelsen [28] and the data for soil carbon was collected from SLU [43].

3.3 Interviews

To get a different perspective on how Georaptor works, its advantages and disadvantages, and future potential, two interviews was conducted. The first interview was with respondent A and he works as a Landscape architect and planner with GIS expertise at Norconsult. He has previously done several multi-criteria analyses, both manually and with Georaptor. The second interview was with respondent B and C. Respondent B works at Norconsult as a software developer and he is one of the developers behind the geo tool Georaptor. Respondent C works as a GIS and remote consultant at Norconsult and has expertise from research of integrated carbon observation system (ICOS) data and ancillary. The respondents agrees to the conversation being recorded and transcribed. The interviews consisted of multiple open-ended questions that were prepared before. The interviews was expected to take approximately 30 minutes and will be conducted via a videocall on Teams.

4
Result

This chapter presents the results from the case study as well as a summarized description of the conducted interviews. For the reader's understanding, this chapter presents the steps of the weighting process, alongside calculations and a few assumptions.

4.1 Weighting of criteria in Georaptor

This section discusses and shows how the different global, local and sub criteria are weighted. The different levels of criteria were separately weighted and the result is presented in the sections of this chapter. The five global criteria which were selected are Land use, Soil type, Natural environmental factors, Cultural environment and Climate. In addition, the sixth criterion NOGO is separately accounted for (section 4.1.3.6).

4.1.1 Weighting of Global Criteria

Soil type is weighted as the most suitable for construction because it is possible to build regardless of the soil type in the area, although there are preferred grounds to construct a road on due to settlements and other factors see section 2.5.2. Land use, Natural environmental factor and Cultural environment were weighted equally suitable for construction but less suitable for construction in comparison to soil type. The climate criterion is weighted as less suitable for construction because it stores a lot of carbon that will be released during road construction, see section 2.8. Figure 4.1 below presents the weighting.

	Land use	Soil type	Natural environmental factors	Cultural environment	Climate
Land use	1	3	0.33	0.14	0.33
Soil type	0.33	1	0.14	0.11	0.2
Natural environmental factors	3	7	1	0.33	5
Cultural environment	7	9	3	1	3
Climate	3	5	0.2	0.33	1

Figure 4.1: The figure show how the global criteria are weighted.

4.1.2 Weighting of Local Criteria

The weighting of local criteria consists of the criteria climate biomass carbon and climate soil carbon. Both criteria are weighted as equally suitable for construction because both criteria store a lot of carbon that will be lost during road construction. Figure 4.2 presents the weighting.

	Climate Biomass Carbon	Climate Soil Carbon
Climate Biomass Carbon	1	1
Climate Soil Carbon	1	1

Figure 4.2: The figure show how the local criteria climate biomass carbon and climate soil carbon are weighted.

4.1.3 Weighting of Sub Criteria

Each sub criteria was weighted against the other criteria in the same global criteria. The different weightings are explained in this section.

4.1.3.1 Land use

The global criterion Land use include the sub criteria Buildings, Power lines, Sunken land, Forest, Water course, Roads, Arable land and Open land. The sub criteria were consciously weighted according to the suitability of construction, see section 2.5.2. The factors which were considered were potential challenges like reinforcement for unstable ground, demolishing of existing construction work, value to landowners and potential risk of needing permission or using more building materials than needed. The result of the weighting is presented in figure 4.3.

	Buildings	Power lines	Sunken land	Forest	Water course	Roads	Arable land	Open land
Buildings	1	5	5	7	5	9	7	9
Power lines	0.2	1	0.33	5	0.2	9	3	9
Sunken land	0.2	3	1	5	0.33	9	3	9
Forest	0.14	0.2	0.2	1	0.2	5	0.33	3
Water course	0.2	5	3	5	1	9	7	9
Roads	0.11	0.11	0.11	0.2	0.11	1	0.14	3
Arable land	0.14	0.33	0.33	3	0.14	7	1	7
Open land	0.11	0.11	0.11	0.33	0.11	0.33	0.14	1

Figure 4.3: The figure shows how the sub criteria in the global criterion land use are weighted

4.1.3.2 Soil types

The global criterion soil types include the different soil types that can be found in the area. The soil types are characterized and divided into five sub criteria which are clay, sand, peat, morain and fill material. The criteria was weighted depending on how balanced and susceptible the soil is to settlement in order to be suitable for road construction see section 2.5.2. Figure 4.4 illustrates the result of the weighting.

	Clay	Sand	Peat	Morain	Fill material
Clay	1	7	0.33	9	1
Sand	0.14	1	0.14	3	0.14
Peat	3	7	1	9	3
Morain	0.11	0.33	0.11	1	0.11
Fill material	1	7	0.33	9	1

Figure 4.4: The figure shows how the sub criteria clay, sand peat, morain and fill material are weighted.

4.1.3.3 Natural environmental factors

The global criterion Natural environment consist of five sub criteria. The weighting was based on the suitability for construction which resulted in from lowest to highest there is water protected areas, protected deciduous and coniferous trees, potentially contaminated areas and lastly Natura 2000. Figure 4.5 illustrates the resulted weighting.

It was considered that a new road in the area would impact the water supply minimally due to the local circumstances, see section 3.1 which therefore led to the low ranking in comparison to the other sub criteria. The criterion which represents the two key biotopes, coniferous trees respectively deciduous tree were weighted with the reasoning that the trees don't have any protection legally. Therefore the criterion was ranked as more suitable for construction than potentially contaminated areas and Natura 2000 areas but also less suitable for construction than water protected area.

Contamination in areas where the construction will be located would demand for sanitation, see section 3.1. Therefore, due to the extra work that would be brought by the process of sanitation, potentially contaminated areas was weighted higher than water protected areas, and the protected species of trees. However, Natura 2000 areas was weighted as the least suitable in this global criterion, see section 2.5.2.

	Natura 2000	Potentially contaminated area	Protected deciduous trees	Protected coniferous trees	Water protected are
Natura 2000	1	5	7	7	9
Potentially contaminated area	0.2	1	3	3	5
Protected deciduous trees	0.14	0.33	1	1	5
Protected coniferous trees	0.14	0.33	1	1	5
Water protected are	0.11	0.2	0.2	0.2	1

Figure 4.5: The figure shows how the five sub criteria in the global criteria natural environmental factors are weighted

4.1.3.4 Cultural environment

The global criterion Cultural environment consist of three sub criteria, cultural heritage management, historic buildings and ancient monument. Factors which were considered was the existing objects in the case study area, see section 3.1 for more details. In this weighting, cultural heritage management was determined as the most suitable for construction followed by ancient monuments and historic buildings. Because that the cultural heritage management is a specific type of landscape in the area it was considered the most suitable and furthermore ancient monuments was considered more suitable to cross than the only historic building in the area . Figure 4.6 illustrates the resulted weighting.

	Historic building	Ancient monuments	Cultural heritage management
Natura 2000	1	3	5
Potentially contaminated area	0.33	1	3
Protected deciduous trees	0.2	0.33	1

Figure 4.6: The figure shows how the three sub criteria historic building, ancient monuments and cultural heritage management are weighted in the global criterion cultural environment

4.1.3.5 Climate

The global climate criterion contains the two sub criteria Soil carbon and Biomass carbon. The criterion of Soil Carbon was divided into five intervals which represents different volumes of carbon (the process of inventory and calculation of the amount of carbon has earlier been disclosed for in section 2.7). Biomass carbon was also divided into five intervals however this data layer consist of the volume of forest and have the unit m^3/ha. To get an average value of the amount of carbon is the volume of forest converted into kg C/ha, see subsection 2.5.2 carbon in biomass. This is made by multiplying the volume of forest with 750 and 0.5. One cubic meter dry weight biomass correspond to 750 kg and 50% of the biomass is assumed to consist of carbon. Figure 4.7 illustrates the converted biomass.

Calculation of Carbon in Biomass	
0 - 40 m^3/ha	0 - 15 000 kg C/ha
40 - 180 m^3/ha	15 000 - 67 500 kg C/ha
180 - 380 m^3/ha	67 500 – 142 000kg C/ha
380 - 550 m^3/ha	142 000 – 206 250 kg C/ha
550 - 1 933 m^3/ha	206 250 – 724 875 kg C/ha

Figure 4.7: The figure shows how the biomass volume is converted into biomass carbon.

The weighting of both data intervals was based of an interpretational assessment in the GIS program ArcGIS. The data was distributed with help from the attributes which described the intensity of volume that existed in every pixel. Some values appeared more often than others which allowed the process of dividing them in to separate intervals of distribution. Weighting the intervals (1-5) in Georaptor was then simple as the first interval (1) was considered the least impactful option.

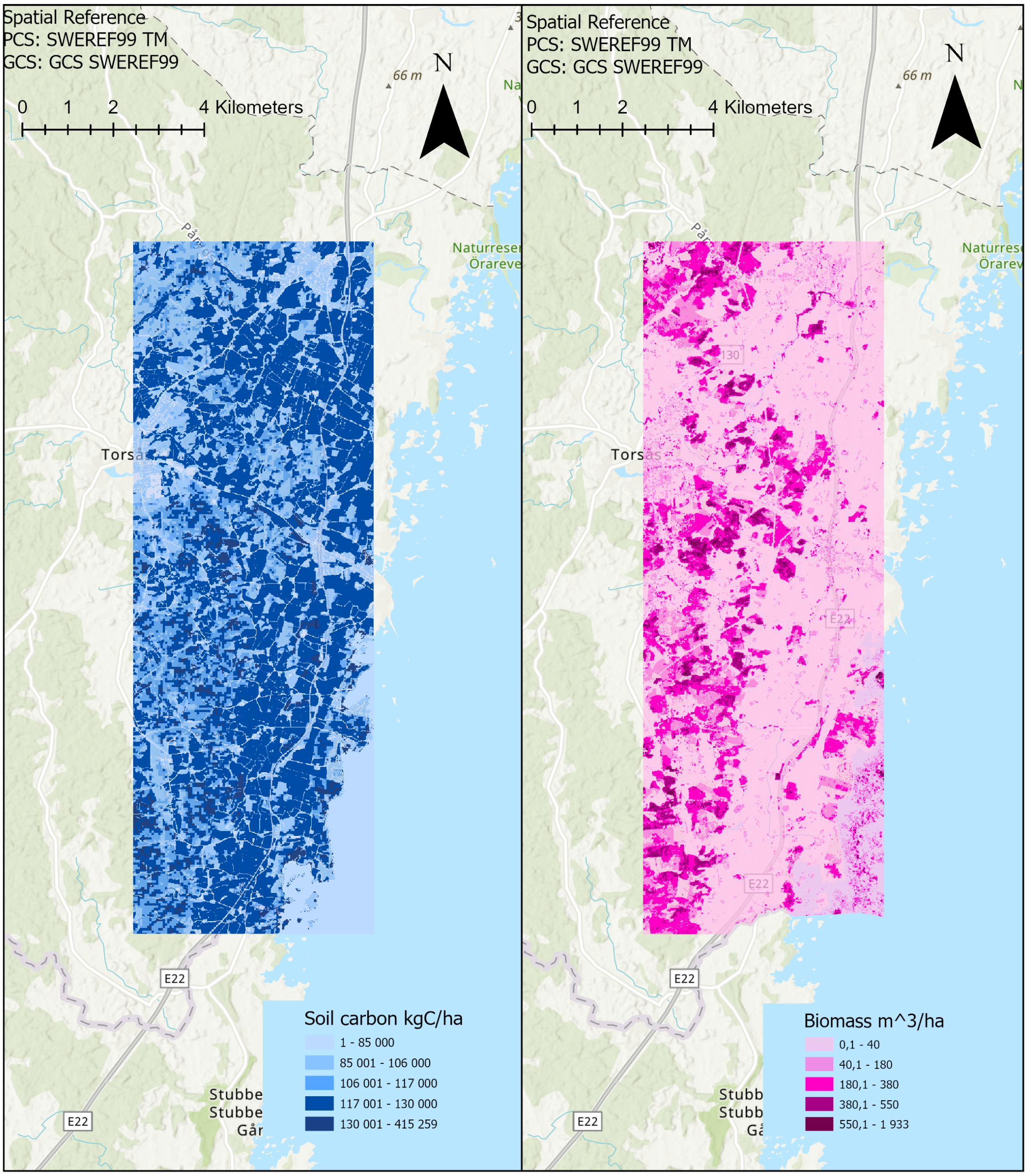

Figure 4.8: The map to the left in blue shows the amount of soil carbon kg C/ha and the pink map to the right shows the biomass with unit m^3/ha.

	Biomass carbon 0 - 15 000 kg C / ha	Biomass carbon 15 000 - 67 500 kg C / ha	Biomass carbon 67 500 - 142 500 kg C / ha	Biomass carbon 142 500 - 206 250 kg C / ha	Biomass carbon 206 250 - 724 875 kg C/ha
Biomass carbon 0 - 15 000 kg C / ha	1	0.33	0.2	0.14	0.11
Biomass carbon 15 000 - 67 500 kg C / ha	3	1	0.33	0.2	0.14
Biomass carbon 67 500 - 142 500 kg C / ha	5	3	1	0.33	0.2
Biomass carbon 142 500 - 206 250 kg C / ha	7	5	3	1	0.33
Biomass carbon 206 250 - 724 875 kg C/ha	9	7	5	3	1

Figure 4.9: The figure shows how the sub criteria Carbon in Biomass is weighted

	Soil carbon 0 - 85 000 kg C / ha	Soil carbon 85 000 - 106 000 kg C / ha	Soil carbon 106 000 - 117 000 kg C / ha	Soil carbon 117 000 - 130 000 kg C / ha	Soil carbon 130 000 - 415 259 kg C / ha
Soil carbon 0 - 85 000 kg C / ha	1	0.33	0.2	0.14	0.11
Soil carbon 85 000 - 106 000 kg C / ha	3	1	0.33	0.2	0.14
Soil carbon 106 000 - 117 000 kg C / ha	5	3	1	0.33	0.2
Soil carbon 117 000 - 130 000 kg C / ha	7	5	3	1	0.33
Soil carbon 130 000 - 415 259 kg C / ha	9	7	5	3	1

Figure 4.10: The figure shows how the sub criteria Soil Carbon is weighted

4.1.3.6 NOGO

This criterion was chosen as a representative group that includes factors which were considered too complicated to counter with the construction of a new road. The term "No go" was therefore used as the term to describe where the corridor wouldn't be able to cross, see section 2.4.1. For this specific area in Kalmar county Wind power plants and Lakes were selected since it was considered unsafe to locate a road nearby wind power as well as it was considered infeasible to reason for crossing any lakes.

4.1.4 Summary of weighting

The figure below 4.11 shows a summary of how the global criteria, local criteria and sub criteria were weighted. Each global, local, or sub-criteria adds up to a total weight of 100%.

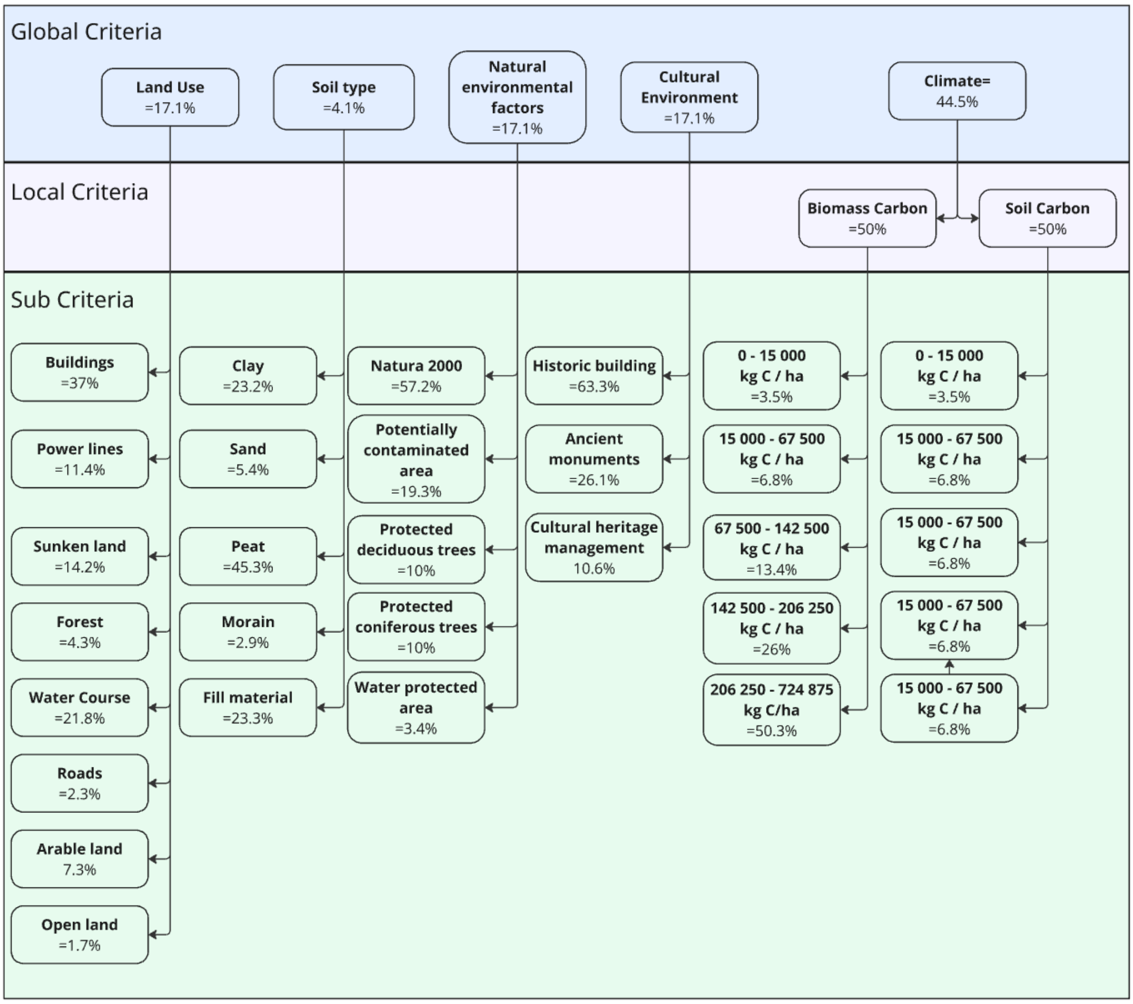

Figure 4.11: The figure shows a summary of the weighting of the global criteria, local criteria and sub criteria.

4.2 Output from Georaptor

Georaptor generated a map consisting of the merged weighted data layers. Figure 4.12 below shows the merged weighted data layers in purple. The scale from lighter purple to darker purple shows the percentage of criteria that overlap. For example, the darkest purple with a value of 16.939 to 27.788 indicates that 16–27% of the criteria overlap. The fewer criteria that overlap indicate that it is more suitable to construct a road, while the more criteria that overlap indicate that it is less suitable to construct a road. The blue part in the figure 4.12 below shows a corridor where it is more suitable for the construction of a road. The lightest blue has a value of 0 the second lightest blue with a value of 0.6% indicates that it is 0.6% less suitable for construction than the lightest blue.

The case study focused on the climate criterion, which can be supported by the global climate criterion that has a weighted value of 44.5%. Which is the highest value in comparison to other global criteria which have the highest individual value of 17.1 %. This means that the road section will be located to a greater extent where biomass carbon and soil carbon are the least. In the figure 4.8 is the carbon stocks mapped out, it is possible to identify that the brighter colors with less carbon are placed to the right. It is the same location as where the corridor is located.

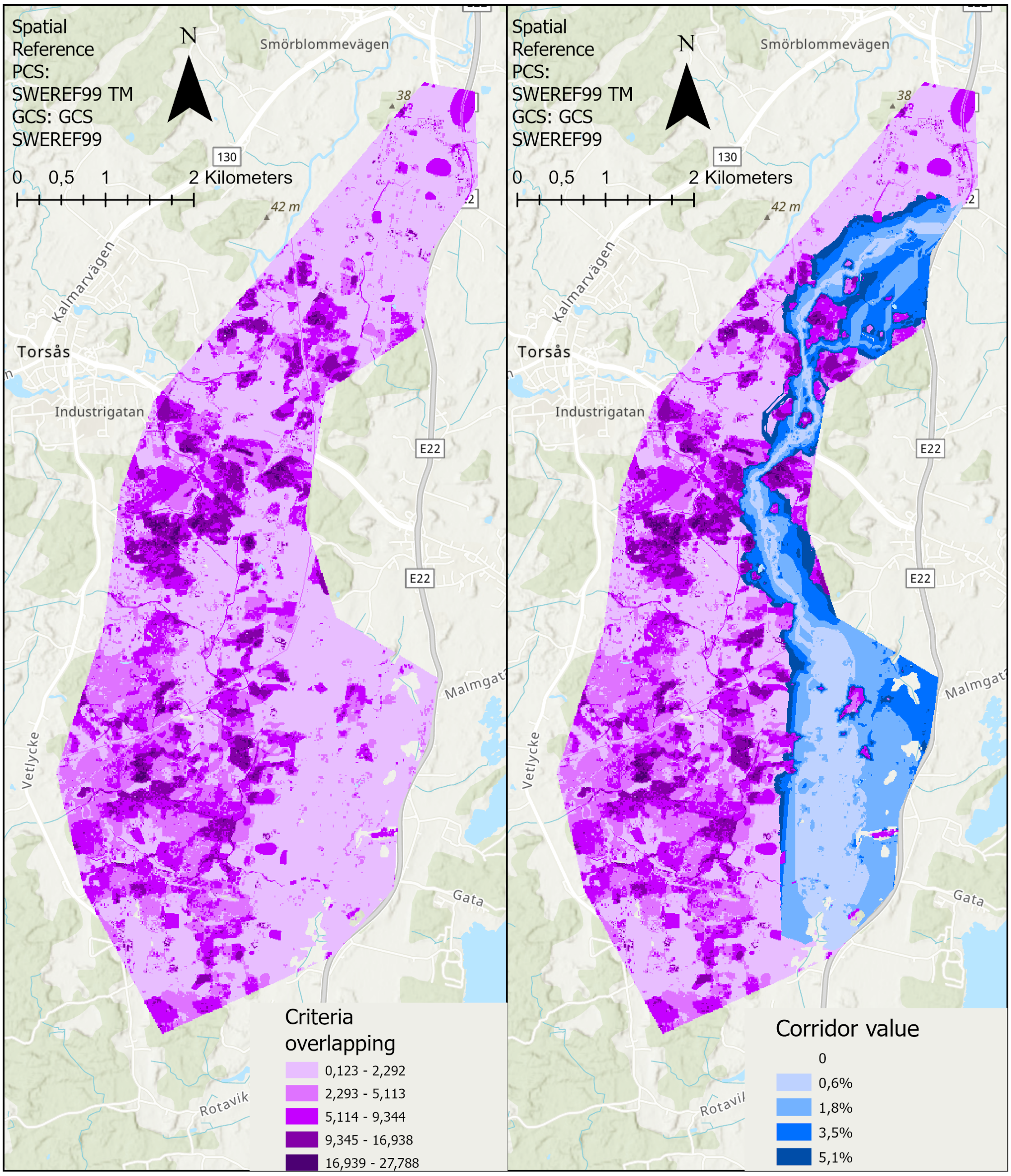

Figure 4.12: The figure shows the output from Georaptor, the purple shows the criteria overlapping and the blue shows the corridor where it is more suitable for construction of a road.

4.3 GeoRaptor Results with High vs. Low Weighting of the Carbon Criterion

A comparison where the climate criterion was weighted high versus low was made to illustrate how important the climate criterion is and to get a broader perspective on how the weighting process works in Georaptor. The figure 4.13 below shows how the global criteria were weighted when the climate criterion was given high versus low weighting. In the first alternative, where the climate criterion was weighted highly, it received a percentage of 69.2% while the other global criteria were weighted at 7.7% each. In the second alternative where the global criteria were weighted high, the climate criterion received a percentage of 2.4% while the other global criteria received a weighting from 9.9% to 36.1%.

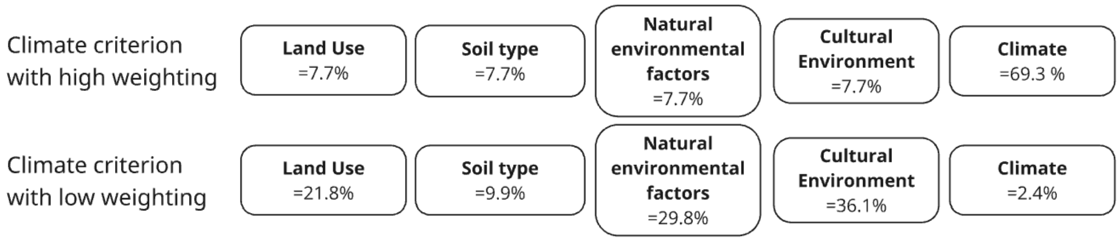

Figure 4.13: The figure shows how the global criteria were weighted when the climate criterion was given high versus low weighting.

The figure 4.14 below shows the output from Georaptor, in the figure to the left has the climate criterion a high weighting while in the figure to the right has the climate criterion a low weighting. It is possible to identify differences between the two figures, when the climate criterion was weighted higher, it resulted in a corridor that was much more specific to its route in comparison when the climate criterion was weighted lower.

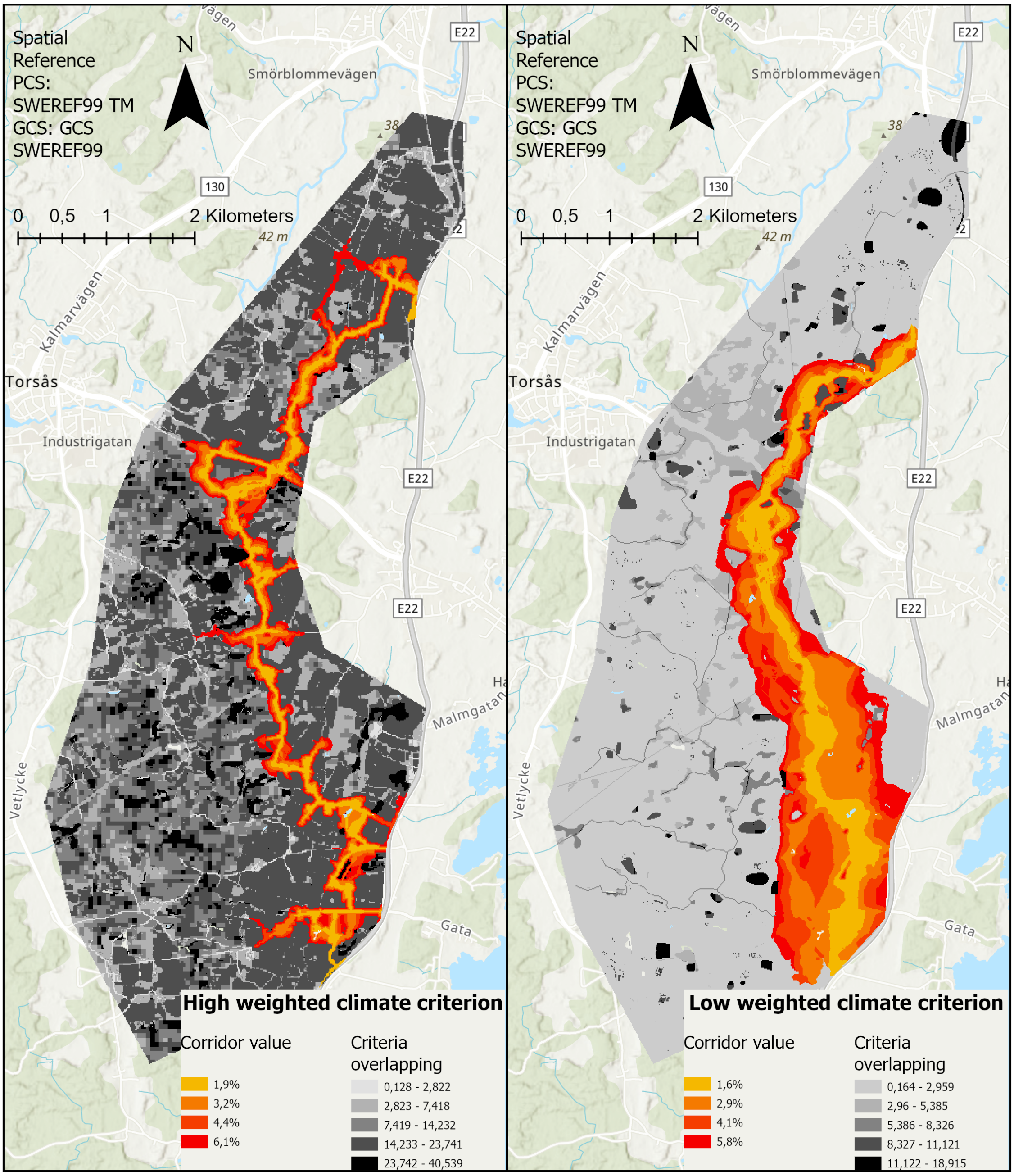

Figure 4.14: The figure shows the output from Georaptor, the grey shows the criteria overlapping and the yellow-red shows the corridor where it is more suitable for construction of a road.

4.4 Result from interview

Two interviews was conducted, a summarize with highlights from the interviews are presented below.

4.4.1 Interview with Respondent A

The respondent A believes that a common problem when conducting a multi-criteria analysis to find the most suitable corridor for a new road in a project is coming up with different alternatives and choosing between them. In complex locations, it is difficult to demonstrate transparency about why alternatives to corridors have been chosen and why alternatives have been rejected. When using Georaptor, the user get a good overview of different corridors and their pros and cons. The respondent emphasizes that it is important for the user to know how Georaptor works and how the program has processed the data to avoid incorrect results. The respondent highlights that it is good that Georaptor is an open process where you can control all processes and add more data.

In multi-criteria analyses that are carried out without geo tools, the step where corridors are created is experienced as both time-consuming and complicated by both the respondent and his colleagues. Georaptor streamlines the workload because the program helps generate multiple corridor alternatives that can then be manually evaluated against each other. Georaptor is based on the method AHP and the respondent highlights that it provides a sense of security to have a structured and reliable workflow to rely on. To streamline the work, it would have been possible to save weights from old projects in Georaptor. This can be seen as a risk because the weighting will not be site-specific for the specific project and instead the quality of the site study may be reduced. The respondent believes that it is important to supplement open data with site-specific inventories. Furthermore sees the respondent advantages in adding a climate criterion to Georaptor that calculates carbon. Adding criteria such as material use and shortest path is considered positive for the future. In manual multi-criteria analyses, aquatic environments are often missed. the respondent believes that this would be a suitable criterion to add to Georaptor because data for aquatic environments are usually available in open data.

4.4.2 Interview with Respondent B and C

Respondent B is one of the developers of the geotool Georaptor and the respondents points out that the program's developers have consciously chosen to limit Georaptor's functionality to only include cost raster and a single corridor. This decision is made on the fact that other features, such as material use and elevation differences, are complex to implement in the tool and there is often a lack of available data for these features. Furthermore, the respondent B points out that Georaptor is intended to be used as an assistive device, it is then up to humans to decide where the final corridor should be placed based on laws and other technical constraints. Regarding whether saved weightings are useful, are these considered to be a challenge as regions differs, datalayers available in one area may not necessarily exist in another. The respondent, however considers saved weightings to be better than guesses. In order to achieve reliable solutions, it is necessary to review what data is available in the local area and how that data should be weighted.

Georaptor's further development is intended to consist of two different interfaces, one for internal use at Norconsult and then a customer-focused interface aimed for municipalities, contractors or road authorities. In the customer-focused version, the idea is that only saved weightings will be available for use, and that the customer will not be able to apply their own weightings, as it is possible in the internal-use version. If the customer wants more specific weightings tailored to their area and needs, they will need to contact Norconsult so that the weightings can be adjusted accordingly. Respondent B also mentions that the database Geopangea which Georaptor use is updated once a week, and that the data is synchronized between Geopangea and Georaptor once a month. When it comes to data collection, local surveys are difficult to include in Georaptor, mainly because field surveys are expensive and require high resolution. In the future respondent B believes that the community will need to collect more data both to support more detailed analyses in Georaptor as well as for entirely different types of investigations in other programs.

Furthermore, Respondent C states that in the future, it is important to continue researching how climate and environmental data can be included in various studies to broaden decision-maker's knowledge and perspective. In the near future, Respondent C would like to see further research and development of climate layers, exploring whether it is possible to include more greenhouse gases such as methane in Geo tools, and then investigate how other environmental and sustainability aspects can be taken into account. The respondent C also believes that it is important to discuss the accuracy of carbon data. For example, the amount of carbon currently stored in a forest does not necessarily reflect the forest's future potential to sequester carbon.

5

Discussion

5.1 Research questions

- How can climate data be effectively integrated into a Geo tool for infrastructure development?

The climate data, specifically carbon storage for biomass carbon and soil carbon, was successfully integrated into the geo tool Georaptor. The climate criteria in Georaptor were displayed as a merged raster with five intervals from high carbon dioxide storage to low carbon dioxide storage. This raster, in combination with the weighted criteria, enables conclusions to be drawn regarding the most suitable locations for road construction.

- How do geotools contribute to mitigation of climate impacts in infrastructure projects?

By integrating climate data into the geo tool, it is possible to identify areas of high ecological value that should be preserved. By avoiding sensitive areas, projects can minimize their carbon footprint. Furthermore, the visualization gives an early indication of how much impact the construction will contribute with.

- How effectively do geo tools support and streamline the decision-making process to reduce climate impacts in infrastructure projects?

Georaptor combines and weights data within the specified area to identify the most suitable corridor for the planned construction. This structured working method enables the integration of large amounts of data that would otherwise be complex to interpret or identify patterns in. The process of when the corridor is decided in an infrastructure project is often time-consuming and complicated. Respondent A stated that Georaptor helps streamline the decision-making process by generating multiple corridor alternatives. These corridors can later be manually evaluated by comparing them with each other while also indicating their advantages and disadvantages. The possibility to quickly identify different alternatives minimizes the workload and provides transparency, as it offers an overview of the various corridor options and the reasons why they were selected or rejected.

5.2 Evaluation of the method

The case study was based of the area of south Kalmar county which has also been earlier investigated by Trafikverket's location study. To be able to get a broader perspective of how the climate data can be applied to Georaptor, other projects should be investigated with the same method. Conclusions which are made from this case study and associated interviews can therefore not be completely trusted to fit other projects equivalently. To be able to get more nuances and professional perspectives regarding the potential development of Georaptor, more interviews would have been necessary. Furthermore, this thesis only regards Georaptor as Geo tool. A clearer result of how to develop Geo tools with further environmental aspects in general would have to include similar investigations of other tools similiar to Georaptor.

The value of data sources is specifically related to this thesis since analyses made from Georaptor are dependent on data which are up to date with changes that are made, both natural and from human activities. This relates to any of the criteria such as volumes of biomass, volumes of carbon, cultural and natural values etc. There could also be differences in the level of detailed data, some input layers are more detailed mapped than others. Furthermore, there may be differences in how small geographical units the data is divided into, for example the data for biomass volume and soil carbon are provided with a 10*10 meter raster, see chapters 2.6.2 and 2.6.3. It is therefore important to note that the quality of the output is depending on the quality of the input of the data sources.

5.3 Evaluation of result from case study

The result of the case study consists of a corridor that is located in the eastern part of the area which could be retrieved by the merged data raster indicating the most suitable area for construction. Yet it is important to note that the result completely depends on the criteria that are included and how they are weighted. The case study and the weighting of the criteria were carried out by the authors of this report. The weighting is based on personal judgement but is supported by weighting done in previous projects, Trafikverket's location study in Bergkvara as well as the authors academic background in civil engineering. This means that the result may be biased and influenced by personal judgement, and may not fully correspond to the outcome that would have been achieved if the project had been carried out by more experienced professionals, with thorough preliminary studies, site investigations and interdisciplinary consultations between different professions.

The weighting of the subcriteria were all based on knowledge from the literature study together with the personal judgements of the authors of this thesis. Comparisons with earlier weightings of the Kalmar project were also executed. The reasoning was focused towards comparing two alternatives at the time and to the question of what would be more costly in comparison. While trying to decide whether it would be more suitable to construct a road through a forest or close to water courses or which type of natural or cultural values to avoid it became clear that a lot of experience, especially with potential common issues, would be necessary to make decisions. Hence, there was a realization of the type of complexity it takes to find the least costly alternative in terms of social, economic and environmental aspects. In addition, though the focus was towards environmental issues, it was inevitable to not come across the question of what would actually be the most realistic solution. Meaning that for example demolishing a building or perishing agricultural land to avoid an area of forest with carbon stocks might not be the most suitable alternative. Regarding the reasoning of the NOGO criteria, lakes and wind power were selected. This because it was considered unsafe to locate a road nearby wind power as well as it was considered infeasible to reason for constructing bridges over lakes. However, more data could have been added to this criteria such as buildings or specific areas such as Natura 2000. Additional reflection on the NOGO criteria regards the future of adding more environmental inventories such as protected species to Geopangea which is brought up in section 5.6.

This thesis focused on how carbon data effectively can be integrated into Georaptor and therefore the global climate criterion was chosen to have a weighted value of 44.5%. This value may appear high in comparison to the other criteria. The choice of increasing the weight of the climate criterion was conscious to get understanding of the effect from the input of climate data layers in comparison to the earlier study which was made in the area by Trafikverket. It is important to keep this in mind when analyzing the result, in order to understand why the outcome appears as it does. The climate criteria focuses on the carbon stocks and carbon flows and hence purely based on volumes of carbon in the given area. This aspect is important because biomass carbon and soil carbon are vital carbon sinks for the climate. Since 1850, it is estimated that 30% of fossil fuel emissions have been stored in the terrestrial carbon sink, see section 2.6.1. Mature forests are estimated to store more carbon dioxide than younger forests and sequester carbon dioxide at a higher rate than younger forests. Thus, they are assumed to have a greater value, which is also reflected in the weighting, where larger forest volumes are assigned higher weighting.

The final corridor identified by Georaptor is located approximately in the same area as the corridor identified in Trafikverket's location study. This, since the south area of Kalmar County which was investigated in this thesis is a relatively homogeneous area in terms of soil type, forestry, open fields and small communities, see section 3.1. If another area with more varied characteristics had been investigated, the corridors identified in the two studies would probably differ more significantly from each other and be more diverse. In such cases, a minor difference in the weighting of criteria would certainly affect where the corridor is placed and create larger differences. In addition, a more heterogeneous area would certainly result in multiple more precisely and smaller defined corridors, rather than one corridor that is spread over large area as seen in the corridors located in Kalmar County.

A comparison between a highly weighted global climate criterion and a low weighted global climate criterion was made to illustrate the impact of the weighting in the output, see section 4.3. In this study, it can be identified that the alternative with a higher weighted climate criterion provided a much more precise and selective corridor than the alternative with lower weighted climate criterion. This brings clarity to how much the weighting process matters to the output of the merged raster pixels and thus the proposed corridor. In general, the two corridors are similar in the comparison study, however the higher weighting illustrates some detours in the proposed corridor, indicating that the climate criterion has a dominant influence on the overlapping pixels.

5.4 Comparison between case study and Trafikverket's location study

Trafikverket's has conducted a location study for the new road section of the E22 and their most prefered road location is shown in the figure 3.2. When comparing the result from the case study 4.12 and the result from Trafikverket's location study, it is possible to identify many similarities. At a quick glance, it is possible to identify that both road corridors are located in approximately the same place. However, the indata in the two studies differs, Trafikverket's has done deeper analysis of the area and included more criteria, for example has they done inventories and conducted analyzes in the area to map out animal groups, beach protection and outdoor life. In contrast the case study has only used information that has been available in data layers such as data available in Geopangea for the criteria but has on the other hand included climate data. This means that the depth of the studies may differ. Remarkably, both Trafikverket's study and Georaptor take the shortest possible road section into account. In Trafikverket's study, it can be observed that the proposed corridor is located as close to Bergkvara as possible, which means that the shortest route has been taken into consideration. Georaptor takes the shortest road section into account by comparing different corridor options, a shorter corridor receives a lower cost since fewer pixels are included, while a longer corridor receives a higher cost as more pixels are included.

5.5 Analyze of Georaptor

Georaptor demands for an understanding of multicriteria analysis, specifically AHP, as well as an experience of managing data layers and GIS programs such as ArcGIS Pro or QGIS. Therefore it is not completely suitable for just anyone to use and therefore limits the numbers of users. Furthermore, the process of uploading data and weighting layers against each other will have to be done whenever a new project will be created in the program. This process makes sure that the weighting is made with up to date experience and requirements and fits the local surroundings. Since time is usually a directorial cost factor during infrastructure projects, it is important and favorable if the the process would not be too advanced or time consuming.

The weighting between objects such as buildings, lakes and forest will be considered rather similar apart from smaller local attributes and thus the same weighting should be applicable at many places. However, during the interview with a professional who conducts site studies, he expressed concern about saved weightings and stated that it poses a risk. Predetermined weightings are not tailored to the specific project site, which in turn can reduce the quality of the site study.

5.5.1 Comparison with similar Geo tools

The advantage of Georaptor is that the output is completely dependent on the input data. This increases the possibilities of area of usage. Meaning if some type of resource use, cost or environmental impact is desired the program will be able to visualize the most optimal route as long as there are data available. The weighting process makes the important difference, whereas if the goal is to find the least costly corridor in terms of investments the weighting can be adjusted to reflect this specific area. Later, additional calculations and analyses in e.g., GIS software can be done afterwards if it is needed.

Other tools which are described in section 2.1.1 Trimble Quantm and section 2.1.2 Geokalkyl are used in the profession. Both tools has different focus areas and properties than Georaptor which may be desirable in infrastructure planning. Trimble Quantm has the advantageous that it can forecast the CO2 emission from moving materials, preparing land and building infrastructure projects. Another advantageous that the program possesses is forecasting of CO2 emission from the traffic that will use the new infrastructure by calculating the traffic flow, average speed and fuel consumption. The advantage of Geokalkyl is that the tool can identify where the greatest costs for earthworks and geotechnical reinforcement measurements arise and thereby minimize the economic cost, energy use and carbon emissions.

5.6 Future studies

Due to time constraints the thesis is limited to the implication of considering areas that are large carbon sinks as especially valuable as well as comparing it with earlier project results. However, for the continuous work of aiming to keep the global warming below 1.5°C and to achieve both national and global environmental goals, future studies should continue with finding solutions to optimize work and construction of infrastructure. Construction industry is yet one of the remaining industries that affects the emissions of carbon dioxide the most.

Further development of Geo tools would be interesting to see together with not just corridors of the road but for an example cross sections of the ground or specifically standard road embankments implemented as a alternative function after the corridor is set. This because a standard embankment could make it possible to get direct volumes of material usage and therefore the climate effect from it. In the social aspect, this would mean an easier way to present a less environmental costly alternative to clients which could mean for a difference for future sustainable decision making. However, discussion during the interview with the program developer it might not be possible to make it happen. Yet, while understanding the complexity, perhaps a complimentary function which is not directly a part of Georaptor could still be possible to make it happen.

Connected to the perspective of material use, corridors created in Georaptor does take the shortest way into account however according to the input data which has been weighted. As there is currently no not an option of accounting for material usage, consideration of other routes might have to be examined manually. Looking at the comparative weightings of the higher and lower weighted climate criterion, see figure 4.14, there are opportunities where the corridor could have followed a shorter and more direct route. In this case, it would likely result in reduced material use for construction, which in turn could lead to different climate outcomes if material consumption were taken into account.

Moving forward, there are many other aspects that could have been considered in the climate criterion to make an absolute examination of how the climate is affected when constructing a road. In addition to carbon dioxide, greenhouse gases like methane and nitrous oxide contribute to the climate change, see section 2.7 and 2.8. Methane and potentially nitrous oxide are released from undisturbed peatlands, whereas drying them out for example, during road construction leads to carbon dioxide emissions. Moreover, a new road contributes to changing traffic flow, and an increase in traffic flow leads to higher fossil fuel emissions. In addition there are indirect climate effects which are not focused to the specific area where the construction will be established such as the material used for construction as well as transportation and machines used during the construction phase.

In the future, it is possible to expand the climate criteria to include both climate and environmental aspects. Respondent A identified potential in adding a criterion related to aquatic environments, as there are available data to support this criterion, see section 4.3.1. There are other criteria that may be relevant to add in the future, for example biodiversity, hydrological effects such as drying out or flooding of wetlands and watercourses, noise disturbance, water quality as runoff from roads can affect lakes and watercourses, and air quality due to increased emissions from vehicles. Respondant B during the second interview however, reminded of the fact that new inventories and much more data would have to be available for Georaptor to make this possible. Although, whenever it is available, with more data of inventories of protected or red listed species would make it easier to avoid those areas for an example by using the NOGO criteria.

6
Conclusion

This thesis has investigated how climate data can be effectively integrated into a geo tool to mitigate climate impacts in infrastructure projects, as well as how effective geo tools support and streamline the decision-making process during the design phase. Through Georaptor, which uses the AHP weighting method, it was possible to conduct the case study in Kalmar County to evaluate the tool's usefulness and functionality. The results show that Georaptor is useful for identifying corridor alternatives to find the most suitable location for a new road, taking climate values into account. It became clear that it is possible to identify areas that store a lot of carbon and areas that have great potential to store much carbon in the future. With the improved environmental understanding about the area, it is possible to select a road location that has a lower carbon footprint and also avoid areas with high ecological value. The tool streamlines the decision-making process by generating multiple corridor alternatives, which can then be compared with each other manually. This step is perceived as both time-consuming and complicated by professionals conducting these location studies manually. Georaptor is based on the AHP method, a framework that helps users rely on a consistent and reliable workflow, providing a sense of confidence. By evaluating the pros and cons of different corridor alternatives, transparency can be demonstrated, which strengthens the credibility of location studies. Although the tool offers many advantages, it also has some limitations. Georaptor requires technical expertise in GIS and an understanding of how to weight criteria with AHP. This can limit the program's accessibility, as it requires experience and skill in conducting location studies from users. However, for future research and future development a suggestion would be to continue using the tool with other climate and environmental data such as aquatic environments and biodiversity as well as standard road embankments to be able to estimate volumes of material usage. Furthermore, evaluating new functionalities in the program that seek to deeper knowledge of the area of investigation would be interesting to see in the development of Georaptor. In summary, the study shows that geo tools have the potential to continue contributing to sustainable and climate-conscious infrastructure planning in order to achieve the national and global goals that have been set. This potential can be fully realized as long as the tools keep pace with technological advancements and continue to develop in line with industry needs.

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A
Appendix 1

Interview with Göran Sevelin. He works at Norconsult as a Landscape architect and planner with GIS expertise, and has participated in the location study in Bergkvara and the location study in Härlöv. He agrees to the conversation being recorded and transcribed.

Vendela Lönkvist
- Hur är din uppfattning kring Georaptor, fungerar det bra och vad ser du för potential i programmet?
Göran Sevelin
- Jag ser stor potential med Georaptor och liknande lokalisering-och multikriterieanalys men sen ser jag också faror. Främst i den typen av processer där man har komplexa lokaliseringar är det alltid svårt att komma framåt och hitta alternativ och välja mellan alternativ. I de projekt jag har jobbat med har det alltid varit svårt att komma framåt och uppvisa transparens om hur man har nått fram till de förslag respektive valt bort alternativ. Jag tycker Georaptor och liknande multikriterieanalyser hjälper bra till med detta.
Vendela Lönkvist
Georaptor är ju ett verktyg som tar fram en korridor och hanterar inte flera vägar samtidigt.
Göran Sevelin
- I projektet jag jobbade med i Härlöv gjorde vi en första analys, därefter gjorde vi justeringar i värderingar och satt begränsningar för var programmet fick dra korridorer och inte fick dra korridorer. På detta sätt kan man tvinga korridoren till vissa platser och därmed testa robustheten i analysen.
Vendela Lönkvist
Ja, det är sant.
Göran Sevelin
- Detta är en ganska viktigt del och sen en annan viktig sak för att inte hamna i fallgropar så är det bra att att man vet vad man gör och inte bara stoppar in data i ett dataprogram och så knuffar den ut en korridor utan att man faktiskt har folk som har koll på vad dataprogrammet gör. Jag har tittat på en liknande multikriterieanalys som jag inte har varit med och gjort. Då läste jag rapporten och försökte från den berörda kommunens sida bedöma hur för- och nackdelar föreslogs i det ärendet. Jag var väldigt kritisk till hur den presenterades och även i de val man hade gjort. Jag hade svårt att få överblick över varför de hade valt bort områden och dessutom tyckte jag att de för lättvindigt hade satt NOGO-zoner som styrde resultatet väldigt mycket.
Mia Rostén

Just det.
Vendela Lönkvist
Jag har fått uppfattningen att Georaptor är ett tidskrävande program eftersom när vi har använt det har vi ägnat mycket tid åt datan, vi har öppnat den i GIS och kollat igenom den. Känner du ändå att Georaptor effektiviserar arbetet?
Göran Sevelin
- Ja, jag tycker att Georaptor effektiviserar arbetet särskilt i det avseende att få framdrift och komma fram till ett förslag som man sedan kan utvärdera. Sen tror jag också att det är viktigt att göra en manuell utvärdering förslagen, men att fram flera alternativ som man sedan kan utvärdera mot varandra tycker jag underlättar arbetet väsentligt samt att man får en stabil grund att stå på inför den utvärderingen.
Vendela Lönkvist
- Jag funderar lite på den datan man har möjlighet att använda sig av i Georaptor. När vi har gjort vår case study i området kring Bergkvara har vi inte kunnat få in all data som kanske behövs för att göra en grundlig undersökning. Hur ska man jobba för att få bort detta dataglapp för man vill ju ta hänsyn till all data i området?
Mia Rostén
Tänker du på data från inventeringar och sådan data man upptäcker på plats?
Vendela Lönkvist
- Ja för våran case study är inte lika utbredd som trafikverkets case study. Vi har bara använt oss av information som funnits tillgänglig i olika databaser.
Göran Sevelin
- Ni har bara använt data från offentliga källor och öppna data
Mia Rostén
- Precis.
Göran Sevelin
- Ja, jag tror man oftast behöver komplettera den öppna datan med specifika undersökningar. Sen finns det ju ingen begränsning i multikriterianalysen och Georaptor som gör att man inte kan ta in fler datalager. Utan det är ju en möjlighet vi har med Georaptor och i multikriterieanalyser att man kan lägga till fler datakällor.Sen tycker jag att en styrka i Georaptor är att från Norconsult sida att det är en öppen process. Det är en programvara vi har skapat. Vi kan styra alla steg i den. Vi vet vad som händer när vi stoppar in data. Det finns ju andra kommersiella produkter. Georaptor är ju Norconsults kommersiella produkt som norconsult säljer eller vi säljer inte produkter utan vi säljer utredningen som produkten resulterar i. Men det finns ju andra kommersiella program som man kan köpa från externa parter som genomför multikriterieanalyser. Då har man inte full kontroll över hur datan som stoppas in hanteras alla gånger och det ser jag som en förutsättning att den som genomför analysen vet vad som händer med datan man stoppar in annars så riskerar man att göra tabbar. Sen gäller mycket av de begränsningar som finns i Geodatahantering över lag gäller i Georaptor också. Problem med generalisering, modified area problem och den typen av statistisk analys samt samt problem med värderingar påverkar resultatet i alla typer av multikriterianalyser.
Vendela Lönkvist
Okej, vi har kanske gått in på detta, men vad skulle du säga är största skillnaden

mellan att jobba med Georaptor och att göra en “vanlig” multikriterieanalys.
Göran Sevelin
Oj? Jag vet inte. Som jag ser det är Georaptor en strukturerad multikriterieanalys. Eller ja, den viktigaste skillnaden som jag kan se är att det finns en värderingsmodell, ett strukturerat arbetssätt att göra värderingarna på. För det är en av de svåraste sakerna när man gör en multikriterieranalys att veta hur man sätta värderingar. Georaptor är både en programvara och samtidigt en arbetsmetod för hur värderingarna ska sättas med hjälp av analytisk hierarisk process.
Vendela Lönkvist
Finns det verktyg som man använde sig av innan Georaptor och multikriteriaanalys kom?
Göran Sevelin
Det finns andra exempel på system som andra bolag använder sig av. En sådan är trimble quantm som jag vet användes i Lund Hässleholm projektet som blev avbrutet. Sen är det vanligaste innan dessa verktyg att göra manuella analyser. Då utreder man området och samlar in data utifrån olika teknikområden. Sen försöker man komma fram till en korridor och det är ju egentligen så vi har jobbat i projektet kring Bergkvara. I lokaliseringsutredning i Bergkvara presenteras inte någon multikriterieanalys, för det är ju en manuell analys. Däremot så tror jag att jag har nämnt och visat att jag gjorde en kort multikriterianalys under det projektet också vid sidan om. Det normala är en manuell projekt, en process där man försöker utreda och sen försöker man luska ut alternativ för förslag till lösningar. Där upplever jag att man väldigt ofta kan hamna i en rundgång, att det är väldigt svårt att komma fram till förslag till lösningar och definiera, avgränsa och välja bort. Jag tycker att multikriterieverktygen hjälper till.
Vendela Lönkvist
När vi har använt Georaptor har vi fått uppfattning att det har behövts ett större område för att få det att fungera. Har du fått samma uppfattning och vilka projekt tycker du att Georaptor lämpar sig bäst till att använda?
Göran Sevelin
Man kan inte gå ner hur mycket i skala som helst, nu har jag inte tittat på era resultat så mycket men jag skulle förvänta mig att Bergkvara är ett tillräckligt stort område. Min förväntan är att projektet i Berkgvara har ganska lämplig detaljeringsgrad men jag har inte tittat på era resultat mer än det ni visade nu i början. Men jag kan ju tycka att Härlöv är ett lite litet projekt. Dock har vi haft nytta av det i Härlöv men i grunden tycker jag att det är ett lite litet område för den typen av lokalisering som vi gör.
Vendela Lönkvist
Vi har integrerat klimatdata i vår case study. Tycker du det är bra med dessa utökningar?Vad tror du mer man kan integrera i Georaptor och börjar vikta? Finns det några andra utvecklingspotentialer?
Göran Sevelin
Georaptor är ju inte låst vid specifika lager, utan det är ju tänkt att man ska anpassa vilka ämnen som är relevanta för det aktuella projektet. Jag kan tänka mig att i en del projekt är vattenmiljö relevant att lägga till då jag inte tror att vi fångar upp det jättebra i nuläget. Det finns ju också ganska bra underlag för vattenmiljö i öppna

data så det skulle man lätt kunna utvidga. Ni nämnde att ni inte har haft tillgång till olika arter i Bergkvara. Detta går att lösa genom att det finns habitatanalyser i Bergkvara som man hade kunnat lägga till i en Georaptorkörning.
Mia Rostén
Tror du att det hade funnits någon fördel att spara viktningar i Georaptor som man har gjort tidigare? Om man ska börja med ett nytt projekt och utgå ifrån en liknande viktning som har gjorts tidigare?
Göran Sevelin
Jag tror att det finns faror med det också. Så jag är osäker faktist.
Mia Rostén
Ja.
Göran Sevelin
Jag tror att det kan finnas vissa fördelar att jämföra med tidigare, men jag kan också tänka mig att det finns lite faror för att det inte blir platsspecifikt och det bildas risker istället. När man sätter siffror på någonting har vi en tendens att se det som väldigt sanningsenligt och då finns det en risk att när man sätter en siffra att man förlorar kvalitet. Man får samstämmighet över tid, men man förlorar i kvalitet och platsspecifika egenskaper.
Vendela Lönkvist
Okej, vi har också gått i tankarna att man skulle kunna inkludera materialåtgång i Georaptor. Georaptor tar inte till hänsyn till kortaste vägen men vi tror att det hade varit nyttigt att kunna få fram hur mycket material vi sparar om vi tar den här vägen i jämförelse med en längre väg.
Göran Sevelin
Yes, det hade varit väldigt bra. Det finns ju ett verktyg som heter Geokalkyl som är bättre på att fånga topografi och titta på om man behöver tunnel eller bro på olika sträckor. Detta är Georaptor svag på, det är ju i grunden en 2D projektering, men man kan ju lägga in höjder. Dock är det inte riktigt samma sak som en 3D projektering. Jag vet att vid något projekt har vi tagit hänsyn till hur mycket sluttning det är på en plats, men det är inte detsamma som att ta hänsyn till hur stor höjdskillnaden är på en vägsträcka.
Vendela Lönkvist
Tycker du att Georaptor förenklar beslutsfattningen i projekt?
Göran Sevelin
Framförallt tycker jag Georaptor underlättar i att skapa förslag till korridorer, sen tycker jag att man måste utvärdera korridorerna separat efter det. Processen att skapa korridorer är min erfarenhet att den är krånglig och jag har hört detsamma från kollegor.
Vendela Lönkvist
Som jag har föstått tycker du att det är nyttigt att jämföra olika korridorer med varandra för att komma fram till det bästa förslaget.
Göran Sevelin Det stämmer! och syftet med det är att hitta gemensamma nämnare och outliners för att skapa korridorer som man sedan kan konsekvens bedöma i en miljökonsekvensbeskrivning.
Mia Rostén
- Kan det vara så att man från början i projektet har en uttänkt korridor? Kan

Georaptor förändra dessa tankegångar och föreslå en annan korridor som initialt inte var uttänkt från början?
Göran Sevelin
- I Bergkvara kunde vi ganska tidigt säga att vi har en lösning som är nära Bergkvara och det var ju också den slutsatsen vi hamnade i samt att det också var eran slutsats som ni landat i. Det handlar ju mycket om att återanvända så stor del av befintlig väg i så stor utsträckning som möjligt. Både av markanvändningsskäl att bruka så lite område som möjligt men samt nyttja de resurser som finns. Det kostar mindre asfalt och anläggningsarbetare att anlägga en ny väg på samma ställe. Att bygga ut en befintlig väg kostar mindre än att anlägga en helt ny väg. Sen i Härlöv så fanns det ju ett förslag till korridor som vi ganska snabbt kunde avfärda och som vi inte fick fram i Georaptor hur mycket vi än ansträngde oss för att få korridoren att hamna där. Vi gjorde flera varianter för att tvinga programmet åt det hållet. Det fanns en östlig korridor, men där var det ju också delvis ändrade förutsättningar i att när den första korridoren som kommunen har med i sin översiktsplan ritades så var inte det statliga byggnadsminnet så stort som det är idag. Det hade en annan geografisk utbredning.
Vendela Lönkvist
- Du har ju mycket erfarenhet, brukar man välja den kortaste vägen eller väljer man en längre väg ibland.
Göran Sevelin
- Dagslängden på vägsträckan har en har ju ett direkt samband med kostnad och även klimatpåverkan. Så det är ju en faktor som är viktig, men vi drar ju inte några raka vägar idag. På femtiotalet kunde man rita vägar som ett rakt streck på kartan och så ser det ju inte ut i planeringen idag, utan idag bygger man ju mer hänsyn till områdets påverkan och miljö. Men längden väg är både för väg och järnväg är en avgörande faktor. I Lund-Hässleholm samt lokaliseringsstudien Göteborg-boråsprojektet las det stor vikt vid tidsbristen för själva järnvägen. Det målet var så hårt satt att det begränsade svängradien på järnvägen ganska väsentligt och det kunde inte bli hur lång sträcka järnväg på den, utan det begränsade väsentligt korridormöjligheterna.
Vendela Lönkvist
Varför la man ner projektet Hässleholm-Lund?
Göran Sevelin
- Det var ju ett regeringsbeslut att lägga ner projektet och att starta om det. Min uppfattning är att det i grunden handlar om att man inte fick med sig kommunerna. Kommunerna satte sig motvalls mot de förslag som hade presenterats. Delvis beror det också på ändrade förutsättningar att när man påbörjade projektet så var målet en järnväg med (nu tar jag från minnet), 350 km/h och höghastighetsjärnväg. Det nya regeringsbeslutet gäller en ny stambana med 200 eller 225 km/h och det gör väldigt stor skillnad för vad man kan anlägga.
Vendela Lönkvist
- Det var alla frågor vi hade. Är det något vi har missat kanske vi skickar ut ett mejl. Det var tacksamt att du ville svara på våra frågor så att vi får med fler perspektiv i vår diskussion.
Mia Rostén

- Jag tusen tack för att du ville vara med! Det här kommer hjälpa jättemycket

Göran Sevelin

- Varsågod. Det var så lite så lycka till. Ha det bra! Hejdå

Vendela Lönkvist

- Tack och hej.

B

Appendix 2

Interview with Jonas Bohlin and Ida Storm. Bohlin works at Norconsult as a software developer and he is one of the developers behind the geo tool Georaptor. Storm works as a GIS and remote consultant at Norconsult and has expertise from research in ICOS data and ancillary. The both respondents agrees to the conversation being recorded and transcribed.

Vendela Lönkvist
- Vad ser ni för potentialer i Georaptor? Hur tror ni att Georaptor kan utvecklas i framtiden? Vilka fler funktioner tror ni hade gått att programmera in?
Jonas Bohlin
- Vi har funderat väldigt mycket på vilka funktioner man hade kunnat lägga till och har medvetet avgränsat oss till att göra kostnadsraster och en enkel korridor. Beroende på vilken typ av sträcka man är intresserad av finns det väldigt många andra saker som blir intressanta. Till exempel om man ska gräva ner en vattenledning finns det byggnadstekniska krav som inte kommer snabbas upp av den kortaste vägen utan det måste finnas en procentuell lutning i riktningen som vattnet ska gå och då hade man behövt en annan typ av raster som räknar ut lutningen från en pixel till en annan för alla pixlar. Det är ingenting som det finns riktigt bra data på utan det fick lutningsraster som inte är rikstäckande. Men dem tar inte riktningen av sträckan i beaktning när man går igenom den.
Mia Rostén
- För då skulle det heller inte till exempel vara möjligt att få ut tvärssektioner av marken?
Jonas Bohlin
- Nej, inte rätt upp och ner, men sen när man väl har sträckningen så skulle det vara ganska enkelt att från datan som ligger i Georaptor få ut tvärsektioner, men man skulle behöva sträckningen först. Att göra sträckningen kommer komma med andra krav än vad som snappas upp i den nuvarande versionen.
Vendela Lönkvist
- Jag tänker på materialåtgång. Om Georaptor hade tillgång till självaste sträckan, hade Georaptor kunnat räkna ut hur mycket material som går åt? Hade det varit möjligt att räkna ut hur mycket mer material som sparas om man tar en kortare väg kontra en längre väg.
Jonas Bohlin
- Det är också ett exempel på funktionalitet som inte finns i dagsläget också någonting som vi har tänkt på bara den senaste månaden eller den här veckan. Vi håller på med ett projekt där vi ska dra en väldigt lång ledning. Där hade det varit väldigt relevant att kunna få ut den här infon. Men någonting som också är viktigt

är att komma ihåg vad Georaptor är tänkt att göra och det är tänkt att komma med en korridor som säger basically till slutanvändaren att någonstans här inne vill du dra din i ledning. Sen så är det upp till dig som en människa och utifrån lagar och andra tekniska begränsningar att dra den faktiska sträckan igenom det och använda korridoren som ett hjälpmedel, snarare än att liksom det här är den absoluta sanningen. För man kommer aldrig kunna ta in allt i en sån här viktning och den är alltid begränsad i hur bra ens data är och mycket av datan man vill ha med bygger på modeller som har klassificerat raster eller flygfoton på något annat sätt. Så det är viktigt att komma ihåg att den är bara så bra som datan är. Så det hade varit ett ett annat steg som hade varit lösningskiljd från Georaptor att göra den här räkningarna på sträckor men man använde kanske kostnadsrasters från Georaptor med sin slutgiltiga sträckning tillsammans med sin linje för att få fram de här olika grejerna.

Vendela Lönkvist

- Ja, vi snackade lite med Göran också om programmets funktioner. Då sa han att det viktigaste med Georaptor är att det kommer med exempel på korridorer och att man inte kan lita fullt ut på dessa. Utan man får komma fram med förslag som man sedan kan jämföra med varandra och att det är till väldigt stor hjälp. Georaptor ska användas som ett hjälpmedel och man kan inte lita fullt ut på dess resultat.

Jonas Bohlin

- Nej precis. Och det, det är viktigt att komma ihåg och det är väldigt lätt att glömma speciellt för oss som sitter och bygger upp Georaptor. Vi tänker att det är som en bibel men det är snarare att någonstan inuti i den här korridoren finns bibeln. Vi har ju ett spann att röra sig på som är mycket smalare än när man sitter och kollar på alla de här lagren i ett GIS program och får överflöd av information istället.

Vendela Lönkvist

- Vi diskuterade det här med sparade viktningar med Göran då de hade förenklat processen i Georaptor men han tyckte inte alls det var bra utan att det blir farligt när man börjar använda gammal data. Stämmer inte datan med området så blir det felaktigheter och farligheter istället. Vi tänkte att det vore bra att utveckla programmet med att spara viktningar men då kanske man utvecklar programmet i fel riktning?

Jonas Bohlin

Ja, alltså, det är ju någonting som finns och någonting som vi använder ganska flitigt. Det här är också någonting som vi har kommit fram till är ett problem för vissa av datalagringen. Till exempel finns bara sur klassad sulfatjord längs med kusten och framförallt i Norrland. Om det är någonting som är väldigt viktigt för sitt projekt och så hamnar man någonstans i Skåne med den sparade viktningen från Norrland och i Skåne finns nästintill ingen sur sulfatjord även om det känns osannolikt. Då får vi vara väldigt tydliga med att den här sparade viktningen inte är en 100% fullgod lösning. Den är antagligen bättre än många andra gissningar men om man vill ha ännu mer säkerhet i resultatet så behöver man göra en lokal utredning för att veta vad för data som finns i det området. Den här datan behöver dessutom vara öppen som vi kan få tillgång till och sen bygga viktningen utifrån den. Sen det här med att data blir utdaterad, så länge den uppdateras hos Lant-

mäteriet eller de stora öppna dataleverantörerna så sinkar vi med dem så alltid den senaste datan finns tillgänglig men ja det är inte 100% heller.
Mia Rostén
- Ja, för jag tänkte fråga det, uppdateras Geopange automatiskt?
Jonas Bohlin
- Ja, den körs en gång i veckan och sen så synkar vi från Georaptor mot Geopangea, kanske en gång i månaden. Bara för att det är väldigt sällan som någonting ändras och det är en ganska involverande process där man måste gå igenom alla datalager som används av alla i alla riktningar och ändra vilken dem pekar på och ändra om det har hänt en uppdatering i Geopangea. Det är en liten bökig koppling som kommer ifrån att varje gång Geopangea hämtar data så skriver den om alla tabeller även om ingenting har ändrats. Så där skulle det behövas någon form av lösning som kan göra att man får mer koll på om det faktist är någonting som har förändrat. Och det går inte riktigt att göra för alla lager är rikstäckande i princip och då blir det för mycket data. Man kan inte gå igenom rad för rad och undersöka. Det är något som vi vill utveckla där och vi har lite ideer men ingenting som är konkret tyvärr.
Vendela Lönkvist
Vi tänkte lite på det här vem programmet är riktat till? Vilka är användrarna? Är det bara Norconsult och de som utför lokaliseringstudier är det utanför Norcosnult också som kan tänkas använda Georaptor?
Jonas Bohlin
Ja, det har ju hänt väldigt mycket på den här fronten under tiden från när ni började med ert exjobb och nu sitter vi och bygger ett mer kundfokuserat gränssnitt. I det här fallet mot kommun, entreprenör eller vägverket. Någon som kanske ska gå in och bygga en elledning mellan två punkter eller bygga en väg eller göra en annan typ av analys där man får ut en lista med de färdiga viktningarna. De kommer får göra en analys där de får ut en lista med de färdiga viktniningar och då kommer asterixen, dom är generella för Sverige (rikstäckande) och det finns stor sannolikhet att de inte täcker upp väldigt lokala speciella krav. Men då är tanken att de ska kunna köpa en licens av oss och sätta ut start och stopp för en korridor och sen fortsätta göra sin fortsatta analys på vårt resultat. Sen finns det ett gränssnitt som ni har suttit som är mest till för internt bruk. För att kunna skapa de här viktningar som sedan kan flyttas över som mallar till alla kunder.
Mia Rostén
- Så dem får alltså tillgång till den sista delen av programmet.
Vendela Lönkvist
Dem får bara tillgång till redan viktade grejer, kan det inte bli så att de vill vikta på något annat sätt?
Jonas Bohlin
- Ja och då om man vill vikta på något annat sätt då är det så illa att de får höra av sig till oss och betala oss för att få fram en viktning som stämmer för deras lokala behov. Det går inte att att tänka att det finns någon slags viktning som är tillräckligt generell för en typ av projekt som funkar oavsett vilken plats i Sverige man befinner sig i. Det är en fantasi värld som hade varit väldigt trevlig men som inte stämmer överens med verkligheten, tyvärr.
Mia Rostén

Jag har en kanske lite mer generell fråga till er båda två. Vi har ju undersökt kollager om man skulle vikta lite mer klimat och miljömässigt vad hade ni sett att man kanske undersökte mer då? Ska man fortsätta vikta metanlager och liknande lager?
Ida Storm
Ja, men jag kan flika in först på det och jag tror vi hade det i början av konversationen. Vi pratade lite om hållbarhet, brett om ekologisk hållbarhet, social hållbarhet. Och så blev det ett fokus på kollagring.
Mia Rostén
- Ja precis
Ida Storm
- Och där har vi använt ett lager och man kunde kanske ha kollat på fler lager så jag tror det handlar om att man kanske får avgränsa men att det här kanske blir ett kriterie då som ni nu är inne på. Men det känns ju väldigt stort och brett om man ska försöka få med allt.
Mia Rostén Jag tänkte mer på när vi ska fylla i vårt avsnitt om vad man kan göra i framtiden, näst på tur efter vårat arbete?
Ida Storm
Ja, men precis så där är det väl liksom vi pratade om indata att det är en begränsning. Vad finns det för bra indata och vad kan det alltså bli tydlig med? Vad symboliserar det liksom och vad passar det in i hållbar eller klimat och bara vara tydlig med definitionerna? Men så här konkret, vad vi kan kolla på mer först hade jag velat kolla på kanske fler lager kopplat till då växthusgaslagring. Ni var inne på metan alltså, det finns nog mer att göra där och fundera på den biten.
Mia Rostén
Ja.
Ida Storm
Men då sen bara var tydlig med att definiera okej, vad är det vi kikar på här nu? Hur definierar vi miljö?, Vilka lager är möjliga? Vad finns det för öppna data som är kopplat till något som man kan kategorisera? Sen tänker jag att man har lite av en svit av olika typer av lager som symboliserar olika grejer och sen får man ta vad som är viktigt i miljö och hållbarhet för er och vikta ihop, men där måste jag ju säga att jag har ju själv inte jobbat med Georaptor mycket, utan det är kanske mer är en fråga för Sonja till exempel eller Jonas. Men jag tror att det behövs mer forskning eller att man behöver fundera på hur går det i litteraturen. Vad är vettigt att använda för lager?
Mia Rostén
Precis. Och det är ju så att man behöver data för allting man lägger in i Georaptor för att få ut ett resultat. För det är väl lite intressant att se när vi tittade på den här lokaliseringsstudien i Bergkvara? Där har man ju gjort väldigt mycket manuella inventeringar. De hade varit bra om man hade kunnat få in detta på något sätt, men då måste man ju skapa ett nytt lager och det är ju lite krångligt.
Jonas Bohlin
Det är framförallt dyrt att skicka ut ett gäng i fält som går och inventerar med tillräcklig hög upplösning. Det är ofta det som behövs, tänker jag, speciellt när det kommer till liksom kollagring och sånt det är svårt att avgöra från något ortfoto eller satellitbilder. Vad som funkar liksom? Och det är ju, det kommer ju tillbaka till

begränsningen att behövs mer data på de här sakerna och inte bara för Georaptor skull, utan det känns som någonting som behövs samlas in för samhällets bästa. Det blir viktigt att ta saker och ting på lite mer allvar än vad man har gjort hittils.
Ida Storm
Ja, men precis och det var där jag pushade lite för det här med. Ja, men vad säger forskningen? Vad är senaste? Jag vet där jag jobbade innan att det finns ju en del datalager och jag tror jag länkat till dem tidigare. Det kom också upp i en diskussion med Sonja. Om man tänker med trädmassa, det är ju bara brown biomass. Det är liksom, ja, men här har det lagrats och så har det lagrats i mark också och man kan ha inventering för det. Men sen har vi också pratat hur mycket kol som har lagrats historiskt. Det finns ung skog som växer snabbare och då samlas mer kol snabbare. Det är kanske inte bara statistiskt hur mycket kol som lagras nu. En skog kanske inte är bättre för att det lagras kol nu, det säger inte mycket om potentialen att lagra kol framöver. Men ja, så det är väl det lite? En komplex fråga och nu valde vi att fokusera mer på det. Det finns mer att göra där redan, men sen är det väl upp till your imagination vad för typ av klimat och miljö och sustainability som ni väljer att ta med.

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