Road infrastructure planning using spatial tools from a perspective of poverty reduction

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Abstract

Road infrastructure planning is often believed to contribute to poverty reduction and many development bank and NGO’s invest time and money in these projects. However, few of those projects were subject of impact evaluations. Besides, feasibility studies are often based on financial criteria rather than economic, social or ecologic criteria (Van de Walle, 2009).

Keshkamat (Keshkamat, 2007) developed a method in which Spatial Multi Criteria Evaluation or SMCE can be used for route generation and selection. This has proven to be a successful method for the spatial planning of corridors that includes different stakeholder views and is capable of including economic, social and ecologic as well as technical criteria. The question therefore rises whether or not social criteria (especially poverty reduction as stated in the Millennium Development Goals) can be a useful addition to the SMCE method.

The research will be supported by a showcase of the Asian Highway Network. This international highway network will connect Asian countries. Focus will be on a stretch of road in Mongolia known as the Millennium Road or AH 32, which will run from the capital of Ulaanbaatar to Khovd in the western end of the country.

The main objective of the research is:

To analyse the potential of geospatial technologies and SMCE in the planning of highways as a means of contributing to MDG-1 (poverty reduction)

The literature review discusses three topics, road infrastructure planning, poverty and poverty reduction and SMCE. This showed that:

- The planning of road infrastructure derives from policy. Planning is often guided by a framework. The generation and selection of route alternatives is not guided by a framework nor is the process transparent.
- Poverty is a complex principle from which many definitions do exist. Poverty is both multidimensional and spatial. In literature, many links do exist between poverty reduction and road infrastructure planning. They can be summarized as that road infrastructure planning contributes to poverty reduction by creating better access to opportunities.
- The SMCE method is versatile. Research shows that it can be used with economic, ecologic technical and social criteria and it can be used for decision support for areas, corridors and networks. Furthermore, SMCE has been used for design and evaluation principles.

The conclusions that can be drawn from both theory and case research are that:

- Road infrastructure planning can contribute to poverty reduction by improving access to opportunities. One of the major opportunities is employment.

- It is possible to include poverty reduction criteria to the process of spatial multi criteria evaluation, by emphasizing on the location of poor people and their lack of access to opportunities.

- Planners should make use of SMCE to provide a holistic and transparent method for the planning of road infrastructure from a perspective of poverty reduction.

More research is needed on:

- The impact of geographical scale on the SMCE process. It is presumed that geographical scale plays a role in the SMCE process. Planning roads using SMCE on a local level is assumed to be different from planning on a national or international level. Since no considerations towards scale were made in this research, the impact should be topic of further research on road infrastructure planning using SMCE.

- The links between road infrastructure planning and poverty reduction. Current research is not supported by impact evaluations. This should be done to improve the links between road infrastructure planning and poverty reduction.

- The impact that the SMCE might have on the political process of road infrastructure planning. When decision support systems help on the planning of road infrastructure, the political planning power might reduce. A study should be done on the possibilities and political willingness of road infrastructure planning using spatial tools.

Abstract (Dutch)
Het wordt algemeen aangenomen dat het plannen van weginfrastructuur een positieve invloed heeft op armoede vermindering. Ontwikkelingsorganisaties steken daarom veel tijd en geld in infra-projecten. Dergelijke projecten zijn echter nog niet onderworpen aan impact evaluaties en haalbaarheidsstudies benadrukken vaak financiële haalbaarheid boven economische, ecologische of sociale haalbaarheid (Van de Walle, 2009).

Keshkamat (Keshkamat, 2007) heeft een methode ontwikkeld waarbij ruimtelijke multi criteria evaluatie kan worden gebruikt voor routeontwerp en routeselectie. Deze methode is succesvol bevonden voor de ruimtelijke planning van routes. De methode maakt het mogelijk om verschillende actoren en verschillende criteria (op economisch, ecologisch, sociaal en technisch gebied) mee te laten wegen in de ruimtelijke routekeuze. De vraagt rijst of sociale criteria zoals armoede vermindering ook toegevoegd kunnen worden aan deze methode.

Dit onderzoek wordt ondersteund door een casus van het Asian Highway Network. Dit is een internationaal snelwegennetwerk dat Aziatische landen verbindt. Specifiek wordt gekeken naar de AH32 of Millennium Road, dat een deel van het netwerk vormt en de hoofdstad van Mongolië, Ulaanbaatar, verbindt met de provinciehoofdstad Khovd.

De doelstelling in dit onderzoek luidt:

Een onderzoek naar de mogelijkheden van het gebruik van ruimtelijke multi criteria evaluatie bij het plannen van hoofdwegen met als doel het verminderen van armoede.

In het literatuuronderzoek zijn de concepten van planning, armoede en ruimtelijke multi criteria evaluatie onderzocht. Hieruit kwam naar voren dat.

- Het plannen van weginfrastructuur komt voort uit beleidsvorming en uitvoering. Planning wordt vaak gestructureerd uitgevoerd. Het ontwikkelen van en een keuze maken uit route alternatieven wordt voor zover onderzocht niet gestructureerd uitgevoerd.
- Armoede is een ingewikkeld begrip met vele definities. Armoede bestaat uit vele dimensies en is ruimtelijk uit te drukken. In de literatuur komen veel verbanden tussen armoede vermindering en het plannen van weginfrastructuur voor. Deze komen neer op dat planning van weginfrastructuur een positieve bijdrage levert aan de verbetering van toegang tot mogelijkheden.
- Ruimtelijke multi criteria evaluatie is een veelzijdige methode. Onderzoek laat zien dat economische, ecologische, technische en sociale criteria gebruikt kunnen worden en dat de methode toepasbaar is voor beslissingshulp voor zowel gebieden als voor routes. Verder is de methode zowel voor haalbaarheids- als voor evaluatieonderzoeken gebruikt.

Uit het onderzoek komen onderstaande conclusies naar voren:

- De planning van weginfrastructuur kan een positieve bijdrage leveren aan armoede vermindering door middel van het verbeteren van toegang tot mogelijkheden. Hierbij speelt de toegang tot werk een belangrijke rol.

- Het is mogelijk om criteria van armoede vermindering toe te voegen aan het ruimtelijk multi criteria evaluatie proces, door de locatie van de arme bevolking en het gebrek aan toegang tot mogelijkheden te benadrukken.

- Planners zouden gebruik moeten maken van ruimtelijke multi criteria evaluatie om zo een integrale en transparante methode te hebben voor het plannen van weginfrastructuur met armoede vermindering als doel.

Aanbevelingen voor verder onderzoek zijn:

- Onderzoek naar de impact die ruimtelijke schaalniveaus hebben op het proces. Aangenomen wordt dat ruimtelijke schaalniveaus wel degelijk een rol spelen in ruimtelijke Multi criteria evaluatie en dat het plannen van infrastructuur op een lokaal niveau met de methode om een andere aanpak vraagt dan het plannen van infrastructuur op een nationaal of internationaal niveau. Omdat dit onderzoek deze vraag heeft laten liggen kan het een onderwerp voor verder onderzoek zijn.

- De verbindingen tussen plannen van weginfrastructuur en armoede vermindering worden op dit moment niet ondersteund door onderzoek op het gebied van impact evaluaties. Dit is noodzakelijk om de verbindingen tussen planning en armoede vermindering te versterken.

- Onderzoek naar de impact die ruimtelijke multi criteria evaluatie heeft op het plannen van weginfrastructuur vanuit een politiek oogpunt. Met de hulp van ruimtelijke beslissingsmodellen is het mogelijk dat de beslissingsmogelijkheden van politici worden ingeperkt. Een mogelijk onderzoek zou zich moeten richten op de politieke wil om ruimtelijke beslissingsmodellen in het proces van het plannen van infrastructuur te achterhalen.

Preface

This report is the result of my MSc research done from February to December 2009 in order to finish my studies on Civil Engineering and Management at the University of Twente in Enschede, the Netherlands. The research was done at the International Institute for Geo-Information Science and Earth Observation (ITC) in Enschede, the Netherlands.

This research will start with a background in chapter 1. Chapter 2 will discuss the research concept including the questions that have to be answered throughout this research. Chapter 3 will discuss the literature that serves as a background for this research. Three concepts will be subject of literature study. These are the planning of road infrastructure, poverty and poverty reduction in combination with road infrastructure and finally SMCE or Spatial Multi Criteria Evaluation. This chapter ends with a theoretical conclusion. Chapter 4 will elaborate on the first two topics of chapter 3, but then in a Mongolian context. Chapter 5 will elaborate on SMCE in the Mongolian context, i.e. an explanation of the model in 5 steps. Chapter 6 will present results followed by a critical discussion in chapter 7. Finally, chapter 8 will present conclusions and give recommendations for further research.

I could have not completed the process of doing the thesis without the help of many people. First, I would like to thank the graduation committee. First I would like to thank my professor, Martin van Maarseveen, for his good advice and overview on the thesis. I would like to thank Mark Zuidgeest for his critical views and remarks that kept me sharp, as well for keeping me motivated from time to time. I would like to thank Sukhad Keshkamat, for being a good teacher and for being so dedicated to the matter. Secondly, I would like to thank my friends and family for their unconditional support, not only during the last few months of my study, but throughout the more than 7 years of studying. Finally, I owe a big thank you to Anne, for receiving the unlimited supply of support, an occasional pep talk and a lot of love. Thanks to all.

Jacco.

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1 Background

With the Millennium Development Goals or MDGs as clear goals for governments, Non Governmental Organizations (NGO's) and financial institutions such as the World Bank or Asian Development Bank, the ability to measure their project outcomes in terms of these goals is crucial. An important type of projects that is often regarded as contributing to MDGs is the planning of road infrastructure in developing countries. The planning of (rural) road infrastructure is said to provide people with access to opportunities such as employment, education or healthcare. Many researchers have written about the positive effects of road infrastructure on the wellbeing of (rural) population. Gannon and Liu (Gannon & Liu, 1997) are describing the role of transport in poverty reduction as being a complementary one. Transport alone cannot reduce poverty. Gannon and Liu state that the strongest relation exists between transport and economic development. The ADB (ADB, 2006) did research on the questions how rural roads help reduce poverty and how rural road projects need to be designed accordingly. Rural road infrastructure improvement may have strong effects on changes in transportation services, changes in travel patterns, changes in village profiles, changes in income and welfare. The IFRTD (IFRTD, 2005) states that transport plays a key role in reaching alleviating poverty. According to IFRTD, investments in road infrastructure can be effective in lowering input prices, increasing agricultural production and reducing the monopoly power of agricultural traders by facilitating better access to markets.

However, as stated by Van de Walle (Van de Walle, 2009), only few of the aid-financed rural road projects in developing countries were subject to impact evaluations. Although many claims have been made on the positive impacts of road infrastructure, so far there has not been a proper research on the impacts of road infrastructure route planning. Feasibility studies are often based on financial criteria such as the Internal Rate of Return (IRR), Net Present Value (NPV) or vehicle operating cost (voc) savings without taking into account economic, ecologic or social criteria. Van de Walle recognizes that assessing the impacts of rural road projects is a very difficult task, but states that a credible rural road impact evaluation requires panel (with pre-intervention) data for project and appropriate non-project areas and other relevant data sources.

Keshkamat (Keshkamat, 2007) has already done research on the possibility of using spatial tools, specifically Spatial Multi Criteria Evaluation (SMCE) tool to improve the planning of (rural) road infrastructure. A SMCE is a powerful tool in a GIS environment which helps to make informed spatial decisions using multiple spatial criteria. By taking the views from several stakeholders and combining these into a set of spatial criteria values that influence the planning of road infrastructure, several alternatives can be developed with the possibility to estimate impacts beforehand. Keshkamat has proven this method to be successfully for a case study of the Via Baltica Highway in Poland.

When the positive (social) impacts of rural road infrastructure can be measured with a certain method, the current feasibility studies can be improved by adding such a method in which the economic, ecologic and social impacts of planning road infrastructure can be estimated. By adding an estimation of possible impacts beforehand, assessment can take place with the project after implementation.

This research will look at the possibilities of using geo-spatial tools and especially the use of SMCE in road infrastructure planning. It will investigate whether social criteria can be included in a SMCE as an addition to the economic and ecologic criteria that are already proven. It will look at the possibilities of including SMCE in feasibility studies as a tool to estimate the impacts that road infrastructure routing may have in terms of social impacts. It will therefore be guided by known effects many researchers have written about, such as the positive impacts of road infrastructure on MDG goals. The prime focus of this research will therefore be on MDG-1: the eradication of extreme poverty. However, when successful other goals such as the right to education and healthcare could also be estimated, whenever road infrastructure can contribute to these goals.

The research will be supported by a showcase of the Asian Highway Network. Currently the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), together with countries in Asia and Europe, is working on a project to create an Asian Highway network; a network of highways crossing international borders such as there is in Europe (TEN-roads), the Americas (Pan-American Highways) or Africa (Trans-African highway project). One of those countries through which a cross border highway network will run is Mongolia, landlocked between Russia and China and the least populated country in the world. Three Asian Highways will run through Mongolia, of which the AH32 or Millennium Road will cross the country from east to west. This research will focus on this AH32, and in particular the part west from the capital of Ulaanbaatar, which connects to the AH4 in the regional capital of Khovd in the western end of the country. Currently, Keshkamat is doing a PhD research on developing a spatial decision support system for the environmental assessment, formulation and evaluation of optimal transport corridor alternatives in which this case is also used.

Keith Griffin (Griffin, 2001) mentions in the strategy for poverty reduction in Mongolia a few themes that are central in reducing poverty in the country. Among those are creating employment, the need for investment (in human, infrastructural and natural capital) and a decentralization of planning. This means that investments in road infrastructure in Mongolia could contribute to the country poverty reduction strategy as well.

It is expected that this research can contribute to the discussion on the links between road infrastructure planning and poverty reduction, and that it is possible to include poverty reduction criteria in the SMCE process.

This introductory chapter will be followed by a description of the research methodology. This research methodology will consist of two parts, the conceptual design of the research and the technical design of the research.

2 Research Concept

The research plan consists of two parts. First the main research problem and research objective will be presented. Accordingly the questions that should be answered during this research and why these questions need to be answered will be discussed. The second part consists of a description of the research methodology. The research methodology will discuss how the research questions will be answered.

As seen in the previous chapter, one of the main problems is that the current procedure of route planning is disputable, especially in the context of planning for poverty reduction. SMCE could be a way of improving the route generation and selection of road infrastructure. Therefore, the main objective of the research has been formulated as:

> To analyze the potential of geospatial technologies and SMCE in the planning of highways as a means of contributing to MDG-1 (poverty reduction).

The next step is the development of research questions, in which the main research questions and supportive questions will be proposed.

2.1 Questions

The first step of the research is the formulation of a main research question. In fact, this is nothing more than converting the main objective into a question. It is important though to do so because it helps to understand what has to be done in the research. The main research question is:

> Can geospatial technologies and SMCE contribute to the planning of road infrastructure as an institutional tool for poverty reduction?

The main research question can be read as two questions in one. The first is: Can geospatial technologies and SMCE contribute to the planning of road infrastructure. This means that current practice will be compared to the use of SMCE. The second is: Can geospatial technologies and SMCE contribute to the planning of road infrastructure as an institutional tool for poverty reduction? In this question, SMCE will be compared with SMCE with the addition of poverty reduction. Hence, the first research question is as follows:

> 1. What is the potential of using SMCE and other geo-spatial technologies for the planning of road infrastructure, compared to current planning practices?

In order to be able to answer this question, supportive questions have to be answered. The supportive questions split up in a theoretical part (question 1a. and 1b.) and an empirical part (question 1c. and 1d.).

1a. What is the current practice in the planning of road infrastructure (in general, for highways, for the Asian Highway network, for AH roads in Mongolia)
1b. How can SMCE and other geo-spatial technologies, in general, improve planning of road infrastructure route alternatives?
1c. Applied to the Mongolia case, what are the differences between a reference route planned with a current approach and a route developed with a SMCE?
1d. Does the use of SMCE to generate alternatives for the planning of road infrastructure bring benefits compared to current practice?

First, the current practices in road infrastructure planning and especially highway planning (in the context of development aid) have to be researched. In order to see which general criteria are used in planning road infrastructure. When this is clear, the possible or potential role of SMCE has to be examined, based on the previous use of SMCE and the answer to the first supportive question.

After answering the first and second question, the SMCE will be applied for the case study with the help of a second research question. When the SMCE is used, the output is a suitability map or several suitability maps from which a route of least impedance can be constructed. Depending on the weighting of criteria, this can be done more times to create more maps and thus more routes. These routes will be compared with the reference route available. Based on these routes, an assessment has to be made if the routes constructed with the help of SMCE can contribute more to poverty reduction than a reference alternative.

Finally, all these answers combined should give answer to the first research question.

As mentioned before, In order to answer the questions 1c and 1d, an answer should be given to the question how poverty reduction can be used as input for the SMCE. The second research question will be:

2. What is the potential of adding MDGs as input to a SMCE for the planning of road infrastructure, compared to using SMCE without adding MDG input?

Supportive questions to this question are:

2a. What is Poverty / Deprivation / Exclusion?
2b. How can road infrastructure contribute to poverty reduction?
2c. How can poverty reduction be used as additional input to a SMCE?
2d. Applied to the Mongolia case, what are the differences between a route developed with a SMCE and a route developed with a SMCE and additional poverty reduction criteria?
2e. Does the addition of poverty criteria to the SMCE bring benefits compared to the use of SMCE without additional poverty reduction criteria?

The first step is to figure out what poverty is, or how poverty is described in general. The search for the answer goes further than only figuring out what poverty is, but also other often used concepts in the same context such as deprivation and (social) exclusion.

Next the role that road infrastructure can play in poverty reduction is researched.

Next, based on the answer to question 2b, the spatial aspects will be identified, which can be used at a later stage as possible input to geospatial tools such as the SMCE.

After the SMCE is done, question d and e could be answered in order to give the potential of adding social criteria (poverty reduction) to the SMCE.

The two questions are answered around three main principles. These are the principles of road planning, poverty reduction and SMCE. How the two questions hook into the three principles is showed in the figure below.

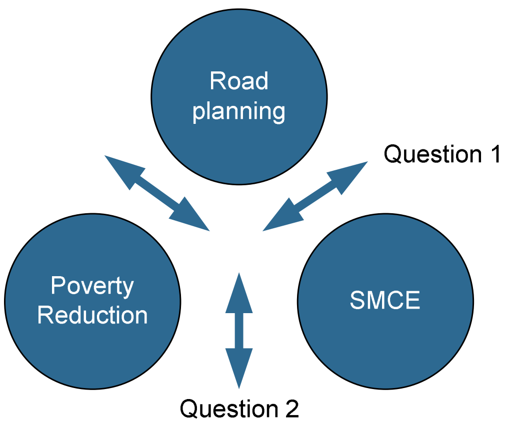

Figure 1: Position of the research questions

The figure shows that one link is not covered by the questions. This is the link between road planning and poverty. Since this link is very important for the general understanding of the research topic and for answering the other questions, the link between road planning and poverty reduction will be discussed as well.

The next paragraph discusses the methodology.

2.2 Methodology

The flowchart below is based on the research issue and presents the methodology used in this research.

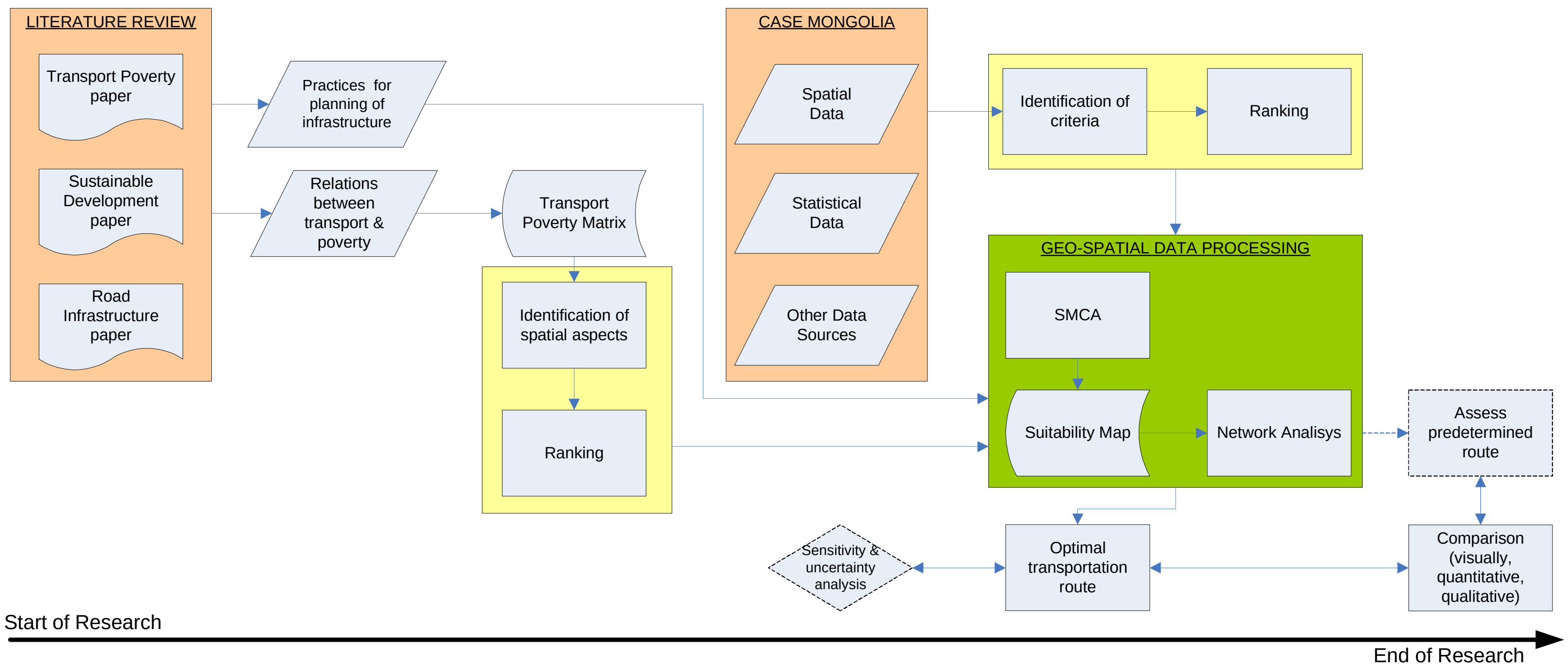

Figure 2: Methodology Flowchart

At the start of the methodology, there are two main bodies of input, which are placed in the orange frame. First there are the papers (or other research sources) which describe relations between transport and poverty, sustainable development and road infrastructure. Second there are case-specific data for Mongolia, which consist of spatial data (geological data and land use data), statistical data (e.g. income figures, employment rate, trade figures) and other data sources (e.g. interviews, law or governmental plans).

Based on the papers, current practices for the planning of road infrastructure are identified, in order to give answer to question 1a. and 1b. These outcomes will also serve the SMCE. Furthermore, a list of relations between transport and poverty is formed. This list will serve as input to the Transport Poverty Matrix. This list will also serve to identify the spatial aspects from which a selection will be used in the SMCE. How this selection will look like, depends on the outcome of the Transport Poverty Matrix and the ranking of relations accordingly. Strong relations are likely to receive preference over weak relations. Finally, a selection will be made and transferred into criteria that can be used spatially in the SMCE.

When the SMCE is fed only by poverty transport criteria (which leads to a pure poverty reduction suitability map), certain constraints are looked over. Therefore, other criteria will be developed from the case. These criteria are for instance constraints regarding soil types, slopes and the crossing of environmental protected zones, but also legislative plans. These will also be ranked (weighed) and used as input for the SMCE. The output of the SMCE is a suitability map. This map is divided into a grid with pixels, where each pixel receives a suitability value. Network analysis will then create a route with the highest possible suitability over the network of existing[1] roads. The process of the SMCE can be done more time, with other rankings of criteria in order to get different alternatives.

The result is several routes constructed over different weighing of the alternatives. These routes can be compared with a reference route. Comparison can be done in different ways. The first way of comparison is visual. Just by looking at the routes and the differences, assessment can be done. However, much information stays hidden this way. Quantitative comparison is another possibility. Length, impedance and other quantitative characteristics can be compared. The best way of comparison however is a qualitative way in which something can be said about if and to what extent a route contributes to poverty reduction. This will be done using the method of cost-benefit analysis or CBA. Costs and benefits of the proposed alternatives will be expressed in monetary units. This means that costs of poverty and benefits of poverty reduction have to be expressed in money terms as well. Finally, the result of this method gives answer to the question whether or not the SMCE method contributes to poverty reduction.

[1] As will be made clear in the case paragraph, the network of roads in Mongolia is highly informal, and might not represent reality. This is a implication of the use of the Mongolia case and simply has to be accepted

3 Literature review

This chapter discusses literature that has been reviewed for this research. The literature review will be structured according to a funnel-shaped principle and will be based on three main subjects:

1. Planning of road infrastructure and routing
2. Poverty alleviation through road infrastructure provision
3. SMCE as a tool for impact evaluation of poverty reduction road planning

The figure below presents the structure of chapters 3, 4 and 5 graphically.

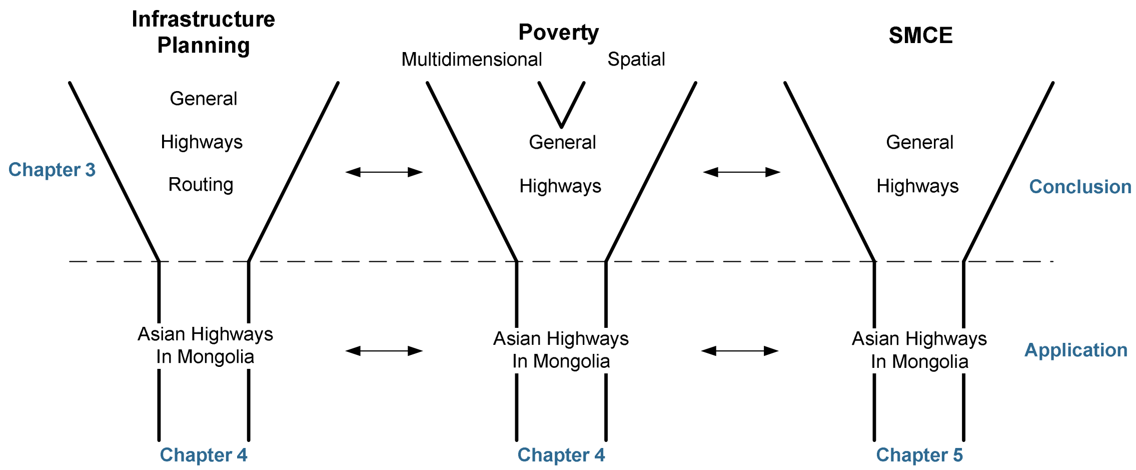

Figure 3: Structure of chapters 3, 4 and 5

Based on the introduction in the first chapter, the planning of road infrastructure and the routing question is discussed first, as it is unclear what the current principles and methods are (especially for the generation of route alternatives). Once insight is gained on this part, the link to poverty and poverty reduction is made. Many claims have been made on road infrastructure and accessibility contributing to poverty alleviation. However, none of these claims have been subject to impact evaluation, which is necessary in order to be able to make prove the claims. Here is where SMCE can fulfill a role in supporting the research and providing a tool that can help in the process of impact assessment. When impacts can be estimated beforehand with SMCE and measured afterwards with the support of panel data, routes can be designed to such an extent that they can actually contribute to poverty reduction.

After a thorough research on these 3 subjects, a conclusion can be drawn on the possibilities of using SMCE as described above. This will serve as a base for chapter 4, in which 2 of the 3 topics are further investigated in order to develop an application. For this research a showcase of the Mongolian Asian Highways will be taken as an example. SMCE is not taken into account for the Mongolian case in chapter 4 yet, since this will be the subject of chapter 5, in which the methodology followed will be described based on the information derived from chapters 3 and 4.

3.1 Planning of road infrastructure and routing

Current practice in the planning of road infrastructure is discussed in this paragraph. Three topics will be discussed here. These are:

- Transport planning in general
- Planning of highway infrastructure
- Generation and selection of route alternatives

Based on a discussion on these three topics, an overview of the current practice in the planning of infrastructure can be given.

3.1.1 Transport planning in general

According to the definition of the Transport Planning Society in the UK, transport planning is:

"Transport planning is taken to be all those activities involving the analysis and evaluation of past, present and prospective problems associated with the demand for the movement of people, goods and information at a local, national or international level and the identification of solutions in the context of current and future identification of economic, social, environmental, land use and technical developments and in the light of the aspirations and concerns of the society which it serves"

What can be learned from this definition is that transport planning starts with the analysis and the evaluation of problems associated with the demand for movement. Initiation of analysis and evaluation is mostly, if not always, guided by governmental authorities, since these usually bear the responsibility for the infrastructure. Usually, when a problem is identified, public authorities react by developing a transport policy. Transport policy can be defined as:

"*Transport policy is the development of a set of constructs and propositions that are established to achieve particular objectives relating to socio-economic development, and the functioning and performance of the transport system*".[2]

The transport policy process (and policy processes in general) can be visualized by the policy cycle. This policy cycle shows the steps that are taken in the policy process. An example of a policy cycle is shown in Figure 4.

[2] Taken from lecture slides UT CTS course Planning & Sustainability 1, 2008

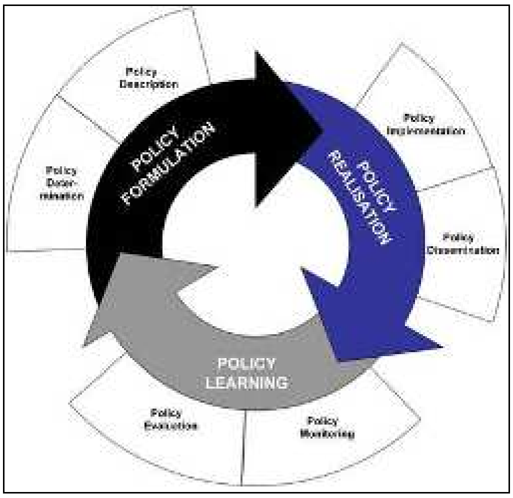

Figure 4: Policy Cycle (as used by ERA-NET TRANSPORT)

The policy process is consisting of 3 phases, the policy formulation, the policy realization and the policy learning. It is a cycle, which means that policy is a continuous process.

The difference between planning and policy is that transport policy has a strong legislative basis. Policies are often, but not always, incorporated into laws and other legal instruments that serve as a framework for developing planning interventions, whereas planning does focus on achieving a particular (meta)goal.

Given the overview of planning in general, the next step is an elaboration on the planning of highway infrastructure.

3.1.2 Planning of highway infrastructure

The planning of transport infrastructure differs for every country. This paragraph will describe the Dutch situation as an example for the planning of highways (network of national roads and express roads). In the Netherlands, planning of highways is done by following a nine step procedure, called corridor / EIA (Tracé / m.e.r.) –procedure. The nine steps in this procedure are:

Step 1: Start note
Step 2: Participation and advice
Step 3: Route note / EIA
Step 4: Participation, advice and check
Step 5: Taking position
Step 6: Preliminary route decision
Step 7: Route choice
Step 8: Construction
Step 9: Evaluation

Step 1 gives an outline of the problem and the direction of solutions the government desires to go. It will also give directions to which environmental aspects will be researched. In the next step, this note can be commented and criticized from the general public. These comments will be taken into account in step 3, in which the problem will be described in detail and detailed solutions including their effects will be given. Again, this note will be available for comments from a general audience as well as from specialists. Based on this round of comments, the minister of the Department of Transport will take position, which will be further developed in the preliminary route decision. After this step a final round of participation by the general public takes place before making a final decision. Finally, the construction phase can be started, followed by an evaluation of the environmental aspects. If necessary, measures are taken to restore possible negative impacts on the environment.

In the third step of the process, route alternatives are generated and for each alternative the environmental impacts are given. It is not stated how alternatives are generated and what type of criteria are taken into account. Moreover, already in the first step directions are given where to search for solutions. Possible solutions can therefore already be biased from the first step on.

Recently a new design manual for highways (NOA) was published by the Dutch Directorate General for Public Works and Water Management (NOA, 2007). These guidelines supersede the old guidelines because of criticism to the former on the lack of stakeholder involvement. NOA no longer takes into account only technical criteria but says design should be based on functional design principles. The idea is to go from policy and technical principles towards a design question. This can be seen as a framework to generate solutions and test them according to the design question. The subjects that are discussed in the framework are: Accessibility, Safety, Environment, Infra-providing (maintenance), Traffic Management and Costs. The remaining of the report is used to elaborate on the technical criteria of planning motorways such as curvature, slopes, viewing angles etc. The amount of technical criteria and their nature makes that these criteria might influence the route generation to a very large extent.

Not only the Netherlands have such guidebooks on the planning of motorway infrastructure.

The road planning and design manual of the Queensland Government in Australia (Queensland, 2002) shows as well a high focus on technical criteria with only limited attention to function of roads or stakeholder involvement.

In the location analysis chapter of the Final Design Concept Report of the US60: Florence Junction to Superior, (US60, 1999) the process of location analysis is discussed and the various options are clarified. Again, almost all criteria mentioned are technical by nature, although the introduction starts with mentioning other criteria as well.

It seems that the generation and selection of route alternatives is not formalized in documents, although EIA procedures in the Netherlands for instance show that multiple routes are generated and that often variants of alternatives are created after a round of public participation. It is important to gather knowledge in how the generation and selection of route alternatives is done at this moment, since SMCE possibly intervenes in this particular process.

Therefore the next paragraph will focus on the question to how the generation and selection is done.

3.1.3 Generation and selection of route alternatives

There is little known about the procedures that are taken for the generation and selection of route alternatives. This paragraph will try to dig deeper into the topic to see whether any formalized rules do exist. If they don't exist it is interesting to see how the informal process is done in a particular project. Therefore a short interview with a project leader of a Dutch highway project was organized, which will be presented in this paragraph as well.

The Indian Road Congress has published a manual on route location, design, construction and maintenance of rural roads (IRC, 1997). This manual discusses the route selection in short. The paragraph on route selection says:

> *"Route selection is one of the basic steps in providing a road and calls for careful study. A number of considerations need to be taken into account before finalizing the alignment, for instance population to be served, existing road network, topography and subgrade conditions, environmental factors, availability of materials etc. Salient points to be kept in view while this is done are spelt out in appendix 1. It would be rare that a single alignment satisfies all the factors involved. In most cases it will be necessary for the engineer to exercise his judgment and decide on the optimum alignment keeping in view the technical and other considerations."*

The points to be kept in mind from appendix 1 are purely technical. Besides a strong focus on technical criteria (a point already seen in the previous paragraph, the latter part of the quote shows that route selection is based on judgment of one single engineer. Although this part does not say anything on route generation, it shows that selection is done based on judgment of an engineer, which makes the selection a fairly subjective process.

Catbagan and Regidor (Catbagan, 2003) describe in a paper the development of a route selection system using three dimensional cost models. In this paper, an outline is given of various ways highway design and route selection is done. They describe a two step procedure on the process of route generation and selection. In step 1, which is the location step, a draft route is proposed. This is followed by step 2, in which detailed alignment is supported by technical drawings. They show a flowchart of a particular highway location and design process, as can be seen in Figure 5.

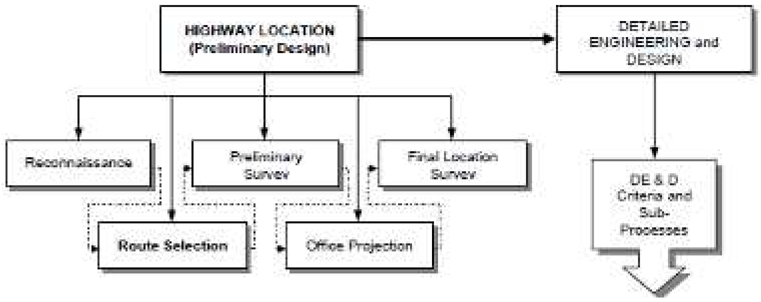

Figure 5: Highway location and design flowchart (Catbagan, 2003)

Catbagan and Regidor have further mentioned that route selection is basically a refinement of feasible alternatives, after which they mention a number of (almost all) technical criteria on which feasibility is based. On alignment of alternatives they say that a designer can propose a route everywhere between a start and an end node, but aims on choosing a location with lowest construction cost, the right land, traffic and social consequences and respecting technical constraints.

In the book Route Location and Design by Hickerson (Hickerson, 1967), a number of controlling factors for the location and design of line infrastructure (which also includes motorways) is given. The most important are traffic to be accommodated and terrain. Although in flat country a straight line would be the easiest, curves are applied to avoid monotony of driving and to avoid certain places. Mountainous terrain calls for different solutions. The specific part on highway location and design mentions again two main considerations. These are technical criteria and proper traffic research, including traffic census, OD studies and demand forecast.

In (Nederveen, 2007), the process of route generation is also discussed. From a perspective of cutting down on travel time and on construction costs, a straight line is the most effective solution, unless there are technical boundaries, such as mountains. In areas where there is higher stress on land use, more constraints will occur, which makes the straight line not possible and limits the overall options of route generation. Therefore bundling of infrastructure is used more and more to limit the negative (and diffuse) effects of generating new corridors.

To get information from a recent existing project, an interview was organized with Mr. Marcel Meeuwissen (Meeuwissen, 2009) from the Municipality of Enschede. He is one of the senior members of the city’s urban planning department and has been involved in 2 projects concerning the planning of roads including route design and location. The first is a local project where the University of Twente in Enschede will be connected to the A1 motorway. The second project he’s involved in is the upgrading of the N18 to A18, a motorway which will connect Enschede and Arnhem through the Achterhoek region. He has been asked several questions on the generation and selection of route alternatives with respect to his projects. Main questions asked to him were:

- How many varieties of possible routes connecting the pre-set origin and destination were developed and with what level of detail? How did those routes differ from each other?

- Who designed the routes and what were the criteria, constraints or wishes with respect to designing the routes.

- How were the routes assessed? Was the assessment formalized or developed for this project only?

The project that should connect University and A1 started with the local mobility vision in which this project was initiated. While this project has a long time to go until completion, the route generation and selection would go as follows:

First, the start and end point of the connection should be decided upon. This is done by logical reasoning by the project team. The next step is that a project team would design several alternatives, based on expertise and based on the constraints of the area. Such a team would consist in this specific case of traffic specialists, spatial planning specialists, environmental specialists and perhaps some of the larger stakeholders in this project such as University representatives. Based on their expertise, the goals of the project and the constraints set by the environment they will design several alternatives and will assess those alternatives based on criteria they choose. These criteria are usually a mix of qualitative and quantitative criteria. The alternatives will be sent to the cities executive board (college van B&W) who will decide on a preference for a certain alternative. This alternative will be approved or rejected by the city council (gemeenteraad). The process is highly informal as this is usually the case with road that are being planned / constructed under local authority. When roads belong to higher authorities things change.

The N18 belongs to a higher level road authority, which is in this case is the Dutch Directorate General for Public Works and Water Management. Although the planning process is highly formalized in these projects (the earlier discussed Trace / m.e.r procedure) the design and selection of route alternatives is not. Based on 2 main criteria, connecting Twente with Arnhem and increasing safety in the surrounding region, alternatives were developed by the project team. Those alternatives differ from each other in whether they pass villages and on which side. More variants are brought in by stakeholders and finally all variants are assessed using a multi criteria analysis.

An interesting point on the N18 route is that the 2 main criteria differ in scale, which will have an effect on the final route planning. Connecting Twente and Arnhem is on a large scale in which the whole route is taken into account. Improving safety along the corridor is a local scale criterion with local effects from local decisions. Meeuwissen stresses the importance of taking into account scale issues and opts for a distinction between more global and more local criteria.

Although the route selection process became clear from this interview, the actual design process still remains vague. There is a need for clarification though, for two reasons. First, when a transparent design process is known, evaluation of this process would be easier. Secondly, a comparative study between the current process of designing a corridor and the design of a corridor using SMCE could be done. Then the strong and weak points of each method can be found and recommendations can be done on how to deal with both methods.

3.1.4 Summary

Paragraph 3.1 discussed the concept of planning. Planning in general, planning for highways and the generation and selection of route alternatives is discussed in this paragraph. The outcomes of this paragraph create enough background to start with the concept of poverty.

The outcomes of this paragraph also make it possible to answer the question: *What is the current practice in the planning of road infrastructure (in general, and for highways in particular).*

The current practice can be summarized as:

- Derived from policy. Policies in which goals are presented are transformed into actual projects which also incorporate the planning of road infrastructure.
- In the Netherlands the process is highly structured with lots of attention to public participation
- There is plenty written on technical criteria or constraints, but hardly anything on other criteria.
- The process of route generation and selection is a vague process, usually taking into account different criteria. The number of criteria (especially the technical criteria) limits the generation and selection of alternatives. This makes the process of route generation and selection unclear.

Finally, a point that should be taken into consideration is that scale is affecting the planning of road infrastructure. How scale can be considered should be taken into account when using SMCE in the planning process. Although this research will not focus on scale, it will give directions on how scale can be applied to further research in the recommendations chapter.

Now that the planning of road infrastructure is discussed, the next step is to see whether planning can have a positive impact on the reduction of poverty. This difficult question will be discussed in the next paragraph.

3.2 Accessibility, Poverty and Infrastructure

This paragraph will discuss infrastructure, accessibility and poverty. Planning of road infrastructure is believed to have a positive impact on poverty alleviation, which has been supported by many researches. However, none of these researches brings in scientific evidence that really links the positive impacts of poverty alleviation to road infrastructure.

This paragraph will start by giving some definitions of poverty, from which the scope of poverty is made clear. Next, the link between poverty and accessibility (and later road infrastructure) will be discussed. A special paragraph on poverty in chapter 4 will elaborate on poverty and poverty alleviation for Asian Highways and for Mongolia.

Poverty in this paragraph will be discussed from two key aspects. These are the multidimensional aspect of poverty and the spatial aspect of poverty. What these aspects actually mean will be clarified in this paragraph as well.

3.2.1 Definitions of poverty & poverty in MDGs

On poverty, numerous definitions exist. The World Bank says the following on poverty:

> *"Poverty is hunger. Poverty is lack of shelter. Poverty is being sick and not being able to see a doctor. Poverty is not having access to school and not knowing how to read. Poverty is not having a job, is fear for the future, living one day at a time. Poverty is losing a child to illness brought about by unclean water. Poverty is powerlessness, lack of representation and freedom."*

The World Bank describes poverty using several examples. These examples are based on the basic amenities a person needs: food, shelter, healthcare, education, employment and a voice. This description explains the poverty still existing in many parts of the world, in all its dimensions.

The Asian Development Bank (ADB) gives this definition which is taken from (ADB, 1999):

> *"Poverty is a deprivation of essential assets and opportunities to which every human is entitled. Everyone should have access to basic education and primary health services. Poor households have the right to sustain themselves by their labor and be reasonably rewarded, as well as having some protection from external shocks. Beyond income and basic services, individuals and societies are also poor—and tend to remain so—if they are not empowered to participate in making the decisions that shape their lives."*

The definition from the ADB shows similarities with the definition from the World Bank. Both discuss that people are deprivated from needs as food, shelter, health, education etc.

Poverty is also represented in the Millennium Development Goals or MDGs. The MDGs are a set of meta-goals and targets the United Nations has set to accomplish for 2015 for some of the poorest countries on earth. Although very broad and rough they are used by governments and NGO to monitor their policies. In the Millennium Development Goals, the eradication of extreme poverty is represented by 3 targets with in total 9 indicators. Target 1a focuses on monetary poverty, target 1bn employment and target 1c focuses on hunger. An overview of the targets and indicators can be found below.

Target 1a: Reduce by half the proportion of people living on less than a dollar a day

1.1 Proportion of population below $1 (PPP) per day
1.2 Poverty gap ratio
1.3 Share of poorest quintile in national consumption

Target 1b: Achieve full and productive employment and decent work for all, including women and young people

1.4 Growth rate of GDP per person employed
1.5 Employment-to-population ratio
1.6 Proportion of employed people living below $1 (PPP) per day
1.7 Proportion of own-account and contributing family workers in total employment

Target 1c: Reduce by half the proportion of people who suffer from hunger

1.8 Prevalence of underweight children under-five years of age
1.9 Proportion of population below minimum level of dietary energy consumption

As can be seen from the targets and indicators, poverty as described by MDG-1 addresses less dimensions as the definitions given by WB and ADB. The most probable reason for this is the fact that many other MDGs are addressing other dimensions of poverty. Education is addressed in MDG-2, health in MDGs 4, 5 and 6, gender equality by MDG-3, Environment by MDG-7 and Global Partnership by MDG-8.

According to Leipziger (Leipziger et al, 2003), many see that the MDGs are representing the key development challenges for governments and international organizations. To some others, the goals 2 to 8 seem to be superfluous as long as no progress on goal 1 (Eradication of extreme hunger and poverty) is made. Tandon (Tandon, 2005) gives empirical evidence that there is a strong relation between economic growth and a decline in child mortality. Though MDG 1 cannot be seen as the most important of goals, it is a key goal with many linkages and correlations to all other MDGs. Food and shelter are among the basis needs of people and only if basis needs are fulfilled, people can work on reaching other needs.

Many more definitions do exist. Almost every NGO or governmental body creates its own definition of poverty that suits the organization best. However, they will all have a few parts in common. They all address the multiple dimensions of poverty. Poverty is not only lack of food or money. It is consisting of many more dimensions. Another part many of these definitions share is the word “access”. People don’t have access to opportunities. And not having access means there is impedance between the people and the opportunities. Although access can be seen in various dimensions one of the most important dimensions is physical access. People physically cannot reach their opportunities (for various reasons) or the opportunities cannot be brought to the people.

Hence, 2 components are very important in each definition of poverty, and therefore in each poverty alleviation projects or scheme. Those are:

- Poverty is multidimensional. There are many indicators for poverty and poverty is more than just a lack of food or money. Poverty is multidimensional in the different kinds of poverty, but also in the incidence of poverty. Relative poverty (1 person being poorer or less poor than the other) can be seen as a dimension of poverty as well. If poverty is multidimensional, poverty alleviation should be multidimensional as well. All dimensions should be covered in the ideal poverty alleviation tool.

- Poverty is closely related to having access. Poor people do not have access to assets or opportunities which could make them escape their situation. On of the key access indicators is physical access. This makes poverty a spatial phenomenon as well, since poverty is spatially heterogeneous (Stewart, Kuffer, 2007). The fact that poverty can be seen as spatially heterogeneous is one of the justifications of this research. If there would be no spatial differences in poverty in a certain study area, the idea of adding poverty indicators to a spatial multi criteria analysis would make no sense. This also brings in the idea of relative poverty (differences in poverty or wealth between people on different scales) and geographic poverty traps: areas in which people are more vulnerable to be struck by poverty than in other areas.

The two components mentioned above will be subject throughout this paragraph. It will be visible that multidimensionality and spatiality are also of importance when discussing the link between poverty and transport.

The next part of this paragraph will consist of the discussion between these fields of poverty and transport, which is very extensive.

3.2.2 Studies on Transport & Poverty relations

Ample studies have been published about the linkages between road infrastructure and transport. One of the recurring conclusions in nearly all studies is that better road infrastructure is a necessary condition for poverty reduction, but not a sufficient condition. Transport's role is a complementary one, as described by Gannon and Liu (Gannon & Liu, 1997). Transport itself cannot feed poor people, cannot give poor people money and cannot give poor people work (unless the poor are directly contributing to road construction). However, transport creates access to food opportunities, access to health, access to education and transport creates access to having money in creating access to employment opportunities.

In order to show the amount of research that has been done, some examples are given below.

1. Road investment & improved **access** to transport services can be effective in increasing agricultural <u>production</u>. (DFID, 2002) *also seen in various other researches*

2. Transport sector creates <u>employment</u> opportunities by stimulating economic growth and new investments. (Gannon & Liu, 2000)

3. Provision of transport infrastructure and services can facilitate (or constrain) poor people's **access** to locations where there is greater demand for their services (Blume et al, 1995)

4. Transport is a source of employment (Gallager, 1992)

5. Transport sector creates opportunities for employment through labour based infrastructure construction projects (Ravallion, 1990)

6. Improvement market **access** through better transport conditions → increased surplus → lower production & transport costs (ESCAP, 2006)

7. Stimulates economic growth, raises agricultural and urban productivity, generates surpluses, facilitates diffusion of new technology and spread of new ideas and innovations

   Facilitates **access** to employment and product market

   Generates employment

   Facilitates growth of secondary and tertiary sectors

   Promotes tourism along major transport corridors

   Improves food security by increasing food production and distribution through increased efficiency of the supply and marketing chain

   (All ESCAP, 2006)

8. Conditions affected by rural road development are
   - Changes in transportation services
   - Changes in travel patterns
   - Changes in village profile
   - Changes in income and welfare

In many of the examples, both employment and accessibility are mentioned as the positive impacts of road infrastructure on poverty reduction. Most of the relations mentioned above can be summarized in the concepts of improvement in transport infrastructure which creates an improved accessibility to employment possibilities. This can of course be generalized, saying that an improvement in transport infrastructure creates improved access to all kinds of opportunities, including employment, education, healthcare etc. This is where the multidimensionality and the spatial component come together over some examples from literature. These concepts will be used further in this research to incorporate poverty reduction in SMCE.

The link with the Millennium Development Goals is also evident. When focusing only on poverty (and not on hunger), employment is even set as a separate target.

In the research methodology the idea of constructing a transport poverty matrix was developed. This is particularly interesting when many dimensions of both poverty and transport do exist. What could be seen from such a matrix is where the focus on research is between poverty and transport. However, it will not be done because it is very difficult to choose the right dimension and classify accordingly. Both poverty and transport are too vague as a concept to find one dimension of categorization. Besides, the relations are very clear cut so the need for such a matrix is not very high.

3.2.3 Impact evaluation of Transport & Poverty relations

Funding of road projects by financing organizations is very popular. As can be seen from Figure 6, 20 percent of loans are related to transportation.

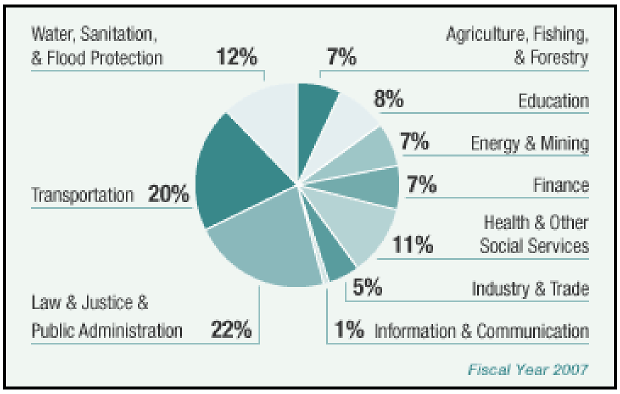

Figure 6: World Bank loans per sector

Van de Walle (Van de Walle, 2002 & 2009) states, that despite the popularity of those projects, few of these projects have been subject to a proper impact evaluation. This means that the knowledge on impacts in limited. However, the potential of rural road projects on poverty alleviation is believed to be high, which gives a high need for those impact evaluations. According to van de Walle, *"a credible rural roads impact evaluation requires panel (with pre-intervention) data for project and appropriate non project areas; detailed information on outcome indicators, baseline attributes and controls for heterogeneity and exogenous time varying factors. Geo-referenced data can also be extremely useful. With the appropriate data and techniques a large number of interesting and far-reaching questions about rural road impacts can begin to be answered and discussed with large public good benefits."*

Although Van de Walle discusses this for the purpose of doing impact evaluation for rural roads, this needs to be done for every type of road infrastructure that is said or thought to be beneficial for the poor people, including higher classified roads such as highways or motorways.

One of the techniques that could contribute to poverty reduction is the use of SMCE. With the appropriate data and techniques the SMCE tool could function as a pre-assessment tool for the impact evaluation of road projects. What SMCE is and how it could serve a purpose will be discussed in the next paragraph.

3.2.4 Summary

This paragraph showed that the concept of poverty is very complex. This starts with the definition. Many definitions do exist, with each of them having similar components but also different views on the concept of poverty. Two components are present in almost every definition of poverty. These are multidimensionality and spatiality.

Poverty as a multidimensional phenomenon can be seen in the Millennium Development Goals among other sources. In the MDGs, almost all of the goals can be linked to poverty. Poverty is lack of food or employment (MDG 1), lack of education (MDG 2) or lack of proper basis healthcare (MDGs 4, 5 and 6).

Poverty is also spatial, because there is distance between the poor people and their opportunities, because poverty is spatially heterogeneous and because poverty is relative. In fact, the spatial dimension of poverty is one of the many dimensions poverty has, which makes poverty a difficult topic to work with when not properly defined. The fact that poverty is multi-dimensional and spatial, makes that scale plays a role here as well. In different (geographical) scales (which is a spatial way of looking at poverty), different dimensions of poverty can have a larger or smaller role.

This paragraph also showed that poverty and road infrastructure (both in construction and use) are linked. There are many researched that show the linkages between poverty and transport. Two things are often seen in these linkages. Many road infrastructure projects are said to contribute to poverty reduction over the creation of employment, or creating access to employment. Access and employment are keywords in the link between poverty and transport, and should therefore be taken into special consideration.

Where should access and employment be taken into special consideration? This should be done when developing a tool that could contribute to the impact evaluation of projects where road infrastructure could contribute to poverty reduction. The methodology possible of creating such a tool (SMCE) will be discussed in the next paragraph.

3.3 SMCE & Poverty & Transport

This paragraph will discuss Spatial Multi Criteria Evaluation or SMCE as a tool that can contribute to the impact evaluation of the positive contribution of road infrastructure to poverty reduction. In the previous 2 paragraphs the planning of road infrastructure (in general and for highways) and the concept of poverty (in general and in relation to road infrastructure) are made clear. This paragraph will first explain what SMCE. Then general applications of SMCE will be explained, followed by a discussion on the use of SMCE for line infrastructure (like highways) and the implications this has for the SMCE process. Before an explanation of SMCE is given, an outline of the general process of multi-criteria evaluation (MCE) is given.

3.3.1 MCE and SMCE

Multi-criteria evaluation is a scientific method to make a rational choice between alternatives. It is used in various scientific areas. The core of the evaluation is that a number of alternatives or solutions do exist, from which a best alternative or solution needs to be selected. The first step is that the alternatives are scored individually on a set of predefined criteria. Next the scores will be standardized. This is the case for the most often used way of MCE, being the weighed sum method. Next, the criteria receive weighs, and the criteria weighs will be multiplied with the standardized scores of the alternatives. This will ultimately lead to a ranking in the alternatives, where the best alternative given the weighs to the criteria will come out. Of course, variation can exist between the weighing of the criteria, which will lead to other ranking in the alternatives.

SMCE stands for Spatial Multi Criteria Evaluation. It is a powerful tool in a GIS environment which helps making spatial decisions using multiple spatial criteria.

SMCE can be used with different themes and different criteria, making a suitable for a large spectrum of spatial projects and making it possible to represent a large number of stakeholder views.

The outcome of an analysis is not only depending on the criteria that are used as input. Large influence also comes from the weight that is given to the different criteria. That this influence is large does also mean that giving weights should be done with care, in order to get proper results and prevent abuse of the tool.

For each of the criteria that are used, a standardization process takes places. With this process, the maps received suitability values. In the example with route alignment close to cities, the closer the distance to the city is, the higher the suitability is. The standardization process tells till where the influence of the city reaches. The suitability value runs from 0 to 1.

The main difference with MCE is the different alternatives are output of the method rather than input. Input maps are scored and standardized on suitability and the weighing of the different criteria (i.e. the standardized scored of the maps) will decide on the output, which can be the suitability of an area or corridor.

In order to explain the process of the SMCE visually, some examples of SMCE are given.

The pictures below are from a SMCE developed by the Australian Bureau for Rural Science or BRS, and gives the potential productivity of grazing. Each of the small pictures is the suitability of one criterion. These added together and given a specific weight, the overall suitability of the potential productivity of grazing is given.

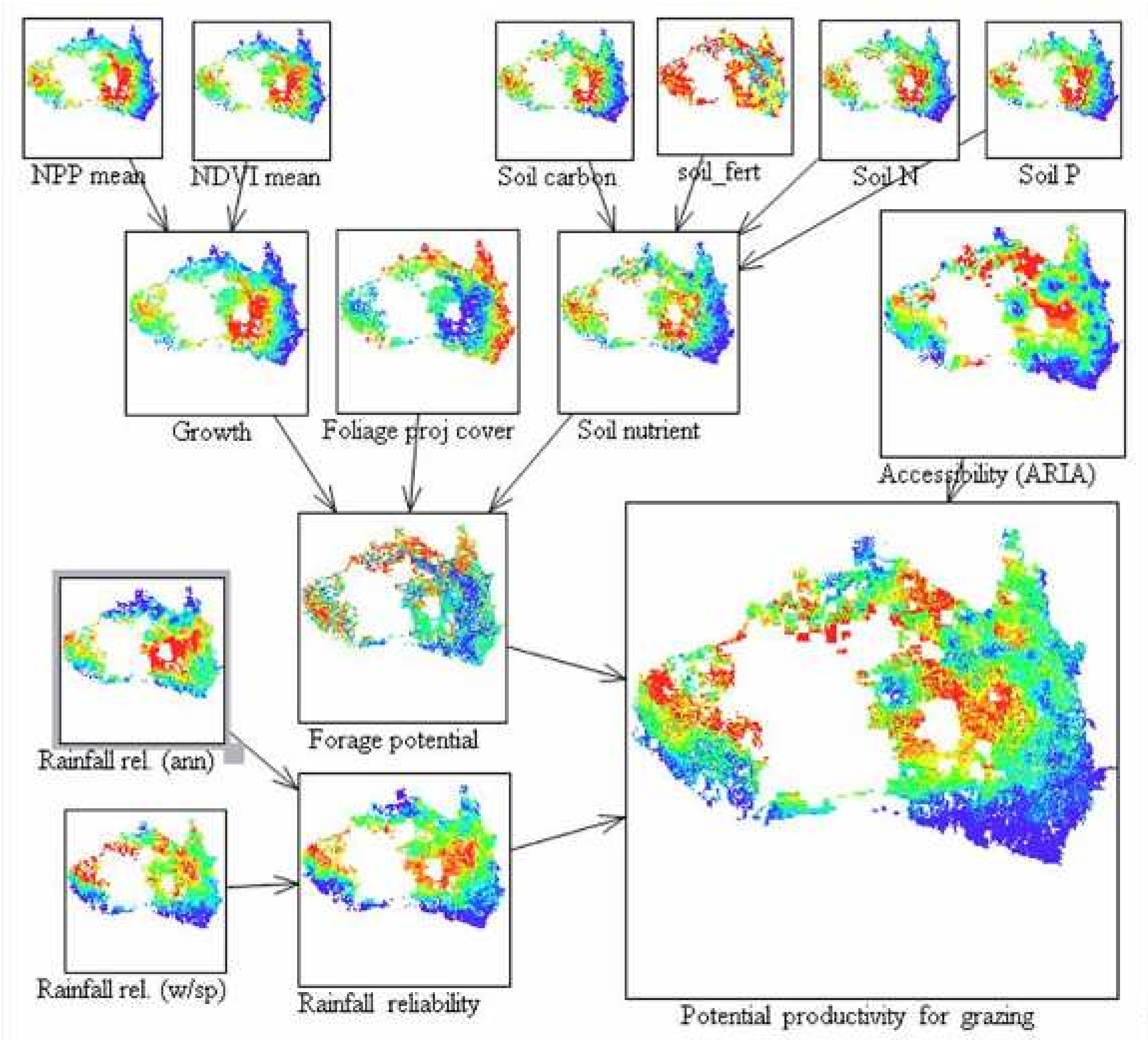

Figure 7: SMCE of potential productivity for grazing (Source: Nicta, Australia)

Another example is the study done on the Via Baltica in Poland by Keshkamat (Keshkamat, 2007). In this study, alternative routes (for upgrading the current network) for the Via Baltica are proposed, based on a SMCE process with different visions. The different visions follow different weights for the various criteria. The Via Baltica is a European Highway which runs from the Polish capital Warsaw to the border with Lithuania. From the suitability maps for the 4 visions (equal, economy, ecology and social), an example of the equal vision suitability map can be seen below.

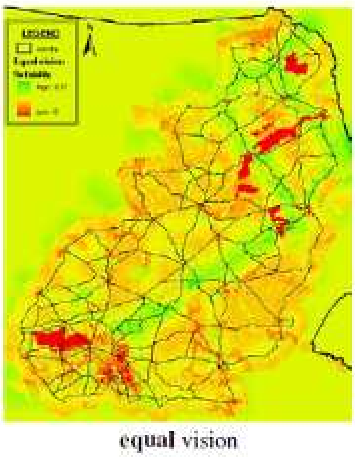

Figure 8: SMCE of suitability map for Via Baltica.

With these suitability maps, routes are created based on a network analysis with least impedance. The results for the equal vision (The Equal Vision Route) can be found below.

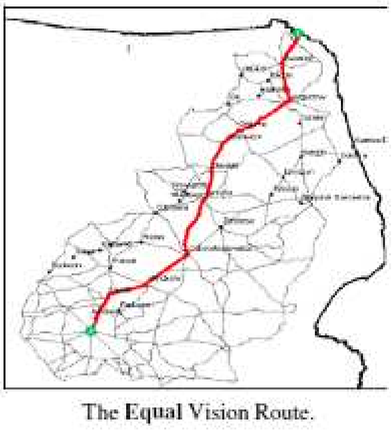

Figure 9: Network analysis for Via Baltica

Now it is clear what the concept of SMCE is about, with applications given for both a landuse and a route generation. However, in order to fully understand what SMCE can do, and to be able to use the full potential of SMCE for the purpose this research aims at, an overview of the use of SMCE is given in order to see where SMCE is used for, and where it could be used for. This overview will be given next.

3.3.2 Use of SMCE

The use of SMCE in research can be divided in three main parts, being economic SMCE, Environmental SMCE and Social SMCE. Between the three main parts, a mix is possible. Below is an overview of some of the research that has been done with the use of SMCE. The majority of research is done with an environmental goal. Less research is done for economic or social projects.

Economic
A Generic Spatial Decision-support System for Planning Retail Facilities. (Arentze et al, 1996)

An integrated spatial decision support system (SDSS) for rural development department of Orissa (Ghose. A, 2004)

Construction on Decision Support System for Route Location Based on GIS (Tae-Ho et al, 2008)

Environmental
Spatial decision support for strategic environmental assessment of land use plans. A case study in southern Italy. (Geneletti et al, 2007)

Multi-objective Spatial Decision Support System for Afforestation Management in Mountainous Regions (KU Leuven research theme)

OSS: A Spatial Decision Support System for Optimal Zoning of Marine Protected Areas (Crossman et al, 2007)

A Knowledge-based Geo-Spatial Decision Support System for Drought Assessment (Kozal et al, 2004)

Integrating spatial multi-criteria evaluation and expert knowledge for GIS-based habitat suitability modelling (Store, Kangas, 2001)

Zoning Marine Protected Areas through Spatial Multiple-Criteria Analysis: the Case of the Asinara Island National Marine Reserve of Italy (Ferdinando et al, 2002)

The formulation and evaluation of transport route planning alternatives: a spatial decision support system for the Via Baltica project, Poland (Keshkamat et al, 2008)

Social
Spatial Decision Support System using GIS based infrastructure: Planning in health & education for Ranchi district (Glosh et al, 2002)

Preliminary Design Of A Spatial Decision Support System For Poverty Management (Akinyemi. F.O. 2004)

An integrated spatial decision support system (SDSS) for rural development department of Orissa (Ghose. A, 2004)

Although this is just a short list of the research where SMCE techniques have been applied, it can be seen that the majority of research focuses on environment or a combination in which environment is primarily involved. But in general, the extent of applications is very broad. Furthermore, all the researches are involving complex problems with many stakeholders and often a large area of influence. Two pieces of research in the box above have particular interest. These are the cursive articles by Tae-Ho et al and by Keshkamat et al. These will be discussed in more detail.

Tae-Ho et al discussed the construction on a decision support system for route location based on GIS. The aim of the study is the application of Analytical Hierarchical Process (AHP) for route location, including a quantitative evaluation. This study takes into account many indicators in various themes. Below, the application map of AHP is presented, which shows the indicators.

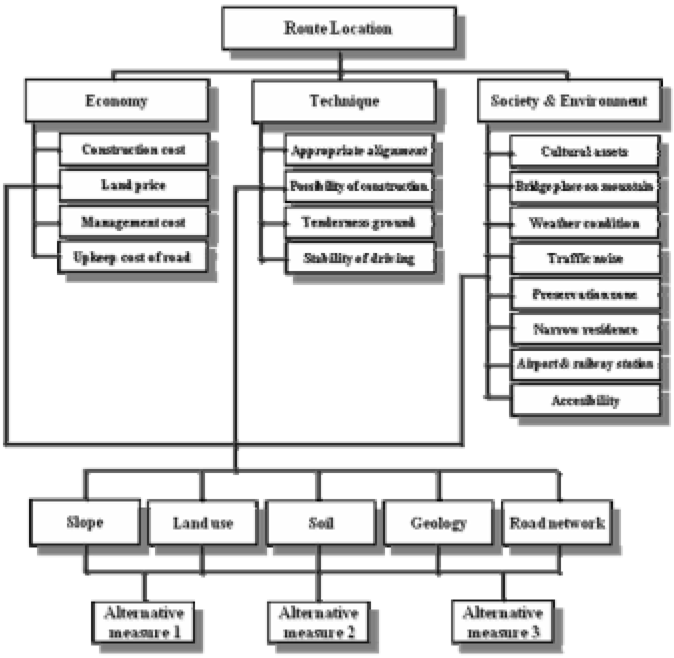

Figure 10: Application map of AHP (Tae-Ho et al, 2008)

What can be seen Figure 10is that in the AHP process three main categories are distinguished. These are Economy, Technique and Society & Environment. Under technology, there is another branch with technical criteria for the construction of highways. This gives insight in the possibilities for the construction of criteria for a SMCE process.

The study was able to quantitatively evaluate the appropriateness of established road alignments by applying the AHP based on GIS. Second, the study improved the technique to select road alignments by applying the decision making system.

Keshkamat introduced the combination between SMCE and planning of road infrastructure, and presented a case in Poland. The main findings of this research were that the combination of input of various stakeholders early in the project and via the SMCE can lead to a route that has less negative (environmental) impacts and more benefits. The planning process becomes more structured and transparent. Hence the method can be used to improve Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA).

From the list presented, another categorization could be made. This is the distinction between use of SMCE for areas and corridors. The majority of the examples from the list are on areas, e.g. the planning of retail facilities or the zoning of marine protected areas. On the other hand there is the line infrastructure SMCE research, with more discussed research from Keshkamat and Tae-Ho. The big difference between these two is the effect that choices will have on the environment / surroundings and can be illustrated with two figures.

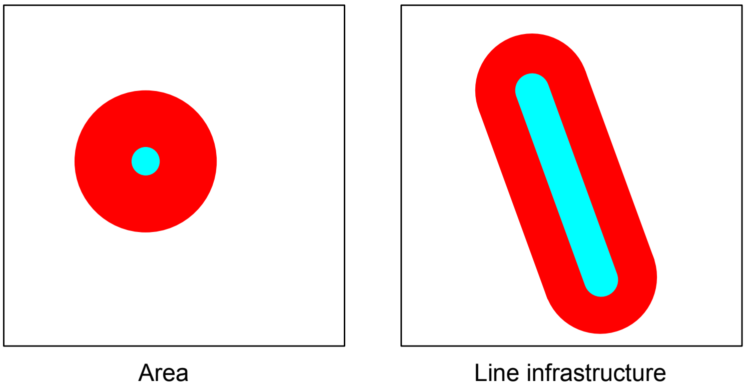

Figure 11: areas vs. line infrastructure

What can be seen from these two figures is that when planning for line infrastructure, the influence will be way larger towards the surroundings. More stakeholders need to be taken into account, more geologic or geographic criteria play a role, i.e. more land in terms of km^2 is involved. This makes the process more difficult, what makes the planning of road infrastructure (especially the route generation and selection) a process well suited to use SMCE for. Since SMCE works structured, it simplifies the many processes that are involved when planning road infrastructure and selecting routes.

Finally, a third categorization can be made. Different research can be categorized in SMCE used for planning and design, and SMCE used for evaluation and assessment. What can be seen from the list is that most of the research has a focus on planning and design, although some do focus on evaluation and assessment or even both. SMCE thus is capable of contributing to planning and evaluation.

3.3.3 Summary

This paragraph discussed what SMCE is, how it is used currently and how it is and can be used for the planning of road infrastructure. SMCE is a tool which helps to make spatial decisions using multiple criteria. These criteria range from economic and ecologic to social and technical criteria.

The number of applications is very broad, from zoning of marine protected areas to the ideal location of shopping centers. The use of SMCE can be classified in two ways. First there is a classification into themes. There has been use of SMCE in economic, ecologic or social themes. Second, there can be a classification into SMCE for areas and SMCE for line infrastructure. SMCE is an ideal tool for use with line infrastructure because of the nature of line infrastructure. The areas of influence are larger, which makes such a project more complicated. SMCE can be supported by bringing a structured method that can contribute to the process of planning road infrastructure and generating and selecting routes.

3.4 Conclusion

In the last three paragraphs subsequently discussed the topics of road planning, poverty and poverty alleviation and SMCE. In this last paragraph, these topics came together and a conclusion could be formulated on answering the first research question: *Can geospatial technologies and SMCE contribute to the planning of road infrastructure as an institutional tool for poverty reduction?*

The process of planning road infrastructure is often guided by a legislative framework. When main road are planned in the Netherlands, this planning has to follow the framework of corridor / EIA (Trace/m.e.r), in which many control points for design and public participation are built in. The process of route generation and selection however is very fuzzy, despite the complex environment to deal with when designing and selecting a route. Planning of road infrastructure is guided first and foremost by technical (design) criteria. Scale is very important in the planning of road infrastructure. Depending on the scale at which a project is considered, criteria are different and impacts are different. Scale should be taken into account when designing and selecting route alternatives.

The process of design and selection becomes more difficult when social criteria are taken into account or better, are tried to be taken into account. Many claims have been made on the positive contribution of road infrastructure to poverty reduction, but no impact evaluation has taken place so far. This difficult task starts with defining poverty and poverty reduction. This chapter showed that poverty can be seen from two main viewpoints: multiple dimensions and a spatial nature. Of all claims made where road infrastructure contributes to poverty reduction, employment and accessibility are often mentioned as factors.

SMCE is very versatile as seen from the applications. SMCE can be applied to economic, environmental and social themes; SMCE can be used for areas or for the more complex projects involving line infrastructure and SMCE has been and can be used for both design stages and evaluation stages. The only constraint SMCE has is that it's input needs to be spatial diverse and spatial data needs to exist.

Since poverty and poverty reduction can be interpreted spatially and ample data resources do exist on poverty reduction (e.g. poverty maps), geospatial techniques but especially SMCE is able to contribute to the planning of road infrastructure as an institutional tool for poverty reduction.

This chapter showed the need for such a methodology from a perspective of road infrastructure planning and from a perspective of poverty reduction and the support by financing authorities. SMCE is capable of providing the methodology.

How the methodology should look like will be discussed in the next chapter. Here, guided by a case in Mongolia, both the ideal model and the model that can be used with data provided for the case in Mongolia will be developed and discussed. First however, the country profile and the 3 main topics from this chapter (planning road infrastructure, poverty reduction and SMCE) will be funneled down towards the Mongolian context.

4 Description of study area

This chapter describes the study area and the study case provided. The structure of this chapter will follow the structure presented at the start of chapter 3. After a general introduction of the country of Mongolia, a subsequent discussion on road planning and route selection in Mongolia and poverty alleviation in Mongolia will take place. After this discussion, the methodology around the case and the application of the SMCE methodology will be discussed in chapter 5. This chapter will be short and will only give an introduction of the country and the countries relation towards road planning and towards poverty and poverty reduction. When the methodology is discussed in chapter 5, the stakeholder analysis will give a detailed view about the country with respect to the case.

4.1.1 Mongolia outline

Mongolia is a republic located in the Eastern Asia region, landlocked between Russia and China. It is the most sparsely populated independent country in the world (less than 2 persons /km^2) and has a total population of 3 million people (CIA, 2009). About one third of the countries population resides in the capital of Ulaanbaatar. Another third lives in the smaller towns and cities and the remaining third lives a nomadic life at the country side. There are however large urbanization percentages, since it becomes more difficult for nomadic people to remain living the life they lived for centuries, due to the pasture their cattle needs becomes sparse.

Figure 12: Mongolia (Source: CIA World Factbook)

Next to the capital the country is subdivided into 21 Aimags, which is the top level administrative division. Each Aimag is divided into several Sums, the lower administrative division. There are a total of 315 Sums. Mongolia is a parliamentary republic and the current head of state is Tsakhiagiin Elbegdorj.

The countries main sources of income are agriculture and mining. Many people (especially nomadic people on the countryside) do have animals for herding. The livestock population in the country is fairly high with high numbers of sheep and horse. Around the cities of Darhan and Erdenet mining takes place (coal, copper, molybdenum, fluorspar, tin, tungsten, and gold).

The Mongolian terrain varies from the Gobi Dessert in the south to the mountainous regions in the north. Much of the countries landmass is of the steppe type with vast areas of pasture land. The highest point is the Khüiten Peak in the western part of the country with 4,374 m. Mongolia has a few larger lakes and 2 main rivers, Selenge and Orhon. The countries climate consists of long extreme cold winters (with temperatures dropping below -30) and short relatively warm summers. Much of the soil is frozen for most of the time in the year.

4.2 Planning of road infrastructure and routing in Mongolia

This paragraph will focus on roads and road planning in Mongolia.

The main modes of transport in Mongolia are car, train and airplane. There are a few rivers and lakes but they are only navigable for a limited period of time per year.

The total amount of roads in the country is 49.250 km, of which only 1.724 km is paved. The majority of the roads in Mongolia are informal in which tracks are created through the countries steppe and semi desert terrain by 4x4 vehicles. Because of the informal nature, tracks are created by the demand of the driver and whenever a track becomes too difficult to follow (because of bad condition or wrong direction) a new track or branch is created. In the end, this leaves spaghetti of tracks, leaving its marks on the Mongolian terrain. An example of the landscape that is created can be seen in the picture below.

Figure 13: Typical Mongolian landscape with a road corridor (photo by Keskkamat)

Mongolia is one of the countries through which the Asian Highway Network is proposed. The Asian Highway Network is an initiative from European and Asian countries and United Nations

ESCAP to improve Asian Highways. Two major corridors cross Mongolia. The North South AH3 connects the capital of Ulaanbaatar with Kyakta in the Russian Federation with Erenhot on the Chinese-Mongolian border. The East West AH32 connects the western city of Khovd via Ulaanbaatar towards the eastern Mongolian-Chinese border.

The case will focus on the AH32 corridor, also known as the Millennium Road. An Indian Consultancy company ICT Pvt. Ltd. has done a pre-feasibility study on the entire 2600 km road in 2001 (FE, 2002).

The rail network in Mongolia is mostly famous for the Trans-Mongolian railway, that crosses Mongolia when travelling from Russia to China. This is one of main railway stretches in Mongolia and travels from north to south crossing the capital of Ulaanbaatar and the country highly industrial regions around the cities of Darhan and Erdenet, which makes this corridor an important rail corridor for the transportation of goods next to the fact that many tourists use this corridor.

4.2.1 Road planning in Mongolia

De research on road planning in general showed that although the actual process of planning is somewhat formalized in legislation. Route generation and selection however is a fuzzy process often left to an engineer.

There is little information on road planning in Mongolia. The information that does exist is taken from the Back to Office Report (BTOR) from Sukhad Keshkamat. In his meeting with the general director of the Millennium Road Project team and the highway engineer for the Erdenet – Bulgan – Unt road he received the following information on road planning in Mongolia.

"Planning process followed is that, the road is proposed by the consultants based on their site surveys. These alternatives are forwarded by them to the Minister of Transport, who places it before the parliament. Parliament may approve as-is, or more usually, with some change as per the wishes of parliamentary members. The decision is political. There are no road planning cells in the Aimags or Sums… all planning is done in UB. Road maintenance depots exist in different parts of the country but their role is limited to maintenance of the roads as per supplies made available to them."

What can be seen from this quote is that route generation and selection in Mongolia is no different from other countries. There is still a high degree of fuzziness. Decisions are made at the political level, and entirely centralized.

The general director and the highway designer are also asked which criteria are taken into account when planning highways.

Criteria that they consider:

- Traffic volume
- Socio-economic development: align with other plans for social development of the people such as permanent settlements, industries, facilities, and mining areas.

- Technical criteria such as soils, bridges, and slopes.
- Ecological criteria such as protected areas.

Originally, they wanted the quickest route, but afterwards they choose to connect Aimag centers, because these are the economic centers of the regions. They also chose to follow existing tracks.

Generally speaking, they do not like to involve stakeholders in the planning process. People in the Aimags don't know what happens on a country scale.

The criterion of traffic volume is interesting. Since Mongolia is the most sparsely populated country in the world, it won't be a surprise that traffic volumes are very low. Traffic volumes won't exceed 1500 vehicles per day in both directions on the busiest highways of the country. From a perspective of road design traffic volume isn't interesting. However, it gives of course an idea of the distribution of traffic in the country.

4.2.2 Summary

Only a small number of roads in Mongolia is paved. Many roads are nothing more than dirt roads only to be driven by 4x4's. Train and airplane connections exist but only limited. With respect to road planning in Mongolia, some similarities can be seen when compared to road planning in general, since here is no formalized process of planning the road. Road planning is done by a central government authority in this case. It is done as a top down method, since the people in the Aimags do not know about the overall scope. Criteria that are considered are mainly technical criteria although socio-economic development is also said to be taken into account.

What can be seen from this quick scan on the planning of roads in Mongolia is that it differs not too much from planning in general, although the strong focus on central planning is remarkable.

Regarding the current informal road network, it can be assumed that when new corridors or when a new network is planned, it could contribute to the environment in the sense that when corridor design would be proper (i.e. the people would use the roads instead of the fields) the trail marks would be less diffuse which means less environmental damage to the steppe.

Next, poverty and poverty reduction in Mongolia is discussed.

4.3 Poverty and Poverty Reduction in Mongolia

When addressing poverty it is important to focus on a countries' specific situation. Poverty is both multidimensional and spatial and different dimensions have to be addressed in different locations (spatially). So when addressing poverty in Mongolia it can still make a difference whether a focus is placed on the country as a whole or just a certain population or a city. In this research, the focus will be on the whole country.

According to the 2007 Mongolia Human Development Report, development in Mongolia is going in an upward direction. The Mongolian Human Development Index (HDI) is at its highest level ever, and the differences in HDI levels between Aimags are shrinking. Economic growth averaged 8,7 percent over the years 2004 to 2007. However, poverty is still high in the country with over 37 % of rural population living in poverty in 2006. Moreover, the gap between rich and poor is increasing and if the trend is not diverted future poverty reduction measures won't help those that need it the most. The Mongolian Government recognizes that there is no automatic link between economic development and poverty reduction. It sees an opportunity in the creation of more and better employment opportunities in order to reduce poverty, because poverty among households with unemployed show that more jobs are needed and poverty among the employed show that better jobs are needed (MHDR, 2007). The focus on providing more and better employment possibilities is also seen in other poverty related documents about Mongolia, such as Mongolia's Poverty Reduction Strategy Paper (PRSP).

According to the UNDP in Mongolia, roads and the connectivity provided by those roads is the only source of development to over 50% over the Mongolian people. When access increases, the access to opportunities such as education and healthcare will also increase. (BTOR, 2008)

Finally, research has been done on spatial poverty in Mongolia, in the form of a poverty mapping report (NSO, 2009). An example of a poverty map can be found below.

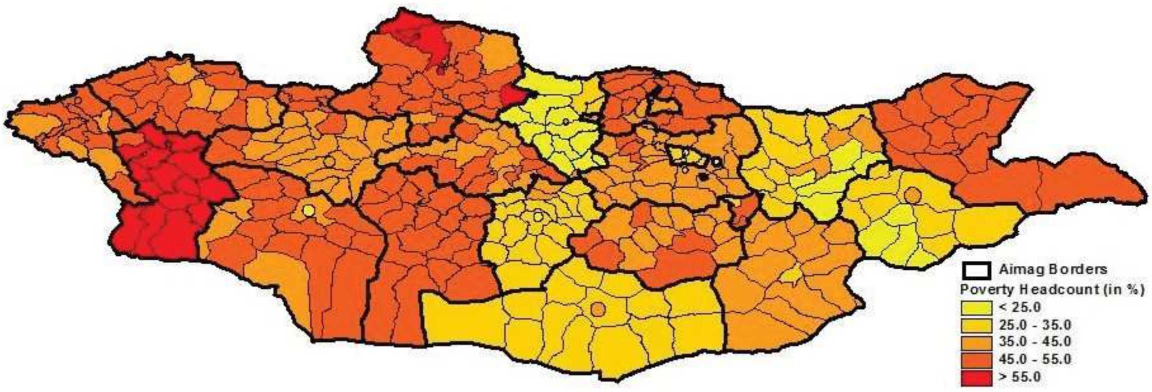

Figure 14 Poverty Headcount map (NSO, 2009)

This map shows the poverty headcount (i.e. the percentage of poor people in the total population) per Sum. The main recommendation of the poverty mapping report is that the information from the report should be used in a way that it will benefit the people of Mongolia. The next chapter will show in what way this report can be used.

4.4 Conclusion

This chapter gave an outline of both the planning of road infrastructure in Mongolia and poverty and poverty reduction in Mongolia. It serves a purpose of introducing the country but also giving direction when trying to address the country in a spatial model, which will be done in the next chapter. Things that can be learned from this chapter and that should be taken into consideration when constructing and running a spatial model include:

- The country is very sparsely populated. This has its effect on the traffic in the country, which is also very sparse. It has an effect on the number of paved roads in the country, which is very low for a country 3 times the area of France. This also has its effect on the population that will be aimed at.
- The government operates very centralizes what planning of road infrastructure concerns. They have a top down focus and look at the broader or even global picture rather than the local picture.
- Poverty in Mongolia is a problem of unemployment. The government aims at employment as the solution to help reduce poverty and help reducing the poverty gap. This of course has to be viewed from the broader perspective the government operates from.

The first part of this research has given a reason why there is a need to come with a tool that can assess the planning of roads from a perspective of poverty. It has also given the framework of a case in which it could be applied and why it can be applied. Now it is time for the application itself. Rather than finding solution for a problem in the case of Mongolia, it will showcase the possibilities of the SMCE tool from a perspective of poverty reduction.

5 Research methodology

This chapter discusses the research methodology used. The methodology is developed as a showcase to demonstrate how a fusion of the concepts of road infrastructure planning, poverty reduction and SMCE could or should look like. The methodology will discuss several steps that were necessary to produce results in the form of route alternatives. The 5 steps that were taken to lead to a result of routes are:

1. Stakeholder analysis
2. Extracting criteria and translating them into spatial constraints and factors
3. Adding poverty in GIS
4. Collecting data
5. Construct model, run it and gather results

These steps are based on own experience on working with the model and data. The methodology will be discussed as general as possible, but examples from the case study will be given to illustrate.

5.1 Introduction into the 5 step model

The research methodology consists of 5 steps. The model will start with a stakeholder analysis. By analyzing the stakeholders, it becomes clear who is involved in the project, what their interest is (including the level of interest) and what amount of power (to decide) they have within the project. Chapter 3 has showed that stakeholder views are an important source of criteria for route generation and selection, next to technical criteria and spatial constraints.

Once stakeholder views are clear, criteria need to be extracted from those views and translated into spatial constraints and factors. It is important to take into consideration the limitations of the SMCE and GIS in this step. Not all criteria are suitable. However, it is better to first develop criteria and skip them later because of technical limitations, than not taking them into account at all in order to find out at the later stage that they were applicable after all or of big influence on the outcomes of the model.

Most of the criteria that are considered are quite straightforward. The use of these criteria is tested and approved in other research. However, as can be seen in the research questions, the aim of this research is to see what the impact is of adding social criteria (and particularly poverty criteria in this research). Therefore research has been done on how to add poverty reduction as a criterion which has been translated to a mathematical model of multi-dimensional poverty and poverty reduction.

The next step is to gather the data that is needed. Important to take into account is that different sources of data often use different geographical projections, different resolutions (cell size in raster based maps) and that many maps don't exist or need to be created out of other maps or other sources than maps.

When data is collected, it can be applied to construct the model. First, the different data sources are prepared in the ArcGIS software (ArcGIS, 2008), in order to give all maps the same boundaries, size, resolution and spatial reference. Next, the maps are imported into ILWIS academic software (ILWIS, 2005). This program has a powerful SMCE module. After preparing and running the SMCE module, the resulting suitability maps are exported back into ArcGIS where a least cost path algorithm will calculate the route of least resistance (or highest suitability through the suitability map). This will be done several times with different weights given to criteria in order to perform analysis and draw conclusions regarding the research questions.

5.2 *Stakeholder analysis [1]*

The selection of criteria that will serve as input in the SMCE can be a difficult and time consuming task.

Typically, it is best to start as broad as possible, taking into account many stakeholders and identifying as many criteria as possible, without taking into account the possibilities (or restraints) of the software that will be used later. It is better to drop certain criteria in a later stage (when motivated properly) than rejecting them beforehand because they might not fit in the constraint of the software being used.

The analysis should start by categorizing the stakeholders which have been identified. A tool which helps categorizing stakeholders is Gardner's et al. (1986) power / interest matrix, which can be seen below.

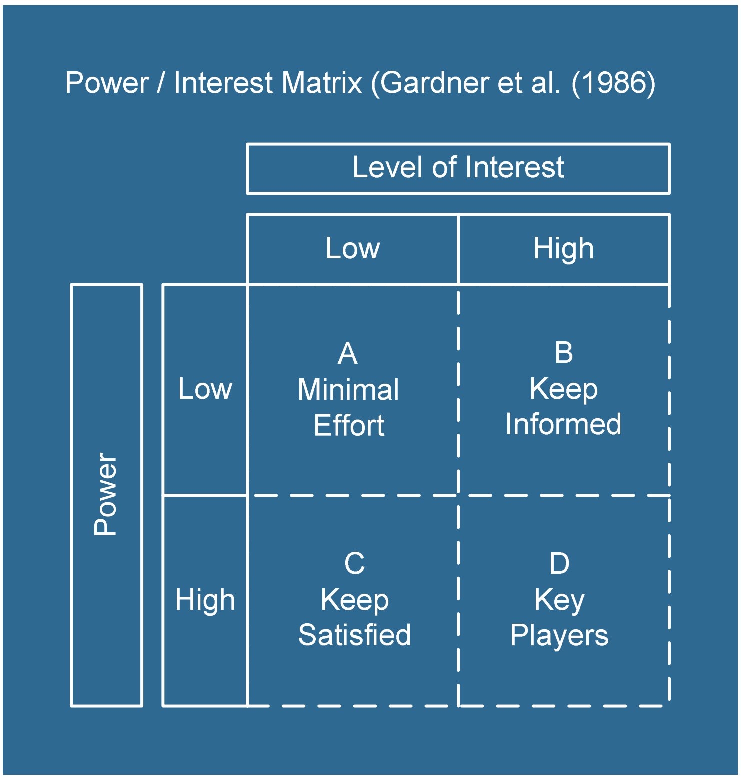

Figure 15: Power / Interest Matrix

Stakeholders have been analyzed in the case of the Millennium Road project as well. The stakeholders for the Millennium Road are collected, based on the background information gathered in chapter 4. The stakeholders that are taken into consideration are:

- China and Russia
- UNESCAP
- Ministry of Roads and Transport in Mongolia
- UNDP
- The Resources and Petroleum Authority of Mongolia
- The World bank
- Asian Development Bank
- The people of Mongolia
- Industries and companies of Mongolia

In the Power / Interest Matrix, for these stakeholders can be depicted as follows the figure below.

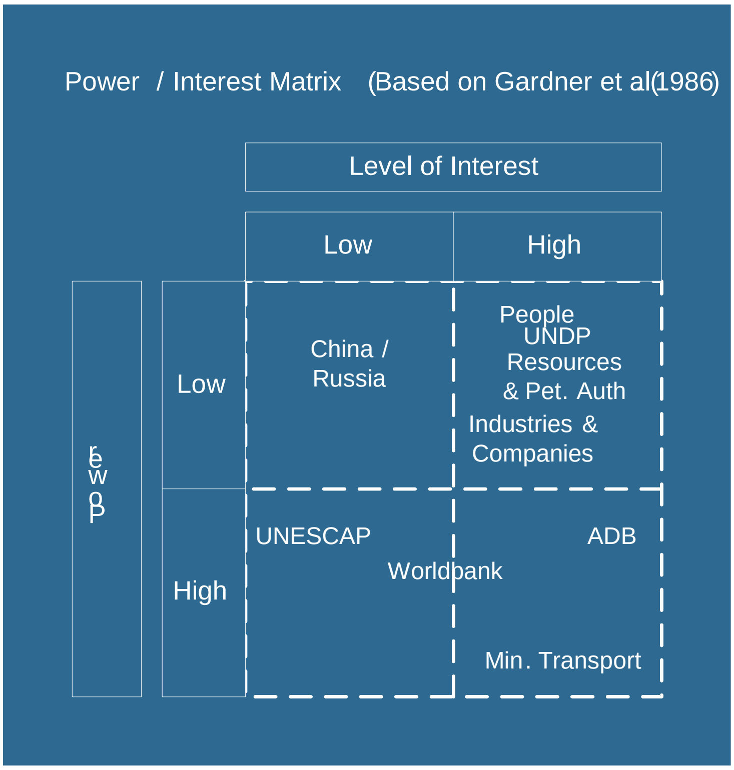

Figure 16: Power / Interest Matrix for the case

5.2.1 China and Russia

Both China and Russia are bordering countries of Mongolia. Russia shares the northern border with Mongolia, while China shares the southern border with Mongolia. They both have low power in the planning of the Millennium road. Their main interest is where to connect their stretch of the international road network to the border with Mongolia. They have a relatively high interest that the road will be constructed, for the benefit of international transport. They have a low interest however in where the road exactly will come, as long as it connects to their own road networks. This is one of the tasks of the UNESCAP as a leader of the Asian Highway project. The criteria (constraints) that will be derived from these stakeholders are that the start and end points of the Millennium Road are fixed.

5.2.2 UNESCAP & Asian Highway Manual

The Asian Highway is a project by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) which has as goal "*to coordinate the development and upgrading of existing regional highways among member countries.*" According to the Asian Highway Handbook (UNESCAP, 2003), the current proposed network consists over 140.000 km in 32 member countries.

Figure 17 shows the criteria and the justification of those criteria as they are found in the handbook. Next to the criteria that are showed, the handbook gives an overview of the important centers that should be connected through the network. Note that the connections which are taken in the criteria have a strong economic and international focus, with no focus on social or ecological criteria. These criteria are defined on a very broad scale of the entire network. This is even broader than the scale of the corridor that is focused on in this research.

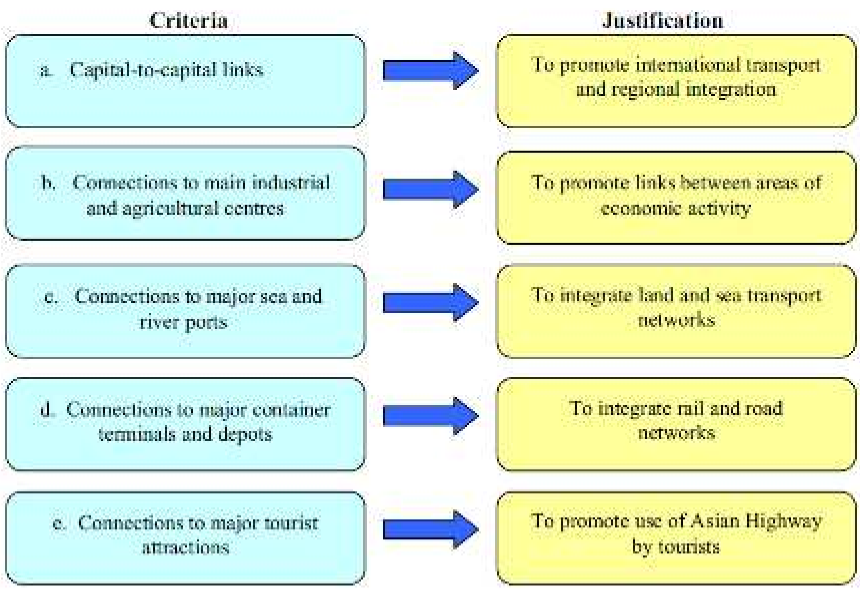

Figure 17: Criteria derived from Asian Highway Handbook (UNESCAP, 2003)

5.2.3 Ministry of Roads & Transport

The Ministry of Roads and Transport is responsible for the development of roads and transport in the country, whereas another organization, the Roads Supervision and Research Centre (RSRC) is responsible for the controlling.

There are two sources from the Mongolia Ministry of Roads and Transport with respect to the Millennium Road that are taken into account. These are a presentation given by the Minister of

Roads and transport and an interview by Sukhad Keshkamat with another official from the Ministry of Roads and Transport.

According to the Minister of Roads and Transport of Mongolia, the national road network needs to be developed because of several reasons: (MRND, 2007)

- Vast territory with a lack of connectivity between urban centers
- Get connectivity with neighbor countries and have direct access to seaports
- Roads need to be developed while taking three criteria with their respective weights in concern: International and regional importance (45%), Economic importance (30%) and Social importance (25%)

The criteria of International and regional importance are further specified as:

- Connectivity to the international corridors and Asian Highway Network
- Passing through regional pillar centers, provincial centers and towns
- Number of villages and settlements within the magnitude of the particular road service area

The expected results according to the Minister are:

- The road network facilitates the countries socio-economic development
- Fostering better connectivity of remote regions, improvement of accessibility of consumers to markets and improved rural livelihood, reduced unemployment and reduced (rural) poverty, which will reduce rural to urban migration
- Construction of a road network increases international cooperation and connection to sea ports.
- Construction of a road network leads to lower transportation cost, lower environmental impact

Keshkamat has interviewed Mr. Bayan Amgalan, General manager of the Millennium Road project from the Ministry of Roads and Transport, who has stated that economic criteria are considered to be the most important, followed by social criteria, in which connectivity is positive and safety negative. Ecological criteria considered are protected areas and wildlife migration, although it is only a minor criterion. Another point that came out of the interview is that planning is done centrally, with only little local planning freedom on Aimag level.

5.2.4 UNDP

According to the United Nations Development Programme (UNDP), one of the major problems to be tackled is the rural to urban migration, which is a big issue in Mongolia. This can be done by improving the situation for rural people, which means looking at the needs for rural people. From the research done in chapter 4, it became clear that rural people need chances for employment, so they won't migrate into the cities anymore.

Another point was brought in by UNDP. Because Mongolian Government insists that industries build there own infrastructure, these companies tend to locate where the infrastructure is better, meaning that they will avoid rural areas. This means that the concentration of industry and work is in urban areas. This point makes it worth taking into consideration the views of one of the largest industries in Mongolia, being the mining industry, which will be discussed next.

5.2.5 Mineral Resources and Petroleum Authority of Mongolia

The view of UNDP is confirmed by a specialist from the Mineral Resources and Petroleum Authority of Mongolia, who says that mines are privately owned and government does not invest in infrastructure for them. This makes that they will search for locations in the country where infrastructure is good and where ores are available of course. They won't choose locations in rural areas.

5.2.6 World Bank

According to an officer from the WB office in Ulaanbaatar, they focus on 3 aspects. First economic, second ecological and finally social aspects. Social aspects mainly concern with the relocation of displaced people. WB says that sticking to the current road network is very important. It was also pointed out that though China and Russia are major stakeholders for the road, Mongolia has also difficult relations with their neighboring countries.

5.2.7 Asian Development Bank

The main criteria considered by the ADB, concerning the Millennium Road is regional integration and cooperation. Another point by the ADB is that they don't pursue to make use of the existing network when finding an alignment for the Millennium Road, unlike the World Bank or UNESCAP.

5.2.8 People of Mongolia

From the 3 million people living in Mongolia, about one third lives in the capital, with another one third in other cities and villages in the country and the remaining one third living a nomadic life. Little is known about how the people of Mongolia look towards the development of the Millennium Road in their country, but the road is built for those people. The people of Mongolia have a rather high interest in the project but very low levels of power. In the ideal situation, the opinion of the people that are affected by the development of the road (either positive or negative) should be gathered over the organization of focus groups. Since this information is not available for this research, no specific views or criteria taken from those views can be taken into account.

5.2.9 Pre-feasibility study by ICT Pvy Ltd.

The Indian consultancy company Intercontinental Consultants and Technocrats Pvy. Ltd. (ICT) developed a pre-feasibility study of the Millennium Road in Mongolia (ICT, 2002). The study consists of a socio-economic analysis, description of the corridor, traffic counts, design and pavements issues, environmental and economic considerations.

The Indian consultant is not a real stakeholder in the project, but brings in several criteria, being mainly technical criteria. The conclusions of the report are that the road can yield an economic internal rate of return of 14.7 percent and improved environmental conditions due to less detoriation of the grasslands. Furthermore, the consultant states that the project helps directly in the creation of employment, reduction of rural-urban migration, improved access to mineral resources, development of tourism and improved international competitiveness.

Major criteria that are taken into account are technical criteria such as:

- Soil Conditions
- Drainage requirements
- Geometry
- Climate (temperature / snow cover / wind)
- Crossing water bodies

5.2.10 Summary

The main stakeholders in this project have now been discussed. What can be summarized from these findings is that:

- It is very difficult to do a proper stakeholder analysis. Ideally, when knowing which stakeholders to deal with, they should be treated in the same way in terms of gathering information and opinions. Ideally, each stakeholder should be asked about their power and influence within the projects, so that criteria they bring in can be weighed according to power and interest levels.

- Criteria that are mentioned are in one of the following five categories: International, Economic, Ecologic, Social and Technical. It would make sense to use these categories when extracting the criteria from the stakeholder views into spatial constraints and factors.

5.3 Extracting criteria and translating them into spatial constraints and factors [2]

After stakeholders and their views are known, criteria have to be extracted from those views.

The first step in extracting criteria is to form groups or themes in which the criteria can be collated. The themes are defined by the stakeholders in this way, that opinions and criteria from stakeholders define the extent of themes. This also defines the scale of the project.

The themes or groups that are going to be used in this research are:

- International Criteria
- Economic Criteria
- Ecologic Criteria
- Technical Criteria
- Social Criteria

For each of the stakeholders, criteria are extracted and placed in one of the themes. This leads to the Criteria Tree as depicted below.

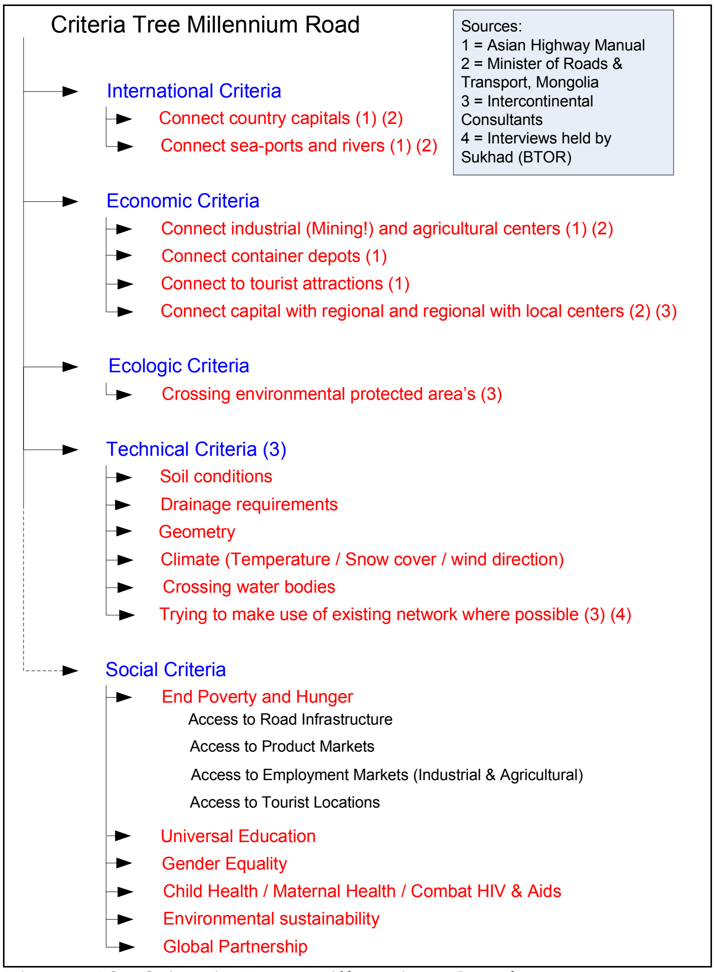

Figure 18: Criteria Tree Millennium Road

This criteria tree contains the criteria that could be extracted from the stakeholder analysis done in step 1. Although this criteria tree contains all criteria that could be derived from the stakeholder analysis, it is not complete. The reason is that the stakeholder analysis could not be done as wished. Stakeholder analysis was mainly done using second hand data and the data was available before the methodology was developed. This makes the data inconsistent and incoherent. When done properly, more structured and with a methodology present, the list would be larger and the analysis better. Social criteria were added in this tree but they are not based on the stakeholder analysis. The 6 main criteria come from the Millennium Development Goals. The criteria specified in "End Poverty and Hunger" come from the literature review done on poverty and transport as well as how is dealt wilt poverty reduction in Mongolia. Further explanation of all criteria will follow.

5.3.1 International Criteria

International Criteria are defined as a separate set of criteria because they are separately referred to by various stakeholders including the Mongolian Ministry of Roads and Transport as well as UNESCAP. In fact, International criteria are mainly economic criteria but at an international scale. Economic criteria that are addressed in the set of economic criteria are on a national scale. Two criteria have been selected because of them being mentioned strictly by the Asian Highway Manual and the Minister of Road and Transport of Mongolia. These criteria are that the Millennium Road serves a purpose of connecting to other country capitals and that connections to rivers and sea ports have to be established. It will mean that the Millennium corridor has to connect with other corridors from other highways. In terms of modeling the Millennium road, this means that a start and endpoint have to be defined. Connections to sea ports and rivers are not taken into consideration because Mongolia is a landlocked country and the amount of navigable rivers is negligible.

International criteria are defined so broad that they may not be applicable for every country participating in the Asian Highway Project, as is the case with Mongolia, a country without sea ports and navigable rivers.

5.3.2 Economic Criteria

The economic criteria that are mentioned are all of one type. The road should connect the areas that are economically important for the country. Areas that economically important to the country are, according to the stakeholders:

- Industrial and agricultural centers. There are no maps that tell where the industrial activity is high. It can be assumed that industrial sites are near regional economic centers. This view was given by the Mineral Resources and Petroleum Authority as well as UNDP. Agricultural centers are very difficult to define, mainly because much agriculture in Mongolia is consisting of herding which has a nomadic feature. However, one agricultural proxy could be used in the research. There are locations with activity in crops.

- Container depots. The criterion of Container depots again comes from an international view, which is not always applicable on a national scale. Mongolia has a container terminal to transfer goods from road to rail, and logically, it is located in the capital. Since the road anyway connects to the capital, no input for this criterion has to be made.

- Tourist locations. Although Mongolia is not a prime tourist destination, there are some tourist destinations in the country. Since tourism can be a great source of income for many people, connecting international roads with tourist locations is economically beneficial.

- Local and regional economic centers. Because there are no exact maps that show where economic activity is higher or lower, the choice is made to assume that Aimag capitals and Sum capitals are resp. regional and local economic centers.

5.3.3 Ecological Criteria

Only one of the ecological criteria is very clear. Because of a legislative basis environmentally strictly protected areas cannot be crossed by the Millennium Road. For the use in the SMCE this means placing a constraint on the protected areas is sufficient. Other ecological criteria that are mentioned are the migration of animals and the protection of the steppe by fencing of the road. These are however unable to use in the SDSS resp. not of influence on the alignment of the road. Finally, there are other ecological areas that are not strictly protected. This means it is allowed to cross them, but avoiding these areas is preferred. Therefore these areas will be included in the model.

5.3.4 Technological Criteria

Technological criteria are derived from the pre-feasibility study by the Indian consultant. Soil is of importance because some soils have a preference of building on them over others because of the ease of Construction, thus less construction costs. The same counts for drainage requirements, which is also connected to soil. A soil map is needed for these criteria. Geometry needs to be taken into account because of slopes of roads. The longer and or steeper the path chosen, the less favorable it is to use in the corridor, again from the point of construction cost. For this criterion, a Digital Elevation Model or DLM is needed. For the Mongolian case, climate is of special interest because of harsh winter conditions. Therefore, snow cover, wind and temperature should be taken into account in order to select areas where snow cover is less which makes the roads easier to clear and use all year long. Crossing of water bodies should be taken into account. It is a constraint at the points where there are bridges at this moment that can be upgraded.

Finally there is a criterion on making use of the current network. Several organizations have different views on this. WB says that using the current network is a priority, where as ADB says that the best alignment is more important than using the current roads. This research will search for the best alignment without taking into account the current network.

5.3.5 Social Criteria

Social criteria are referred to by some of the stakeholders. They mention socio-economic development as one of the criteria which is by some stakeholder further specified as reduction of rural to urban migration, creation of employment or improved accessibility for people in poor connected regions, all aimed at poor people. However, some stakeholders say the importance of social criteria is third in rank behind economic and ecologic criteria.

What can be taken from the stakeholder views is that the social criteria referred to, are increasing the accessibility of poor people to opportunities, creating employment and reduction of rural to urban migration.

These poverty reduction charcteristics are in line with what was discovered in chapter 3 and chapter 4 on poverty and poverty reduction. It seems that, when addressing poverty in the focus of MDG-1, the main characteristics, both in literature and in the case are increasing accessibility of poor people to opportunities and the creation of employment. A case specific focus point is the reduction of rural to urban migration. The next step will try to include these characteristics in the model.

5.4 Adding Poverty in GIS [3]

Although most of the criteria can be added into an SMCE quite straightforward, adding poverty reduction should be done with greater care since it has not been done before.

The MDG-1 on poverty reduction learned that the main targets are reducing the number of poor people and creating more employment possibilities for the people.

Based on the stakeholder views and the discussion on poverty in Mongolia in chapter 4, the focus for this model will be on areas with high poverty and low accessibility. These areas are believed to have a high opportunity to improve accessibility, reduce poverty and reduce the rural to urban migration. The model should therefore answer 2 questions:

- Where are the poor people living?
- Which poor people have a need for improved accessibility in order to reduce their poverty and reduce the rural to urban migration?

Improving accessibility is different from the provision of infrastructure. Infrastructure provision alone cannot reduce poverty. However, the infrastructure provides a base for poor people friendly public transport, so that an increase in accessibility is provided which helps reducing poverty.

Poverty maps show the poverty levels per area, e.g. provinces. However, it is not known where the people live in this area and how many live in the area. A certain area can be very poor, but if only a little amount of people are living there, the opportunity that is created for the few does not outweigh the investment that has to be made to those people. Therefore information from poverty maps (which areas are poor) has to be combined with the Landscan data that gives information on population density per cell. Combining those two sources of information tells where the people live, how many people there are and (from the poverty maps) how poor they are.

Next, a distinction needs to be made between people that are living in a rural environment and people that are living already in urbanized regions. This will be done by calculating the distance a certain area has towards urban areas or areas with opportunities. By making this distinction and placing a focus on the people that live in a rural environment, the result would be for every single cell in a raster divided area:

- The amount of poor people in a certain area
- The distances those people are living from opportunities

Based on these indicators, Areas with high population, high poverty and low accessibility to opportunities could be targeted at.

In this method, the total area that will be focused upon will be divided by a raster, in which each cell has a value for opportunity to poverty reduction (OPR). The raster is based on and has the same resolution as the Landscan (population) raster.

The calculation for the OPR will be:

$$OPR = \left(\frac{\frac{P}{P(\max)} + T}{2} \right)$$

Formula 1: OPR

In which P is the number of poor people in a cell. The number of poor people in a cell will be retrieved by a multiplication of the amount of people living in a cell (Landscan) and the poverty headcount. The poverty headcount is the percentage of the population that lives under a predefined poverty line. According to local standards, these people are seen as poor people.

T is a distance factor. The distance factor represents a certain remoteness of a cell, compared to areas with opportunities. For each cell, a calculation is made of the distance to the nearest Sum, Aimag and the capital. For local people, local centers are of more importance than regional centers or the capital. Therefore a higher weight is given to local centers. However, since local centers are not sufficient for all the needs people have e.g. healthcare, all levels will be taken into account while calculating this remoteness factor. The calculation for T will be:

$$T = \left(\frac{\delta S}{\delta S(\max)} * 0,5 + \frac{\delta A}{\delta A(\max)} * 0,35 + \frac{\delta U}{\delta U(\max)} * 0,15 \right)$$

Formula 2: Distance factor (T)

S stands for Sum, A for Aimag and U for Ulaanbaatar i.e. the capital of Mongolia. T can receive a value between 0 and 1, in which zero would be a perfect accessibility to Sum centers, Aimag centers and the capital and 1 a very low accessibility to Sum centers, Aimag centers and the capital. In order words; when an area is very remote, the value for T will be closer to 1.

Together with P/P(max) which a low value indicates a low amount of poor people and a high value a high amount of poor people, the OPR is given, in which a low value means there is less need to improve accessibility and a high value means there is more need to improve accessibility. This OPR can be used directly as a suitability map in the SMCE module in ILWIS.

5.5 Collecting the data [4]

Once it is clear which criteria will be used, data has to be gathered that will provide input for the model

There are some difficulties with gathering GIS data. Data can have different coordinate systems, both for the geographic coordinate system (GCS), which is the actual coordinate system and the projected coordinate system, which defines the projection (e.g. Mercator) of the data. For this case, the GCS WGS 1984 is chosen as geographic coordinate system, since it is a frequently used coordinate system and it was the coordinate system for most of the data sources. No projected coordinate system is used. This means that the data has no projection so the chance of mixing up projected coordinate systems is zero. However, it also means that distance units are presented in decimal degrees rather than metric units. This will result in some extra work on calculating metric distances.

Compared to the criteria tree that was presented in step 2, quite some criteria cannot be used in the model for various reasons. Criteria that will not be used are:

- Connect sea ports and rivers (not taken into account because Mongolia itself has no seas and no navigable rivers. The influence of international seas and rivers does not reach this study)
- Connect industrial centers (not taken into account, because no proper data source exists). However, it is believed that many industrial centers are close to Aimag or Sum centers and that they will be used implicitly.
- Connect container depots (not taken into account because the locations of container depots is sparse along the North South rail corridor and it won't be of large influence on the SMCE)
- Soil conditions (not taken into account because available soil map is too complicated to use. Moreover, according to the pre-feasibility study, the soil conditions are generally appropriate for road construction)
- Drainage requirements (not taken into account because they are interlinked with soil conditions and a usable soil map is not available.)
- Climate (not taken into account because different factors including temperature, wind direction and precipitation have not been modeled yet in SMCE. Research on how to use them would take too much time)

The data that will eventually be added is:

- Crossing strictly environmental protected areas
- Distance to Aimag centers
- Distance to tourist locations
- Distance to Sum centers
- Distance to crop locations
- Crossing other protected areas
- Slope suitability
- Crossing lakes
- Crossing rivers
- Opportunity to poverty reduction (OPR) map

Next, the data that will be added will be discussed.

5.5.1 Strictly environmental protected areas

Strictly environmental protected areas are areas that cannot be crossed by road infrastructure in any case. They will therefore be defined as a spatial constraint. This means that the suitability of these regions will be 0. The source is a map containing all environmental protected areas in Mongolia. Out of this map, a subdivision in strictly and non-strictly protected areas is made and placed into separate maps. The result can be found in Figure 19, where red areas are strictly protected.

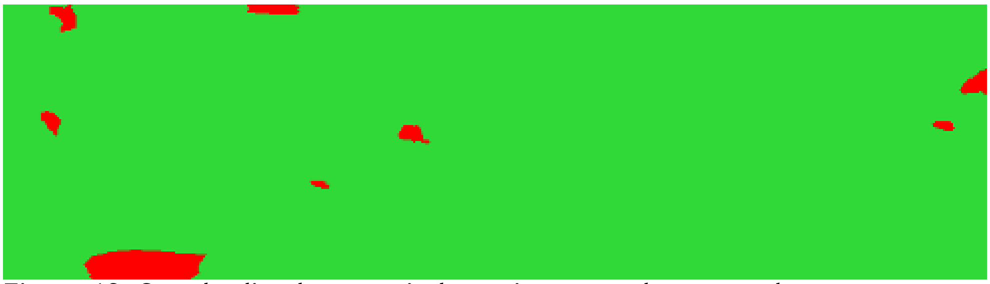

Figure 19: Standardized map strictly environmental protected areas

5.5.2 Distance to Aimag centers

Distance to Aimag centers is based on a point map containing Aimag centers. The first step is that the Euclidian distance to the nearest Aimag is calculated for each pixel, not taking into account any other factors. Based on this Euclidian distance, the suitability is calculated. At the Aimag center itself the suitability is 1 and gradually declines to 0 at 1,5 decimal degrees (measured at 48 degrees North Latitude this is 166 km). From this distance, the suitability is 0. The distance of 1,5 dd or 166 km is a rough assumption of the maximum distance people are willing to travel to an Aimag center. Distance to an Aimag center is defined as a spatial cost, with the cost increasing with the distance to an Aimag center

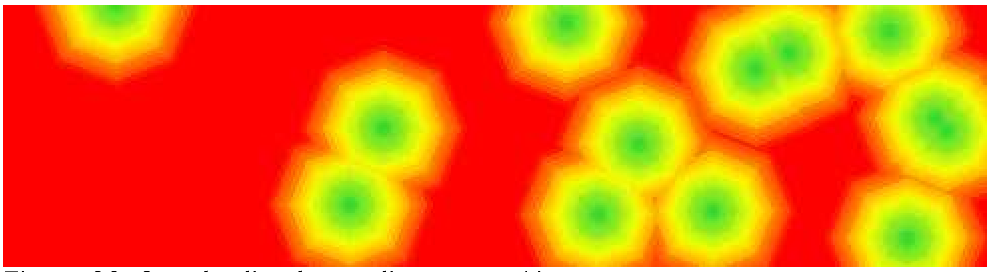

Figure 20: Standardized map distance to Aimag centers

5.5.3 Distance to tourist locations

The map containing distance to tourist locations is based on a map based on information from the Lonely Planet of Mongolia (LP, 2005), in which the most important tourist destinations are described including their longitude and latitude. The Lonely Planet gives this extra information because formal roads hardly exist. This information is used to create a point map, from which the Euclidian distance is calculated the same way as it has been done for the Aimag centers. For each tourist location the suitability is 1 at the source, and declines to 0 in a distance of 111 km. Like the distance to an Aimag center, distance to tourist locations is defined as spatial cost

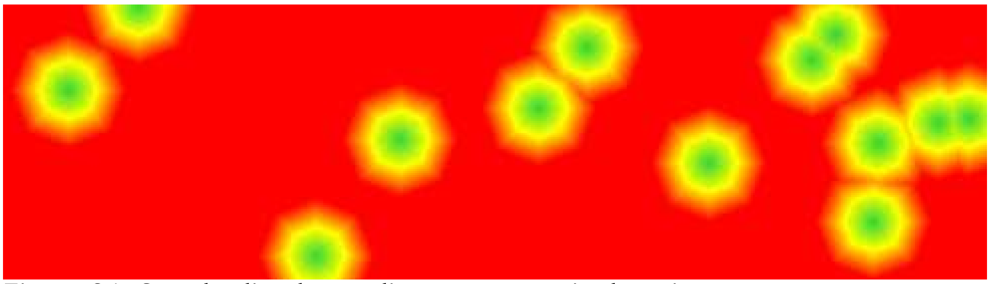

Figure 21: Standardized map distance to tourist locations

5.5.4 Distance to Sum centers

The Sum center information comes from a Sum center point map. Again, the Euclidian distance is calculated, and suitability map is created similar to those for the Aimag centers and tourist locations. The suitability runs from 1 in the Sum center to 0 at 55 km from the Sum. Since these centers offer fewer facilities than the Aimag centers, it is assumed that people want to travel less far to Sum centers than they would like to travel to Aimag centers. Therefore the area of influence is lower than the area of influence of the Aimag centers. Distance to Sum centers is defined as spatial cost.

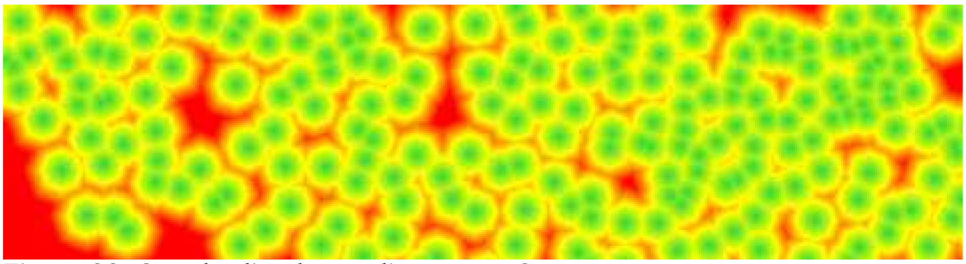

Figure 22: Standardized map distance to Sum centers

5.5.5 Distance to crop locations

Crop locations are added as a proxy for agricultural activity. Although the majority of agricultural activity is herding which uses pasture land for the animals to graze, this is done by nomads. Since nomads are not static, it makes this herding impossible to incorporate in the model. Crop locations are taken from a land use map. Since the locations are often very small, the center points are taken to represent the location, and again a point map is created and the Euclidian distance is calculated. The suitability runs from 1 at the crop locations to 0 at 27 km from the crop location, which is an assumption of the distance people want to travel to work. Distance to crop locations is defined as spatial cost.

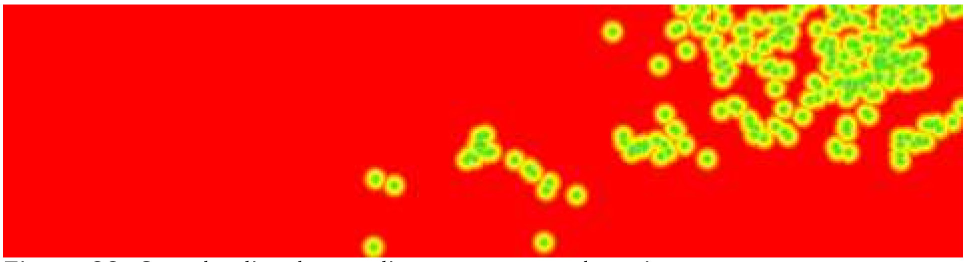

Figure 23: Standardized map distance to crop locations

5.5.6 Crossing other protected areas

Taken from the same map as the strictly protected areas, the other protected areas are simply those that are not strictly protected. They are regarded as less suitable to plan a road through, from an environmental point of view. The suitability of the areas is set at 0.5, which means that the areas can still be crossed, but it is preferred to not cross them. Crossing other protected areas is defined as spatial benefit.

Figure 24: Standardized map crossing other protected areas

5.5.7 Slope suitability

The slope suitability is of influence on the construction costs of the road. The steeper slopes are, the more difficult construction is. Up to a maximum of 50 degrees cross slope (the slope degree perpendicular on the road) construction is possible. Above 50 percent there is a change of instable soil. Slope suitability is created from a digital elevation model (DEM) of Mongolia. A DEM shows for each pixel in the file the height. From this DEM, a maximum slope map is created. This means that for each pixel, the highest delta with the 8 surrounding pixels is found and given as a value to this pixel. This leads to some inaccuracies because the slope is always dependant on the direction of a path, but since a path is only calculated after the SMCE, this is the best way of taking into account slope data. Slope data is calculated in degrees. The suitability is set at 1 when no slope is present to 0 when a 50 degree slope is present. Intermediate slopes have values in between on a linear scale, e.g. a slope of 25 degrees has a suitability value of 0,5. Slope suitability is defined as spatial cost.

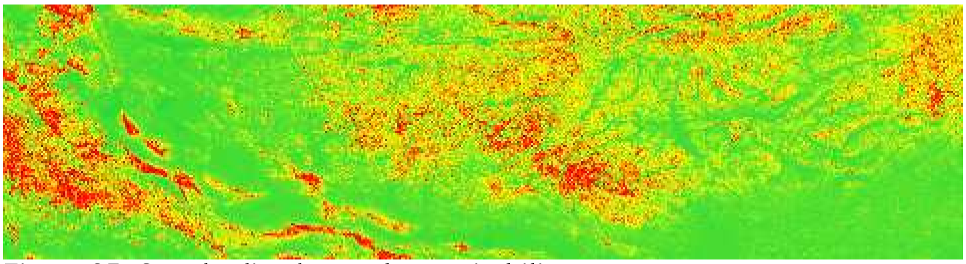

Figure 25: Standardized map slope suitability

5.5.8 Crossing lakes

When planning a road, crossing a lake comes with extra cost of building bridges. Therefore crossing of lakes is considered undesirable and receives a suitability of 0.5. Crossing lakes is defined as spatial cost.

Figure 26: Standardized map crossing lakes

5.5.9 Crossing rivers

When crossing rivers, bridges have to be built which implies extra costs. From a technical and financial perspective this is undesirable. Like the map of crossing lakes, this map also receive a suitability factor of 0.5 where rivers are. Crossing rivers is defined as spatial cost.

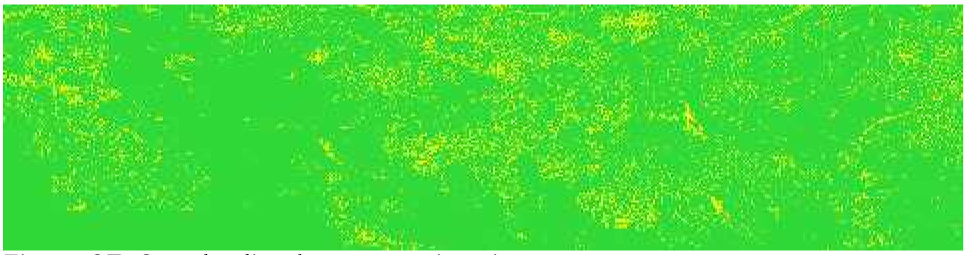

Figure 27: Standardized map crossing rivers

5.5.10 Opportunity to poverty reduction (OPR) map

The OPR map is added to the criteria as it is described in step 3. In this map high suitability factors account for a combination of low accessibility to urban centers and a high amount of poor people. Low suitability occurs in areas with high density of urban centers and low amount of poor people. The main sources for this map were the Landscan population data and the data from a poverty mapping report by UNDP and the Mongolian National Statistical Institute. (NSO, 2009)

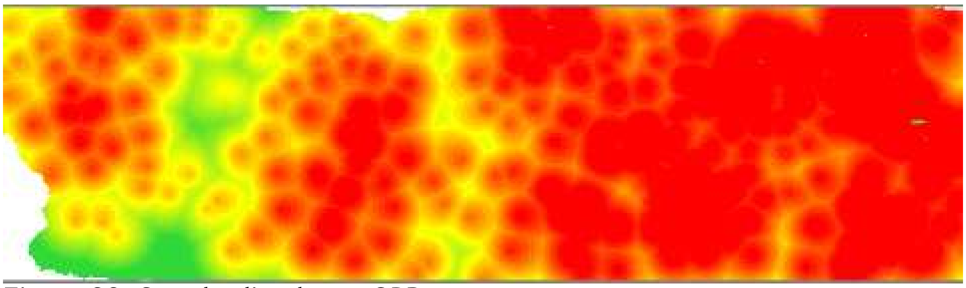

Figure 28: Standardized map OPR

The OPR map is defined as spatial benefit factor, with increased benefit for higher values. Next step is the construction of the model. Al aspects that need to be taken regarding the construction and running of the model will be discussed in this step.

5.6 Constructing the SMCE model [5]

This step will discuss the actions that need to be taken in order to create output and get results.

The suitability maps in step 4 are bounded by a rectangle. This is because the (data for the) study area is bounded. For this case, the choice is made to limit the case to the stretch of the Millennium Road between the capital of Ulaanbaatar and the provincial capital of Khovd, where the Millennium Road connects to another Asian Highway road, AH4. The locations of these places, as well as the boundaries of the case can be seen in below picture.

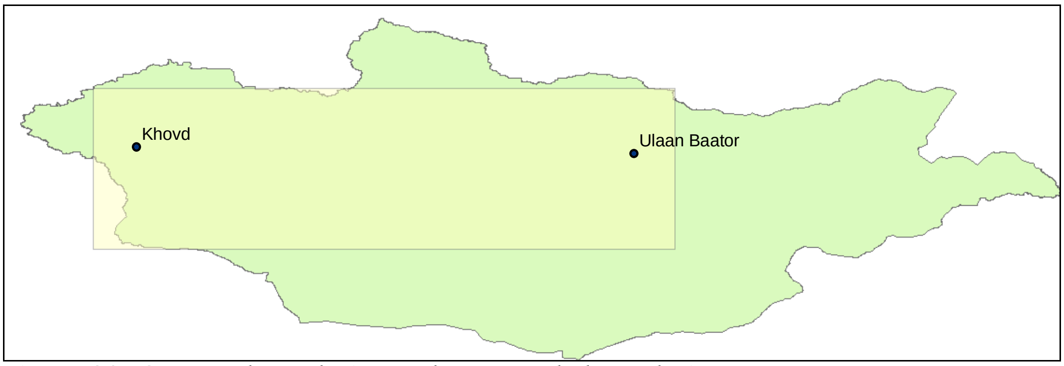

Figure 29: Country boundaries and case study boundaries.

All the data, which is in thematic maps, will be clipped according to the boundaries marked by the yellow box.

The fact that the study area will incorporate the whole area between Ulaanbaatar and Khovd has some implications for the scale. Scale has been discussed already a few times in this research. When addressing the entire area between Ulaanbaatar and Khovd (approximately 1500 km), all criteria that are incorporated in this research will also effect the entire study area. For some criteria, this suits well. Other criteria might need another scale level to function better. However, since the discussion on scale is a whole separate topic, the choice for this research is not to take into account scale and only address the whole study area as defined. Scale will be addressed in the discussion chapter again to discuss what the choices and effects could be of addressing scale issues.

Shapefiles that have been prepared in ArcGIS (step 4) are rasterized and imported into ILWIS. Rasterisation means that data consisting of lines, polygons or points is transferred into raster data. The resolution that is chosen is 0,00333 DD, which is equivalent to 360 meter, which is 4 times the resolution of the Digital Elevation Model (originally 90 m resolution). DD stands for Decimal Degrees and is a unit for the expression of geographical coordinates. One Decimal Degree is the equivalent to approx. 111 km (depending on the latitude). The resolution of the Landscan population data originally was 0,00833 DD (925 m), but is resampled to fit the other resolution. A 360 meter resolution was finally chosen, because of 2 reasons. The first reason is that considering the study area, 360 meters is still a very fine resolution, especially for a country like Mongolia. 360 meters might sound large, but since the study area is largely rural, 360 meters is more than enough to incorporate all necessary features the land has. Second, the 90 meter resolution of the DEM was too fine to calculate with. Calculation times became to long when a first test calculation was done.

Once imported, all files are given the same georeference in order to combine the data in the SMCE module. When given the same georeference, a specific coordinate or cell in the map *x* will align with the same point in map *y*. In the SMCE module, a criteria tree is built by starting with the constraints, followed by spatial costs and benefits for the different themes economic, ecologic, technical and social.

When all the data is gathered in the model, the next step is to assign weights to the various themes and within the themes. Weights are assigned according to the Expected Value Rank Method, which is the built-in method in ArcGIS and where the weights are assigned according to a user defined ranking. The ranking and weights for within the themes and for the different visions are:

Weights within Groups

Economic Group		Dist. Aim. Cent.	Dist. Tour. Attr.	Dist. Soum. Cent.	Dist. Crop Loc.
	Rank	*2*	*4*	*1*	*3*
	Weight	0,27	0,06	0,52	0,15

Technical Group		Slope Suit.	Crossing Lakes	Crossing Rivers
	Rank	*1*	*2*	*2*
	Weight	0,61	0,19	0,19

Weights for visions

		Economic	Ecologic	Technical	Social
Equal Vision	*Rank*	1	1	1	1
	Weight	0,25	0,25	0,25	0,25
Economic Vision	*Rank*	*1*	*4*	*2*	*3*
	Weight	0,52	0,06	0,27	0,15
Economic Only	*Rank*	*1*			
	Weight	1	0	0	0
Ecologic Vision	*Rank*	3	1	4	2
	Weight	0,15	0,52	0,06	0,27
Ecologic Only	*Rank*		*1*		
	Weight	0	1	0	0
Technical Vision	*Rank*	*2*	4	*1*	*3*
	Weight	0,27	0,06	0,52	0,15
Technical Only	*Rank*			1	
	Weight	0	0	1	0
Social Vision	*Rank*	*3*	*2*	*4*	*1*
	Weight	0,15	0,27	0,06	0,52
Social Only	*Rank*				*1*
	Weight	0	0	0	1

Table 1: Weights assigned within groups and for visions

In the expected value rank method, the ranking is done by the user. Ideally, stakeholder views could be used in the ranking as well.

For each of the vision a separate criteria tree is made, from which a combined suitability map is made. An example of a criteria tree, in this case given the weights for the Economic Only vision, is presented in Figure 30.

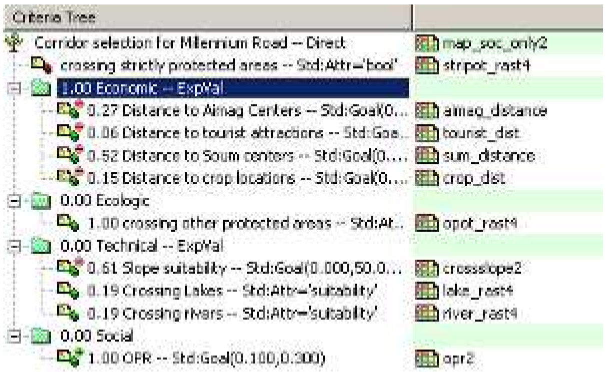

Figure 30: Criteria Tree: Economic Only vision

For each of the visions, a suitability map is created. This is again a raster where values close to 1 represent a good suitability and values close to 0 represent low suitability.

Next, the maps will be exported back to ArcGIS, in which an algorithm that calculates the least cost path through the suitability raster will run. Because the algorithm is based on least cost, the inverse of the suitability map has to be created and used as input to the algorithm (very suitable gives a low link impedance and vice versa).

Instead of the least cost path, there is also the option of calculating the best route based on the roads in a current network using the network analyst function in ArcGIS. The reason why this has not been done in Mongolia, is that the current network is highly informal (as was also explained in chapter 4) as is the data map of the current network. This makes routing over the current network highly ambiguous.

The algorithm is based on 3 steps, the calculation of the cost distance, cost backlink and the calculation of the cost path. The cost distance is similar to the Euclidian distance, but the shortest weighted distance will be based on the input raster, instead of calculating the actual distance. The cost backlink function defines the neighbor that is the next cell on the least accumulative cost path to the nearest source. Both cost distance and cost backlink are calculated based on the source or origin point of Ulaanbaatar. The cost path finally, gives the least cost path, based on the input of the cost distance and cost backlink and given a destination point being the city of Khovd. These cost paths are raster based but can be converted to polyline shapefiles again, which makes them suitable for analysis.

6 Results

This chapter will present the results of the research. First, the suitability maps will be presented and discussed for the various themes. Next is a presentation of the routes that have been created by the algorithm from ArcGIS. These routes will be compared based on their length and impedance and they will be compared to the route that was proposed by the consultant. Finally, sensitivity analysis will be discussed.

6.1 Results of SMCE

Based on the weights of Table 1, the 9 suitability maps are created using the SMCE module in ILWIS. They are presented below. Red areas represent low suitability values, while green areas represent high suitability values. Intermediate values are represented by a red to green gradient.

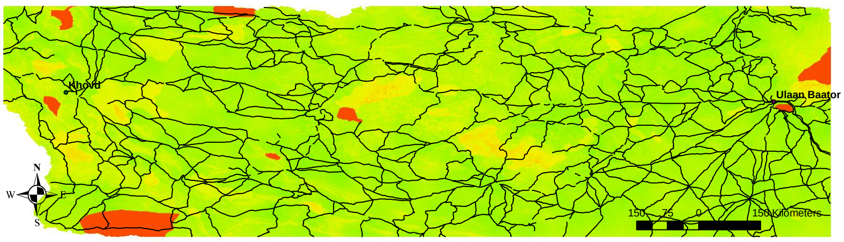

Figure 31: Equal Vision

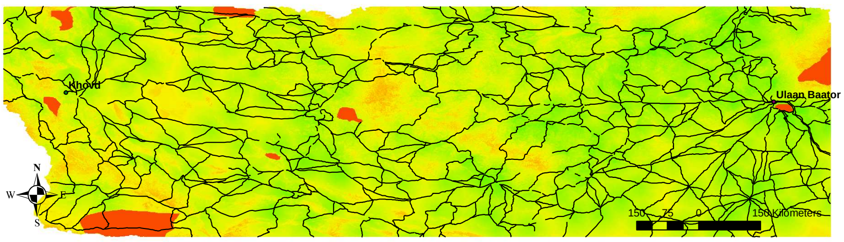

Figure 32: Economic Vision

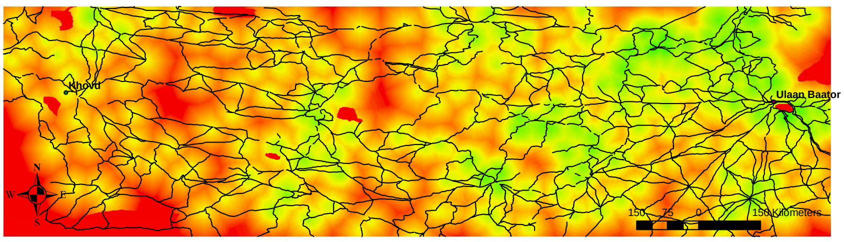

Figure 33: Economic Only Vision

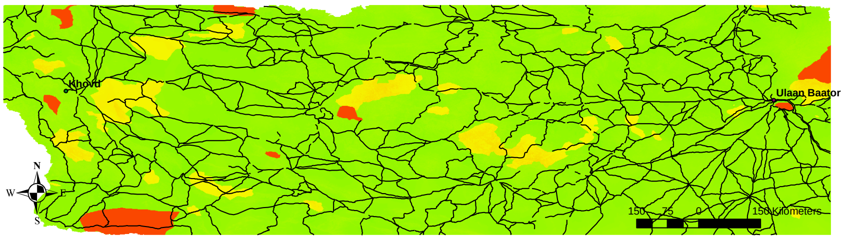

Figure 34: Ecologic Vision

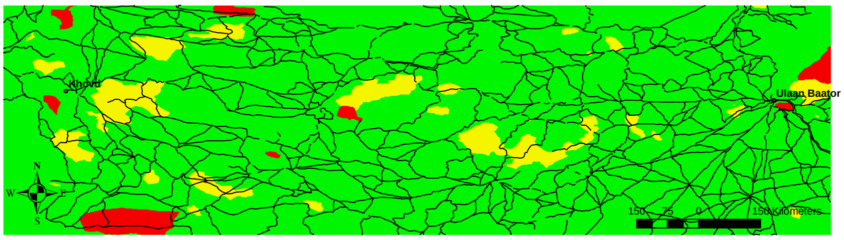

Figure 35: Ecologic Only Vision

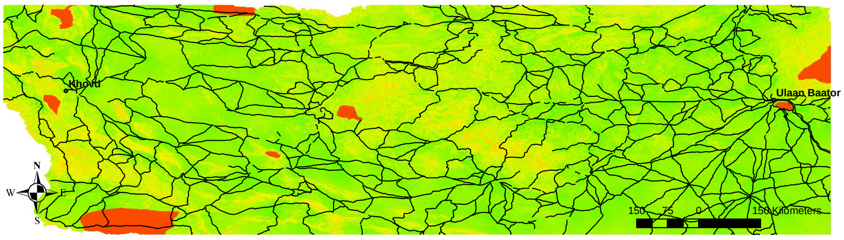

Figure 36: Technical Vision

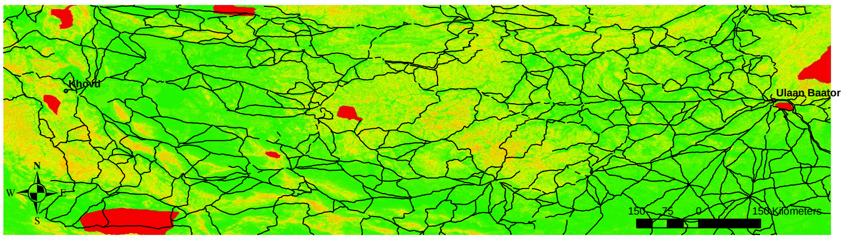

Figure 37: Technical Only Vision

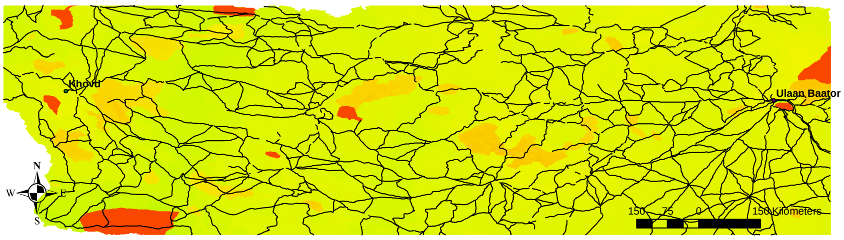

Figure 38: Social Vision

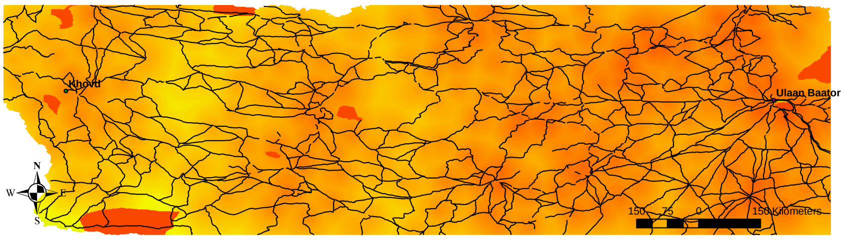

Figure 39: Social Only Vision

From the main four visions (Economic, Ecologic, Technical & Social) other maps are derived that show only one selected branch of criteria, the “only” visions. These vary strong. From the economic only vision, there is a strong focus on urban areas, where rural areas tend to become highly unsuitable. The ecologic only vision has high suitability for most areas, except the areas that are protected to some extent. Since most of the country consists of pasture land without any specific protected areas, the suitability in these areas is high. In the technical only vision there is a strong focus on the crossing of slopes in the country. High slopes are undesirable and receive low suitability. Finally the social only vision shows on one hand a focus on the areas with less access to urban areas (i.e. remote areas) but on the other hand there is a focus on areas that have higher concentrations of poor people (i.e. urban areas). This contradiction makes that most of the map is not outspoken suitable or unsuitable.

When the general visions are considered, they are quite similar among each other, with more of the nuances of features that are discussed about the “only” visions.

Finally, it can be seen that some areas carry zero suitability in all maps. These are the strictly protected areas.

6.2 Results of the Least cost path analysis

The suitability maps presented in the previous chapter serve as input to the least cost path analysis carried out in ArcGIS. This analysis should give an indication of the least cost route through a suitability map i.e. the preferred route for the particular vision. A network analysis has not been carried out (where the least cost route is assigned to an actual existing road network) because of two reasons. First, the network map supplied is very informal and technically inconsistent in its nodes and links.

In order to place things in perspective, the route which is suggested in the prefeasibility report by ICT Pvt. Consultants is also included. The ecologic only route has not been added because the algorithm cannot deal with large areas that have suitability value 1, which created a false route. Please note that suitability maps give high values for high suitability, whereas the least cost path searches for the lowest values through the raster. This meant that the inverse of the suitability maps needs to be created to run the least cost path analysis. Next the different routes (in red) will be compared to the consultant route (in blue).

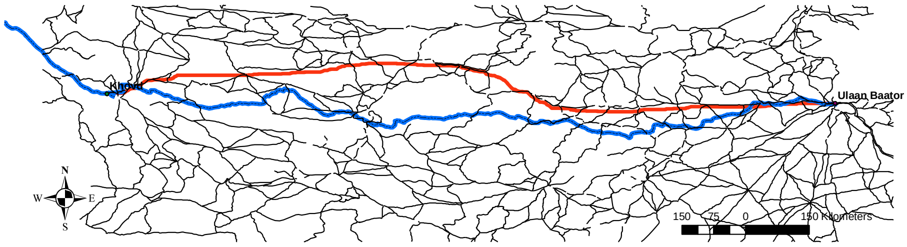

Figure 40: Equal route vs. Consultant route

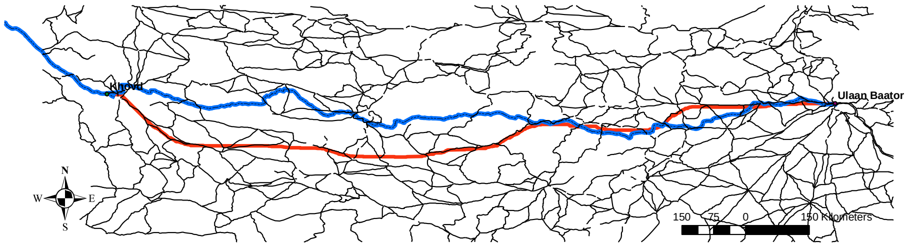

Figure 41: Economic route vs. Consultant route

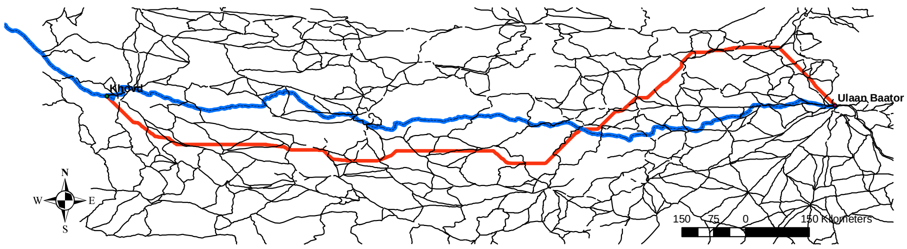

Figure 42: Economic only route vs. Consultant route

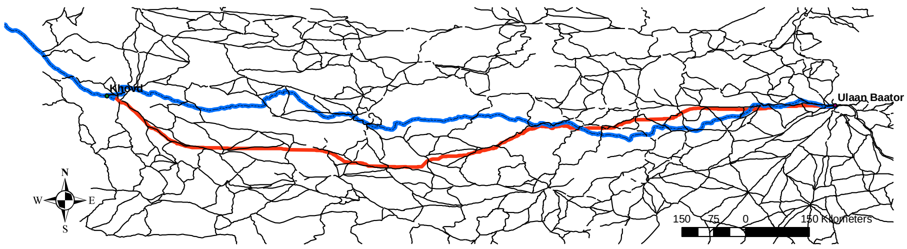

Figure 43: Technical route vs. Consultant route

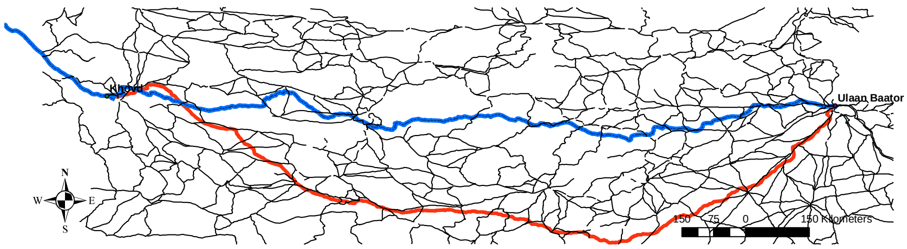

Figure 44: Technical only route vs. Consultant route

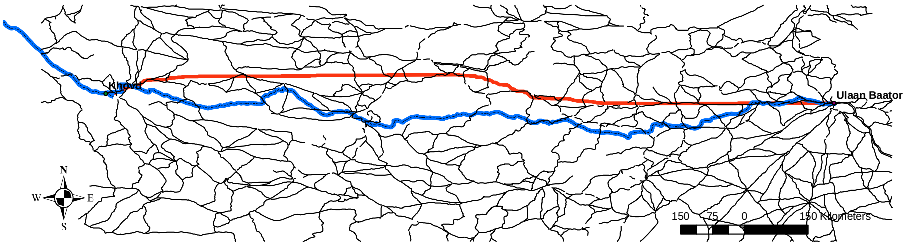

Figure 45: Ecologic route vs. Consultant route

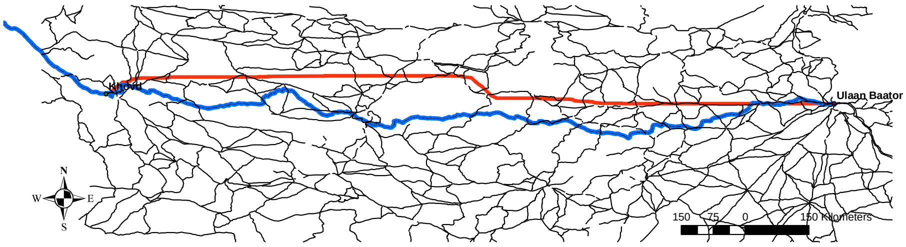

Figure 46: Social route vs. Consultant route

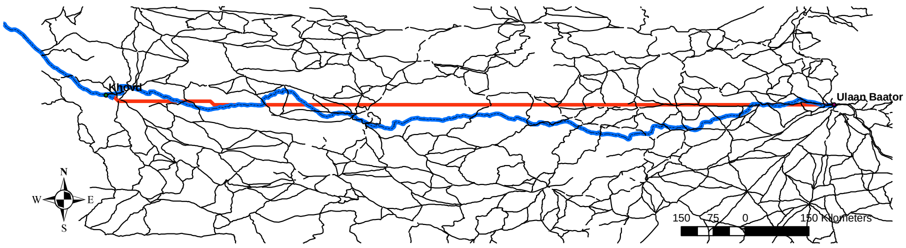

Figure 47: Social only route vs. Consultant route

Again there is a difference between the visions and the “only” routes. The vision routes do align with each other most of the time, whereas the “only” routes have different routing at all.

In general, the visions can be split into two categories being the northern routes and the southern routes, because they all have to go around the mountain range in the central part of the study area, regardless of the weight given to the slope suitability. The northern routes are: Equal, Ecologic and Social. The southern routes are Economic and Technical. The difference between northern and southern routes can be assigned to the weights the different visions receive. Economic and Technical visions receive relatively higher weights for the technical criteria. Therefore the less hilly southern route will be chosen.

The Social only route is different in the sense that it goes more or less in a straight line. This is caused by the fact that from the two components of this map (the accessibility to villages and cities and the amount of poor people) the spatial heterogeneity of the “amount of poor people” is very low which causes the complete map to have a low spatial heterogeneity. The low spatial heterogeneity is completely caused by the low population density in the country (Mongolia is the least dense populated country in the world). Low spatial heterogeneity makes that there is no better or worse routing alternative, so a straight line is the best route (least cost in least amount of pixels i.e. kilometers).

The economic only route roughly follows the same route as the economic vision, apart from the part close to the capital. There it will make a northern detour in order to pass by other areas of higher economic interest and lots of crop areas.

The technical only route is remarkable in the sense that will make an enormous southern detour to avoid many of the slopes (i.e. mountains ranges) that lie in the country. It will roughly go through the flats of the Gobi Dessert before going back North towards Khovd. Next, some statistics from the different routes will further clarify the routes.

6.3 Route statistics

Three types of statistics have been derived from the routes. First, the length of the routes has been calculated. Of course the length of the route is important. There is with some criteria a tradeoff between the length of the route and the score of the route. Secondly, the length weighted mean (LWM) is calculated. This is the mean of all pixels the route crosses. Since least weight cost is calculated, this means that a lower value gives a better overall score. The value of the LWM gives an indication whether the route that is calculated matches the vision. Finally, the total length is multiplied by the length weighted mean to give the Summation of the values of all pixels that are touched by the route.

The statistics are presented for all routes that were included in the previous paragraph (thus the ecologic only route is excluded). From the consultant route, only the length is given. Since no suitability map is existent for the consultant route, there can be no calculation of length weighted mean or Sum.

Route vision	Length (km)	Length Weighted Mean	Sum
Equal	1241	0,35	434,35
Economic	1314	0,4	525,6
Economic only	1483	0,45	667,35
Technical	1333	0,28	373,24
Technical only	1648	0,026	42,848
Ecologic	1200	0,4	480
Social	1199	0,5	599,5
Social only	1163	0,77	895,51
Consultant route	1480		

Figure 48: Route vision statistics

As can be seen from the statistics, there is quite some difference in the length of the various routes. Lengths are measured between Ulaanbaatar and Khovd. The social only route is the shortest with 1163 km, although the credibility of the route needs to be doubted because of the low spatial heterogeneity in the suitability map. The longest route is the technical only route with 1648 km. Overall, the northern routes are shorter than the southern routes and the “only” routes are longer than the visions.

The economic only and technical only routes are both longer than the consultant route (with marginal difference between consultant route and economic only route). All other routes are shorter. It seems that economical and technical criteria are of large influence on the route length. This is probably caused by the criteria of connecting Aimag centers resp. slope.

When looking at the LWM figures, the differences between the routes are also large. The lowest LWM value accounts for the technical only route, which has 0,026. This means this is the route with the lowest cost i.e. the highest suitability. The social only route has the highest LWM at 0,77. This is caused by the overall low suitability. In general, there seems to be a slight correlation between the length and the length weighed mean. The longer a route is, the “better” a route scores. A large fluctuation can be seen among the values. The reason that the technical only route receives a good score is mainly caused by the fact that the suitability map provides a route where the score can be very good. This is the same reason why the social only route scores poor. It is a result of the fact that the average values of the maps are very different. This makes it difficult to compare the different visions based on the LWM. The same counts for the summation of the LWM over the length, where also large differences can be seen.

6.4 Performance analysis

Performance of the results should be measured in order to know how a certain alternative contributes to the goals or criteria set for this alternative. When performance can be analyzed, the SMCE method becomes really valuable for both route design and route evaluation.

The statistical analysis in the previous paragraph in fact is already a performance analysis. However, it would only view the overall performance in terms of length (which is a cost criterion) and (Sum of) length weighed mean of the route of the suitability map. Although these criteria give some ideas on overall performance of the route, it does not provide information on the performance of a certain vision in terms of the criteria that have been used as input, which is desired as well.

The criteria that are used as input should be used as well to test the performance of the output. It would not make sense to use other criteria in the output than used in the input, since it then would have been better to use those criteria in the input in the first place. The only exceptions would be the criteria that cannot be used as input from a technical point of view.

The input criteria of this research could be translated to several output criteria as follows:

- The crossing of strictly protected areas can be measured with the km of route that crosses the strictly protected areas.

- The distance to Aimag centers, distance to tourist locations, distance to Sum centers and distance to crop locations can all be measured with the amount of locations within resp. 166 km, 111 km, 55 km and 27 km (i.e. the buffer zones used in the input) of the corridor. Alternatively, the shortest distance of each point towards the route can be calculated and Summarized for all points.

- The crossing of other protected areas can be measured with the km of route that crosses the other protected areas.

- Slope suitability can be measured with the average slope percentage over the whole route.

- Crossing lakes and rivers can be measured with the km of route that crosses the lakes and rivers.

- OPR can be measured with the average OPR value over the whole route.

These results can be used as input for the Definite 3.1 decision support system software, in which weights can be assigned to the output criteria and ranking of alternatives can be made accordingly.

A complete result can be achieved by doing a cost benefit analysis or CBA, as was presented in the research methodology. In this analysis, the costs of constructing the corridor or the additional cost to the environment will be compared with the benefit for the population in terms of socio-economic criteria.

Again, scale is an important issue in the performance analysis. The methods of calculating performance, which have been presented above, all take into account and measure the effect of the whole corridor on a certain criterion. However, for some criteria (e.g. distance to crop locations or the OPR) the effects will be, if they occur, of a local scale. A justified question on this issue therefore is: Can you attribute local effects based on overall performance of the route?

Better would be to attribute local effects based on local performance and attribute overall effects based on overall performance. How to do this will be discussed in the next chapter, in which a paragraph will be dedicated to scale issues.

The most important point to be made is that the performance is based on a model which is a simplification of reality. One cannot trust on the model and the ranking entirely without doing a field survey whatsoever. Verification of results in the field should always take place. It could be that data is not representing reality so that possible alignments do to fulfill to criteria they were believed to fulfill, e.g. an ecologic route crossing a special animal habitat or a social route missing a village in need of accessibility to the outside world.

For this research, no further performance analysis will be done, since it is believed that the value of overall performance on local criteria is perceived very low, compared to the effort in getting values for output criteria and cost benefit analysis.

6.5 Sensitivity analysis

A sensitivity analysis is done to analyze the effect of an uncertainty in the input (the weights of the criteria) on the change of the output. In other words, when varying the weights of a certain input variable, the route will change as a result. This can be said to be the effect of the change in the input variable. This is basically already done in the form of the comparison between the different visions and the "only" visions. A change in the input variables (weight) caused a change in the output variables (i.e. suitability map and least cost path).

Keshkamat did a sensitivity analysis for the results in the Via Baltica case. The analysis was a test for robustness of a ranking produced in the sensitivity analysis. The software package Definite 2.0 was used for this. The analysis looked at the robustness of the ranking. This meant that when applying a certain percentage of uncertainty (e.g. 5 %) on the weights of the different alternatives, the software would calculate if a change in ranking of the different visions would occur. If not, the results could be called robust. This method is used to say something about the quality of the results. Robustness is one form of good quality.

However, this method is testing the sensitivity analysis between visions, rather than within a certain vision. Though this method tells whether the results are robust, it does not tell how uncertainty in the input has effect on the results of the same output, which is interesting to know.

Recently, research has been published on the use of spatial sensitivity analysis for optimal route generation and selection. Joseph K. Berry (Berry, 2009) has written the book Beyond Mapping III, which is a compilation of articles published in Geoworld Magazine from 1996 to 2009. One of the subjects published in August 2009 is on the use of spatial sensitivity analysis to assess model response. The tabular results below show the outcomes of such a spatial sensitivity analysis.

Map Variable	**Original Weight Set**	**Increased Weight Set**	**Alignment Change** *(percent)*	**Total Cost Change** *(percent)*
Housing Density	**1.0**	***6.5*** , 1.0, 10.0, 10.0	(74/76 * 100)= **97%**	(197/165 * 100)= **119%**
Road Proximity	**1.0**	1.0, ***6.5*** , 10.0, 10.0	(62/76 * 100)= **82%**	(200/165 * 100)= **121%**
Sensitive Area Proximity	**10.0**	1.0, 1.0, ***15.5*** , 10.0	(26/76 * 100)= **34%**	(168/165 * 100)= **102%**
Visual Exposure	**10.0**	1.0, 1.0, 10.0, ***15.5***	(11/76 * 100)= **14%**	(166/165 * 100)= **101%**
Average Weight	***5.5***		*Original route length= 76*	*Original route cost= 165*

Map Variable	**Original Weight Set**	**Decreased Weight Set** *(standardized*)*	**Alignment Change** *(percent)*	**Total Cost Change** *(percent)*
Housing Density	**1.0**	***1.0*** , 6.5, 15.5, 15.5	(60/76 * 100)= **37%**	(169/165 * 100)= **102%**
Road Proximity	**1.0**	6.5, ***1.0*** , 15.5, 15.5	(62/76 * 100)= **97%**	(182/165 * 100)= **110%**
Sensitive Area Proximity	**10.0**	1.0, 1.0, ***4.5*** , 10.0	(26/76 * 100)= **97%**	(197/165 * 100)= **119%**
Visual Exposure	**10.0**	1.0, 1.0, 10.0, ***4.5***	(11/76 * 100)= **57%**	(188/165 * 100)= **114%**
Average Weight	***5.5***		*Original route length= 76*	*Original route cost= 165*

**To avoid negative/zero weight, a constant shift (5.5) was added to HD (-4.5) and RP (-4.5) calculations to adjust to 1.0 as lowest weight value*

Figure 49: Tabular results of spatial sensitivity analysis (Berry, 2009)

The idea is that a change in the weights of the various criteria (either an increase or a decrease with the average weight factor) will have its impact on the alignment (in terms of percentage change of length) or the route cost (which would make a good substitute for the LWM value used in this research). The example showed that a change in the weights can have a big impact on the alignment. In some case, changing one weight resulted in an alignment difference of 97%. In fact, this has been done in this research as well, since various themes with different weights resulted in different routes. The big difference between this research and the research on spatial sensitivity analysis is that in the latter the changes have been made quantitative, which was not the case in this research. The conclusion made in the book is that optimal route should not be taken as it is, but the output should be used with cause. The spatial sensitivity analysis shows how big the impact of a change in weights can be.

7 Discussion and Reflection

This chapter discusses the findings of the research, without answering the research question, which will be done in the final chapter. Several topics have been discussed throughout the research. They will be summarized in this chapter, which will serve as an umbrella of reflection towards the research topics and the research process.

7.1 Discussion on research topics

7.1.1 OPR

One of the topics discussed in this research is on including poverty reduction criteria to the SMCE process. This has been done in what has been called the OPR or opportunity to poverty reduction, which was an exploration into adding poverty reduction criteria in a GIS environment. The OPR that has been used in this research has been created outside of the SMCE model. It would have been possible to use it within the SMCE model, i.e. add the various sources as separate criteria instead of calculating one criterion outside the model. This would have increased the transparency of the OPR and would have made it more flexible.

7.1.2 Scale

One of the central topics discussed throughout the chapters is the scale issue. With scale is meant that one issue, problem, goal or chance has a possibility of addressing it on different (geographical) levels. Though referred to several times, it has not come to considerations on how to deal with scale.

Scale plays an important role because road planning takes places at different levels, where different criteria and different stakeholders are involved. Road planning of a local road in a local community is different from road planning of an international highway network. At a higher level, there is more legislation on planning, different criteria are considered and different stakeholders are involved. Scale also plays a role when addressing poverty reduction through road infrastructure. At different (geographical) scales poverty is defined different, problems are different and thus solutions need to be different.

When the different stakeholder were addressed in chapter 5, it became clear that different stakeholders can operate on different levels of scale in one project and therefore have stakes at different scale levels. This results in criteria that are on different scales. And yet the application of the corridor between Ulaanbaatar is fixed to one scale only, being the country wide scale.

When analyzing results, it became clear that when calculating a route for the entire corridor, it is difficult to attribute local effects based on overall performance, e.g. the fact that a corridor of 1500 km scores very well on social criteria or ecological criteria does not automatically mean that a very poor family will benefit from this corridor or that a small deer population will not be harmed by the corridor.

In a next study, scale should be considered. Ideas on how this could be done will be given in the next chapter, in which recommendations for further research on the scale issue will be given.

7.1.3 Method

When reviewing the method of planning infrastructure using spatial tools from a perspective of poverty reduction, one of the main discussion points is that the method of using spatial tools (SMCE or other tools) is second to the goal of planning. When planning of infrastructure contributes to poverty reduction, and this is mentioned as a goal of planning, the contribution should be as big as possible. SMCE is one tool capable of providing a holistic and transparent method for poverty inclusive planning. If other methods, spatial or not, could reach the same effect, they would be as good of a solution as SMCE can be.

Gannon and Liu (1997) validly state that the role of transport in poverty reduction is a complementary one. Planning a road using poverty reduction criteria alone is not enough to alleviate poverty in a certain area. Even if the model becomes very detailed and based on numerous pieces of evidence where road planning contributed to poverty, the act of planning a road only will not be enough. It is creating access to opportunities rather than it is creating opportunities, although the latter can be true in some instances. Including road infrastructure planning for poverty reduction in a poverty reduction strategy is a precondition, but road infrastructure planning itself is not a poverty reduction strategy. As for poverty, a poverty reduction strategy is multidimensional as well and should contain more than just one precondition.

7.2 Discussion on research process

Looking back, the way the research was formulated, it was not bounded enough. Wherever possible, literature was found and research was done. This prevented the research from going in depth in the research. Especially in a research scope that involves both engineering and social sciences, there is a strong need for strict bounding of the topic.

The methodology of doing the actual SMCE research was prepared in the research plan beforehand. This was done with little knowledge of the software. The only example available on route planning with the help of SMCE was the research on the Via Baltica case in Poland (Keshkamat, 2007). This meant that the methodology was in fact created while doing and problems had to be solved along the way. This resulted in some parts not receiving the attention they should have had, such as the stakeholder analysis and the analysis of results.

Since the stakeholder analysis serves as the basis for the finding of criteria, it is of big importance in the process of the SMCE. As said in the paragraph on the stakeholder analysis as well, stakeholder views were only available from second hand interviews and some internet leads of disputable quality. This resulted in a stakeholder analysis that was not as thorough as desired which made the links to the criteria weaker as well.

Though many factors were of influence on the quality of the results, the plan lacked some analysis on what to expect as outcome and how to analyze the results. Chapter 2 discusses this topic quick, with the solution of doing a cost benefit analysis. This unfortunately was not possible due to a lack of quantitative data on the results. Both a stakeholder analysis and a results analysis could have been stronger if more research was done in the process.

Finally, on the process of doing the case research, there was a lack of feeling for the local situation. The research was not accompanied by a field visit which meant that information was only based on sources, rather than on direct contact. It is recommendable that when this research would be extended or the method of SMCE would be applied to road infrastructure planning in a specific case, it has to involve a field visit. This would not only enhance the feeling for the case, but it would improve stakeholder analysis as well.

8 Conclusions & Recommendations

The main research question of this research is:

"Can geospatial technologies and SMCE contribute to the planning of road infrastructure as an institutional tool for poverty reduction?"

Geospatial technologies and SMCE can contribute to the planning of road infrastructure as an institutional tool for poverty reduction. The conclusions will answer to what extent. The recommendations for further research will give directions what more to research in order to improve the research towards the use of SMCE in the planning of road infrastructure as an institutional tool for poverty reduction.

8.1 Conclusions

Conclusions that can be drawn from this research are:

- Road infrastructure planning is guided by policy, in which goals are translated into projects. The act of planning is often formalized to a certain degree, depending on the scale and the governmental level the planning takes place. The act of developing and selecting route alternatives is often not formalized, resulting in non-transparent processes of designing routes.

- Poverty is a broad concept, of which many definitions do exist. Poverty has many dimensions e.g. hunger, lack of proper healthcare or lack of proper education. Poverty is also spatial, since poverty is about having or not having access to opportunities. This access factor makes poverty spatial.

- SMCE is capable of contributing to the planning of road infrastructure, especially the generation and selection of route alternatives. With the help of a good stakeholder analysis, proper data and modeling and a good performance analysis the use of SMCE is definitely a contribution to road planning, both in feasibility studies and in impact evaluation studies. It provides a clear and transparent methodology in which each stakeholder has an impact on the project development. It is a holistic method of route generation and selection and finally it is capable of integrating criteria from economic, ecologic, social and technical themes into one model. These findings have been confirmed before by the study on the Via Baltica. (Keshkamat et. al, 2008)

- For the purpose of adding poverty reduction criteria to the SMCE method, an overview of the relations between planning of road infrastructure and poverty reduction was made. The main outcomes are that road infrastructure is contributing to the reduction of poverty in terms of providing poor people with access to opportunities. One of the most important opportunities is the opportunity of having employment.

- Explorative research was done on the possibilities of including poverty reduction criteria as mentioned above to the SMCE i.e. translating the access to opportunities spatially. The OPR that was developed accordingly identifies regions where people are poor (based on the amount of people and their relative poverty) and remote (based on their distance to opportunities, where the opportunities are assumed to be concentrated in regional centers).

- As a practical consideration, planning of road infrastructure can be done to serve social policy goals (such as poverty reduction strategies). This research provides a first step towards road infrastructure planning using SMCE from a holistic perspective of poverty reduction.

8.2 Recommendations for further research

This research served as an exploration of the possibilities of new techniques for road planning and an exploration of the use of social criteria in these techniques. Much can be learned from this research but much still has be subject of further research before SMCE can be applied to a real case in the real work field, as was expressed in the conclusions. The following recommendations for further research are therefore given below:

- Scale
- Poverty reduction characteristics
- SMCE for planning road infrastructure

8.2.1 Scale

Further research should have a few focal points, of which scale is the prime focal point. The recommendation is that the distinction in scale should become evident in stakeholder analysis, definition and selection of criteria and in the SMCE process itself. It can be a choice to work with several layers of SMCE analysis in which each next layer zooms in on the target area. In the light of this research this could mean that the model is used first on an international scale, using stakeholders and criteria that are internationally relevant and using international maps. When corridors and connections are derived from this level, they are brought in to the next level as fixed criteria, where on a national scale national stakeholders and national criteria are used. Based on analysis at the national level, more detailed corridors and connections can be derived from the model. These are brought into the next level which can be called the regional level, in which regional stakeholders and regional criteria are used. When decreasing in scale levels the level of detail of increases while the area size decreases. Although the workload will increase, the separation of scales will give better insight in the situation at a certain scale and that the right level of detail will be reached in the end.

8.2.2 Poverty reduction characteristics

The research on including poverty reduction characteristics to the SMCE method was of explorative kind. This research gave directions on where to focus on when including poverty characteristics, being the provision of accessibility to opportunities, with one of the main opportunities being employment. More research is needed on the links between poverty reduction and the planning of road infrastructure, so that the characteristics of poverty reduction that are used in the SMCE method are based on sound research. In order to do so, research should be done on impact evaluation of road infrastructure planning, as was recommended by Van de Walle (Van de Walle, 2009).

8.2.3 SMCE for planning road infrastructure

The possibilities of SMCE as a method of routing road infrastructure for poverty reduction are promising. This research showed the technique is capable, and that with some extra research, the benefits to planners and people can be large. One thing that has not been discussed yet is the willingness of politicians and planners. They are the people that plan roads, which means they are the people that need to adopt or reject the method of using decision support systems for the planning and routing of roads.

One cannot use this method yet ignore the outcomes when it does not match with a political agenda. I therefore believe that an adoption of this method has to involve both the believe in the technical capabilities as well as the confidence to give in on some of the planning power, which does not mean that they have to give in on all of the planning power. A good application of the SMCE would work next to the current practices of planning road infrastructure (whatever they may be) and they would improve each others strength.

More research should be done on how to implement SMCE in the planning process, including research on the possible political barriers and how to overcome those.

It is up to the researchers to improve the research on the planning of road infrastructure with the help of SMCE from a perspective of poverty reduction, education possibilities and health opportunities. It is up to the politicians and planners to believe in the capabilities of planning with the help of SMCE and adapt the method in their planning practices.

References

(Abbey, 1992) ABBEY, L. (1992), *Highways, an Architectural Approach*. New York

(ADB, 1999) ASIAN DEVELOPMENT BANK (1999) *Fighting Poverty in Asia and the Pacific. The Poverty Reduction Strategy*.

(ADB, 2006) HETTIGE, H. & BANK., A. D. (2006) *When do rural roads benefit the poor and how? an in-depth analysis based on case studies / Hemamala Hettige*, Manila, Philippines :.

(Akinyemi. F.O. 2004) AKINYEMI, F.O. (2004) *Preliminary Design Of A Spatial Decision Support System For Poverty Management*. Nigeria

(ArcGIS, 2008) ESRI (2008) *ArcGIS 9.3* [software]

(Arentze et al, 1996) ARENTZE, T. BORGERS, A. TIMMERMANS, H. (1996) A Generic Spatial Decision-support System for Planning Retail Facilities. *Geographic Information Research; Bridging the Atlantic*

(Berry, 2009) BERRY, J.K. (2009) *Beyond mapping III; Topic 19: Routing and optimal paths*. [online] (updated 26 may 2009). Available at: http://www.innovativegis.com/basis/MapAnalysis/Topic19/Topic19.htm [accessed 17-11-2009]

(Blume et al, 1995) BLUME, A.M. (1995) The contribution of railway projects to poverty alleviation; The case of Tanzania. Frankfurt: KfW.

(BTOR, 2008) KESHKAMAT, S.S. (2008) Back to Office Report. Enschede.

(Catbagan, 2003) CATBAGAN, J.L. REGIDOR, J.R.F. (2003) Development of a Route Selection System using Three-dimensional Cost Models. *Journal of the Eastern Asia Society for Transportation Studies, Vol.5, October, 2003*

(CIA, 2009) CIA (2009) The World Factbook. CIA.

(DFID, 2002) DFID (2002) Transport's Role in Achieving the Millennium Development Goals. *Produced by the DFID Transport Resource center*.

(ESCAP, 2006) UNESCAP (2006) Emerging Issues in Transport, Transport and the Millennium Development Goals. *Ministerial Conference on Transport*. Busan, Republic of Korea.

(FE, 2002) UNKNOWN (2002) ICT, KMC Construction Bag Millennium Road Project In Mongolia. *The Financial Express*. New Delhi.

(Gannon & Liu, 1997) GANNON, C. A., LIU, Z., WORLD BANK. TRANSPORTATION, W. & URBAN DEVELOPMENT DEPT. TRANSPORT, D. (1997) *Poverty and transport,* [Washington, D.C.], World Bank.

(Gardner et al, 1986) GARDNER, J.R. RACHLIN, R. SWEENY, H.W.A. (1986) *Handbook of Strategic Planning*.

(Geneletti et al, 2007) GENELETTI, D., BAGLI, S., NAPOLITANO, P. & PISTOCCHI, A. (2007). Spatial decision support for strategic environmental assessment of land use plans. A case study in southern Italy. *Environmental Impact Assessment Review*, 27, 408-423.

(Griffin, 2001) GRIFFIN, K. (2001) *A strategy for poverty reduction in Mongolia; A report of a UNDP mission led by Keith Griffin on the Integration of Equity and Poverty Reduction Concerns into Development Strategy*. Ulaanbaatar.

(Hickerson, 1967) HICKERSON, T, F. (1967) Route Location and Design. McGraw-Hill.

(ICT, 2002) Intercontinental Consultants and Technocrats Pvt Ltd (2002). *Pre-Feasibility Study of Millennium Road, Mongolia*. New Delhi.

(ILWIS, 2005) 52 DEGREES NORTH (2005) *Ilwis academic 3.3* [software]

(IFRTD, 2005) IFRTD 2005. Network Report 2005. IFRTD.

(IRC, 1997) The Indian Road Congress (1997). *Manual on Route Location, Design, Construction and Maintenance of Rural Roads (other district roads and village roads)*. New Delhi

(Keshkamat et al, 2008) KESHKAMAT, S., LOOIJEN, J. & ZUIDGEEST, M. (2008) The formulation and evaluation of transport route planning alternatives: a spatial decision support system for the Via Baltica project, Poland. *Journal of Transport Geography*, 17, 54-64

(Keshkamat, 2007) KESHKAMAT, S. 2007. The formulation and evaluation of transport route planning alternatives: a spatial decision support system for the Via Baltica project, Poland. 92.

(KU Leuven research theme) VANEGAS, P (2009). Multi-objective Spatial Decision Support System for Afforestation Management in Mountainous Regions. *Current PhD research project*. http://www.kuleuven.be/research/researchdatabase/project/3E09/3E090033.htm (accessed October 2009)

(Leipziger et al, 2003) LEIPZIGER, D., FAY, M., WODON, Q. & YEPES, T. (2003) The role of infrastructure in Achieving the Millennium Development Goals. 26.

(LP, 2005) KOHN, M. (2005) *Lonely Planet Mongolia*. Victoria

(Meeuwissen, 2009) MEEUWISSEN, M (2009) *Current practices on the generation and selection of route alternatives* [interview] (Personal communication, 13 October 2009)

(MHDR, 2007) UNITED NATIONS DEVELOPMENT PROGRAMME (2007). *Employment and Poverty in Mongolia*. Ulaanbaatar

(MRND, 2007) MONGOLIAN MINISTER OF ROADS AND TRANSPORT (2007). *Mongolian Road Network Development*. Presentation at the Regional workshop on upgrading of the Asian Highway priority routes. Bangkok, 19-21 June, 2007

(Nederveen, 2007) NEDERVEEN, A.A.J. (2007) Ruimtelijke inpassing van lijninfrastructuur. *Een onderzoek naar de geschiktheid van inspraakreacties voor het beoordelen van lijninfrastructuurontwerpen.* Delft.

(NOA, 2007) RIJKSWATERSTAAT (2007). *Nieuwe Ontwerprichtlijn Autosnelwegen*. Rotterdam

(NSO, 2009) COULOMBE, H. OTTER, T. (2009). Mongolia Census-Based Poverty Map: Region, Aimag and Sum Level Results. Ulaanbaatar.

(Queensland, 2002) QUEENSLAND GOVERNMENT (2002) *Road planning and design manual.* Spring Hill

(Ravallion, 1990) RAVALLION, M. (1990). Reaching the poor through rural public employment: A survey of theory and evidence. *World Bank discussion paper 94.* Washington DC.

(Stewart, Kuffer, 2007) STEWART, G. KUFFER, M. (2007) Where are the poor? A disaggregation approach of mapping urban poverty. *Real Corp 007, Proceedings. Vienna. May 20-23 2007.*

(Tae-Ho et al, 2008) TAE-HO, R. ET AL. (2008). Construction on Decision Support System for Route Location Based on GIS. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B2. Beijing 2008.* Busan.

(Tandon, 2005) TANDON, A. (2005) Attaining Millennium Development Goals in Health: Isn't Economic Growth Enough? *ERD Policy Brief,* Series no. 35.

(UNESCAP, 2003) UNESCAP (2003). *Asian Highway Handbook*. New York

(US60, 1999) ARIZONA DEPARTMENT OF TRANSPORTATION (1999). *US 60: Florence Junction to Superior: Final Design Concept Report*. Phoenix

(Van de Walle, 2002) VAN DE WALLE, D. (2002) Choosing Rural Road Investments to Help Reduce Poverty. *World Development,* 30, 575-589.

(Van de Walle, 2009) VAN DE WALLE, D. (2009) Impact evaluation of rural road projects. *Journal of Development Effectiveness, 1:1,15-36.*