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Mountain Forestry Master Programme

Master Thesis

ELABORATION OF A FOREST ROAD NETWORK IN TRAUCH FOREST DISTRICT, WITTGENSTEIN FOREST ADMINISTRATION, HOHENBERG, AUSTRIA

Submitted by

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Chapter 1. INTRODUCTION

1.1 Problem Statement

In Trauch Forest District from Wittgenstein Forest Administration (Forstverwaltung Wittgenstein, Hohenberg, Lower Austria) was identified an area of approximately 400 ha which has restricted access to the forest resources. The only way of access in the respective forests is through old valley roads which are exposed to the risk of being damaged at an interval of every 2-3 years by the snow melting and the high level of spring and summer precipitations (Bancalari, 2008). Moreover the existent valley roads cannot provide easy access to all forest compartments so that the activities of sustainable forest management could be realized in an appropriate manner. The current harvesting technologies that can be used in the project area are: the tandem harvester – forwarder with a share of 10% of the project area and the downhill mobile cable yarding systems (MCYS) with a share of 90% of the project area. In case of the clear cuts the whole tree system with a Woody processor unit on the loading crane of the MCYS is used. For thinnings and single cuts the cut to length method is being used, generally employing a Tröstel TST 800 mobile cable yarding system (Bancalari, 2009). Consequently the following problems were identified by the project team (see Chapter 2 – Methodology) and need to be solved:

- Increased costs of road maintenance
- Restricted access to the forest and tending operations difficult to realize
- High harvesting costs and high risk of accidents among forest workers

The increased costs of road maintenance represent a straightforward fact if we consider that all existing roads in the project area follow water streams (valley roads). From the same reason and because some of the existing valley roads are still damaged, the access to the forest is restricted and forest management activities are difficult to realize. Especially the third upper part of the slopes are lacking of access, therefore tending operations, thinnings and final harvestings are possible to be realized only by employing downhill cable yarding systems. This harvesting technology involves high costs in comparison with other environmental – friendly harvesting technologies as well as a particularly increased risk of accidents among the forest workers. Therefore, feasible solutions must be found in order to solve these issues and to promote a sustainable forest management.

1.2 Goal and objectives

The goal of the present master thesis is to elaborate a new forest road network with slope roads for the project area of 400 ha identified in the Trauch Forest District, with the focus of solving the identified issues and to fulfill the following objectives:

- To improve the access to the forest and to facilitate tending operations, thinning and other forest management activities
- To reduce the harvesting costs, to open up access for using harvesters and forwarders and to create the possibility for using uphill cable yarding systems
- To make a general road network planning (zero line design) for the whole project area and a detailed planning for the area to be opened up in the 1st year
- To assess the construction costs of the forest road network

Chapter 2. LITERATURE RESEARCH

2.1 Importance and legal framework of forest roads designing in Austria

The construction of forest roads represents one of the more visible forestry operations and can have a number of environmental impacts including landscape, water, soil and habitats. An important and challenging issue of the forestry sector today is the environmental concern about forest development and sustainable use of natural resources. Resource utilization depends on the accessibility of the respective area and therefore it is impossible to give up the construction of forest road networks. Consequently, an important actual challenge of the foresters is to find solutions to improve environmental soundness and public acceptance of road construction activities (*Spaeth, 1996*). In this peculiar context forest road designing plays a critical role in finding the pragmatic and critical solutions which are best adapted to the socio-economic and environmental conditions of a given region.

Therefore, it is of critical importance that all phases in the designing and construction of forest road networks are carried out in a manner that is compatible with environmental values and sustainable forest management. However, one has to take in consideration that construction of forest road networks provides also important multipurpose benefits, such as (*Coulter, 2004*):

- opened access to natural resources
- sustainable management of natural resources
- protection of sensitive areas, habitats, biotopes
- maintenance of forested areas
- accessibility in case of disasters (wind throws, beetles attacks, fire, etc.)
- working places for local population
- safety at work, accessibility in case of accidents
- recreational purposes and tourism
- hunting and fishing possibilities
- accessibility for research, education and awareness raising for special reasons

Therefore designing and building forest roads networks should be regarded in this context of multi-purpose management and by making use of state of the art tools and techniques for reducing the negative impact on the environment. It depends on the professionalism and experience of the planner to find the best possible solution in the design of the forest road network plan which in any way has to be a compromise between the mentioned series of potential benefits.

In order to come closer to the case of the present project, it is to be stipulated that the back bone of the forest management and forestry related activities in Austria, in terms of legal provisions and regulations, is represented by the federal Forest Act which was first elaborated in 1852 and later improved by several amendments and many practice rules in 1960’s and 1970’s. The present Forest Act was last time enforced in 1975 and since than the general rules for forest roads designing and construction are still valid (Sedllak, 1996):

- Negative impacts on forest soils and stands must be minimized. The road density has to be limited depending on technical, economic and environmental considerations.
- Construction, maintenance and use of forest roads must not:
    - cause critical erosion

- impede high water flow in torrents
- enhance avalanches
- cause disturbances of unstable terrain
- influence the runoff in a negative way in critical watersheds.

  - Forest roads must be planned by professional forest engineers and road building must be supervised by forest engineers or foresters.
  - Individual approval by the forest authority with a formal procedure at the district level is required for forest roads planned in mountainous watersheds, and/or affecting protection forests, and/or interfering with public interests, e.g. public roads, railways, power lines, etc.
  - Normal forest road projects outside of these limitations must be announced to the forest authority four weeks ahead of construction in order to check their location.

The rules presented above are peculiar because they represent merely best practice guidelines rather than rules for development of forest road networks. Technical standards (e.g. road profiles, gradients and drainage, as well as planning and construction methods) are described in Austrian forestry literature, but they are not legally enforced. Nevertheless, the individual projects need a particular approval by the regional forest authority so that various details can be adapted to the varying local conditions.

Additionally, environmental regulations became necessary since the "green revolution" (1970's) brought into the public opinion attention the negative impacts of the forestry sector over the environment. The basic arguments of the environmentalists against forestry sector were (Sedlak, 1996) that:

- Forestry disregards the environmental protection, being too much oriented towards timber harvesting and economic profit and,
- Forest road building brings negative impacts to the environment (e.g. forest damage, disturbances of ecosystems and wildlife habitats, deterioration of scenic values, etc.)

At present time there is a dual approval system for forest road projects in Austria: one from the forest authority and the second one from the nature conservation authority.

In order to achieve the *approval of the forest authority*, a forest road project in Austria has to fulfill the following standard conditions (Sedlak, 1996):

- The road construction has to comply with the designing project (plan and profiles)
- Employment of excavators for earth and rock movement on steep ground (>40% slopes) is compulsory
- Special attention must be paid to rock drilling and blasting in order to minimize damage to forest stands and areas below the road
- Surplus of cut material resulted on steep slopes (>70%) must be transported to safe deposit areas
- Road slopes must be stable and they have to be shaped to the natural repository angles of the material
- All road slopes subject to erosion must be re-vegetated by means of appropriate methods as soon as possible, in order to reduce the high rate of surface erosion
- The road drainage system, critical element of road designing and construction, must be closely adapted to the natural drainage system. Therefore, immediate drainage of the

construction site is compulsory to prevent road failures, landslides and serious erosion. The minimum diameter for culverts is 400 mm. The dimensions of stream culverts have to be individually designed depending on a 50-year flood event. Culvert inlets have to be protected against clogging and sediment depositing, outlets against erosion by means of energy dissipating devices (e.g. stone riprap or timber cribs)

- Embankments of critical stream crossings should be kept as low as feasible by means of fords combined with a culvert for the normal water flow. The ford embankment must be stabilized by means of revetments in order to withstand the forces of high floods and mud flows
- Landslides during the construction site must be immediately stabilized
- Gravel pits opened for road construction must be re-vegetated after building the road
- Intersections with public roads and foot trails must not hinder their original use

Although there are some differences regarding the regional legislation on the environment protection, in order to obtain the *approval of the nature conservation authority*, a forest road project in Austria has to fulfill the following general conditions for protection and preservation of nature, landscape and indigenous environments (Sedlak, 1996):

- Environmental disturbance, habitat encroachment and impairment of recreational and scenic values is prohibited
- Proof of an optimized development project by means of evaluating several alternatives
- the road density has to be minimized in favor of mobile cable yarding systems
- Limits of road widths; serpentines are allowed only at insensitive locations
- Protection of wet areas and specific wildlife and/or plant habitats
- Protection of landscape and scenery by means of a road alignment that is well adapted to the terrain
- Stream protection by means of buffer strips and silt traps
- Immediate re-vegetation of road slopes with indigenous plant species

2.2 Best practice guidelines for forest road designing in Austria and technical specifications

As stated before, building a forest road has a huge impact over the environment and the landscape, determined by the long lasting change in use of the former forested land (lifetime of the forest roads is usually more than 30 years). Therefore planning a forest road network represents a key factor in developing further forest management activities and should be made with care and responsibility by qualified forest engineers.

The major issue to be identified before starting the designing process refers to the possible techniques of timber extraction which can be used in the project area, due to the fact that the harvesting technologies have direct influence on the road density needed and consequently on distances between two or more alignments on a slope and to the process of designing the forest road network itself (Stampfer, 2005).

In following paragraphs a brief description of the technical elements which have been used in the designing process of the forest road network are being described.

A. Road Spacing (Road distance)

Road spacing or road distance represents the average distance between the forest roads in a given area. The road distance is derived from the following formulas (Dietz, 1984):

$$WD = \frac{L}{F}(m/ha) \;, \qquad WA = \frac{10000}{WD}(m),$$ where:

WD – road density (m/ha)

L – length of the designed forest road network (m)

F – surface of the project area (ha, area being opened by the new road network)

WA – road distance (m)

Under Austrian conditions road spacing varies from 200 m to 400 m depending on steepness, forest ownership and available skidding equipment.

B. Road alignment

The road alignment is defined by horizontal and vertical alignments. *Horizontal alignments* refer to bends and straight lines that connect the surveyed points in the field (the pegs). Attention must be paid during designing process to the radius of curves that must be adapted to the terrain, to the hairpin bends and to branching of the forest road network. *Vertical alignments* refer to the lines that connect the surveyed points in a longitudinal profile. The standard radius for peaks should be of minimum 400 m and the radius for vats of 200m (see table 1). The practical specifications regarding the alignments that should be taken in consideration when planning a forest road network are presented in the following table (Hafner, 1971; Steinmüller, 2008).

Table 1. Specifications for the alignments of the forest roads (Hafner, 1971; Steinmüller, 2008)

Design elements	Dimensions	
Side slope	< 50%	> 50%
Roadway width	4.5 - 5.5 m	4.0 m
Single-lane width	3.0-3.5 m	3.0 m
Minimum radius (horizontal)	25 m	20 m
Minimum switchback radius	15 m	
Minimum switchback lane width	6 m	
Maximum slope gradient	9 - 12 % (15 %)	
Minimum slope gradient	2 - 3 %	
Serpentine slope gradient	5 - 6 %	
Standard radius for peaks (vertical)	400 m	
Standard radius for vats (vertical)	200 m	

The maximum slope gradient for loaded conditions should not exceed 9%, for unloaded conditions 12% and for short distances it could be up to 15-16%. The maximum gradient in a hairpin bend should be at 5-6%.

Regarding the serpentine alignments it is a well known fact that they are unavoidable in mountainous terrain, but nevertheless the number of switchbacks in a road course must be reduced to a minimum. Zigzag roads with too short distances between switchbacks are not only unsightly and difficult to travel on, but are also sources of landslides and erosion on steep slopes (Sedlak, 1996).

Another important factor which must be taken into consideration during the planning process of a forest road network is the clearing width. In order to be able to start with the construction site, the corridor (alignment) of the future forest road must be cleared out of trees. As for reducing the environmental impacts, but in the same time to provide a good visibility on the forest road and direct light access to the road bed a compromise was reached with regards to clearing widths (see table 2).

Table 2. Clearing widths depending on the steepness of the terrain (Sedlak, 1996)

Side slopes	**Clearing width parallel to slope**		
	Cut section (m)	Fill section (m)	Total (m)
< 40%	6	5	11
40 - 50%	7	6	13
50 - 60%	8	7	15
> 70%	10-15	3-4	13- 19

C. Formation and standard profiles

The formation is the foundation of the road construction and represents the usable limit of the earth works (e.g. embankments, carriage way, ditches, etc.). The angle for cutting and filling material along the alignment according to the ground material should be according to the natural angle of repose of the respective material.

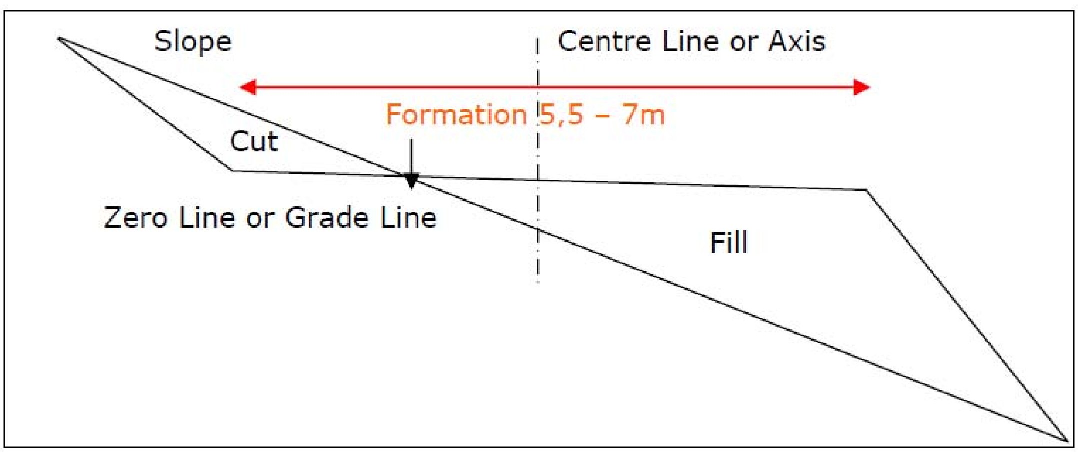

Figure 1. Mixed profile (Stampfer et al., 2005)

The angle for cutting material in case of an earthy material should be in the range of 1:1 till 4:3 and the angle for reposing the filling material should be 3:4. In the same time the usual road bed width will be 4,5 m. The designer as well as the constructor should try to balance the cut material with the material for filling and to reduce longitudinal material or mass transport, due to the increased costs inquired by the last process (Stampfer et al., 2005). In case of rocky terrain, the recommendable angle for cutting material is 5:1, as the terrain is stable and drillings, earth mass excavations and transport should be reduced as much as possible. This is also the reason for reducing the width of the road platform to 4,00 m.

D. Carriageway and drainage of forest roads

Depending on the type of the bedrock each forest road needs a layer of base (foundation) and surfacing material (suprastructure). The thickness of the pavement (carriageway) depends also on the carrying capacity of the subgrade (e.g. rock, soil, muddy soil, etc.) and generally should be between 200 and 500 mm (Stampfer et al., 2005). Long-distance transport of gravel is not only costly, but has also a big environmental impact. If there is the possibility to quarry suitable material for completing the road along the construction site, then those quarries also could serve as widening places or loading bays, as well as remaining useful for maintenance purposes. This material should be transported and spread evenly with trucks, shaped and cambered with a grader and compacted with a vibratory roller. In order to reduce the construction costs as well as the environmental impact caused by quarries, local material for surfacing the road bed should be used (Seedlak, 1996). In case of the current project, there will be sufficient local gravel for surfacing the forest road network.

Water is the major threat of forest roads and if this issue is not well addressed in planning, construction and maintenance than the road will deteriorate rapidly. There are three sections of drainage needed:

- the run-off from the road surface
- the run-off coming from the slope,
- the ground water

To safeguard the run-off from the road surface, the pavement has to be cambered. The transversal gradient of the cambered surface should be approximately 2-3% on each side (see figure 2, Stampfer et al., 2005), then the water will run either in the ditch and further will be evacuated through culverts or directly on the downhill side of the road.

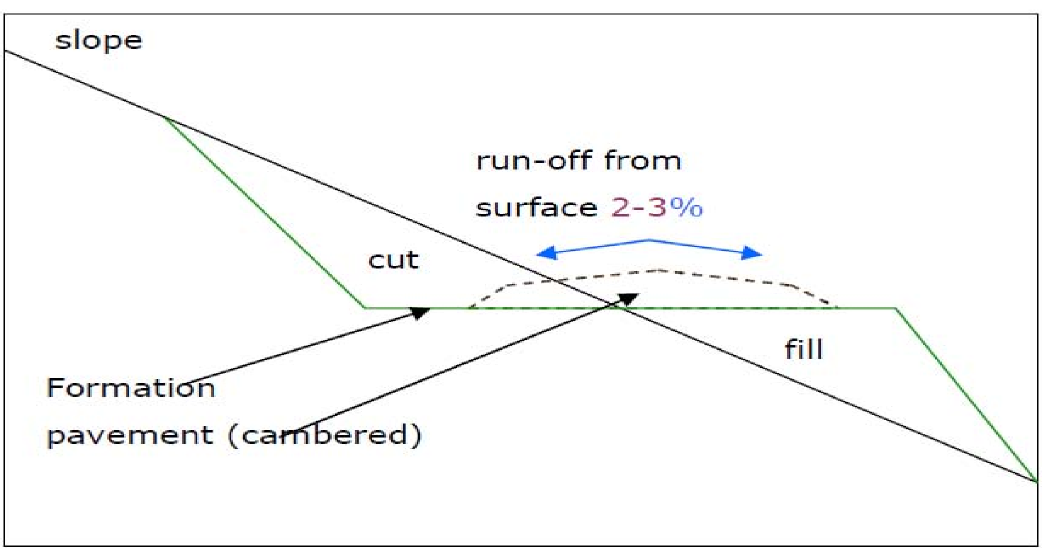

Figure 2. Camber details in cross section profile (Stampfer et al., 2005)

The second necessity for drainage is for run-off of the water coming from the slope. In this case, along the slope side of the road the roadside a ditch is constructed, usually using a grader. The ditch has the role to collect the water both from the slope as well as from the road bed and to evacuate it through the culverts (see Figure 3, Stampfer et al., 2005).

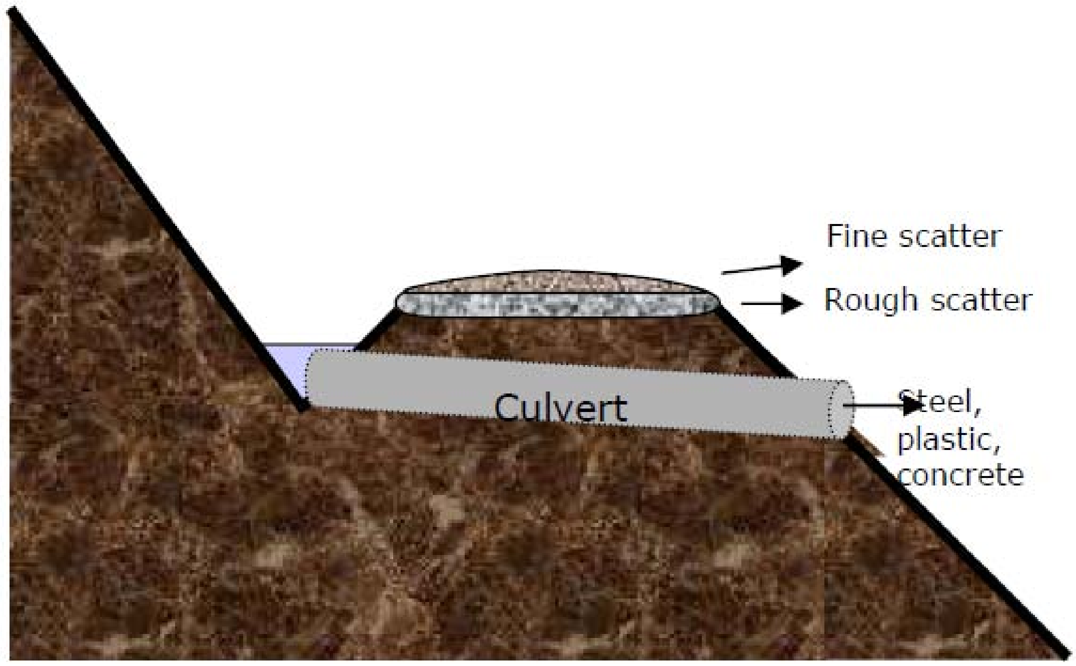

Figure 3. Details of culvert under passing the forest road (Stampfer, 2005)

According to the slope gradient of the forest road and the average amount of water from uphill, culvert spacing can be between 70 and 150 m. In case of the current project a spacing of 70 m between culverts (400 mm metallic pipes) was adopted.

Usually metallic pipes are used as culverts, but other options can also be used: concrete, plastic or corrugated steel culverts; nevertheless, these solutions are more expensive and need more attention when put in place. The advantage of metallic pipes is the possibility to construct them according to the requested length of each culvert in advance before they are transported to the construction site. Additionally they are very easy to pass and install during the construction of the road. In steep slopes it is recommendable that on downhill side of the culvert, big stones should be installed in order to avoid erosion (Stampfer et al., 2005).

For drainage of normal rainwater the average diameter of the pipes should be between 400 and 600 mm and for steadily running small streams the diameter could be extended to 1000 mm or more. If the flow rate requests a larger profile it is recommended to construct an engineering structure (e.g. ford).

E. Engineering structures

The *ford* is the cheapest and easier to build and to maintain engineering structure for water crossings of forest roads. The fords are also preferred by the environmentalists in front of the culverts, due to the fact that the culverts interrupt the water ecosystem. Nevertheless, in critical torrents, a culvert for the normal run-off with a ford for high floods is recommended from the practical point of view (Seedlak, 1996).

There is no need for detailed planning of a ford, but only to construct a converse gradient (+ %) at the downhill side (- %) of the ford (see Figure 4). This converse gradient ensures avoidance of the stream overflowing downhill the road during periods of heavy rainfall. The ford should be build with approximately 25 to 30 cm thick concrete reinforced with steel, but in case of the current project massive blocks of stones are available and can be used for building the ford.

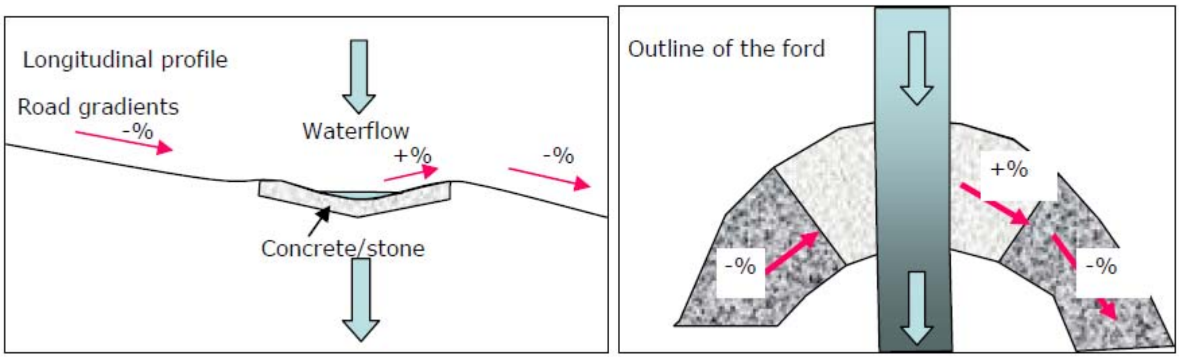

Figure 4. Details of a ford (Stampfer et al., 2005)

Due to the underground of the road alignment there are some special cases when it is necessary to fasten the embankment uphill (to avoid landslides), downhill side (to avoid declining of the road bed itself) or both sides. Construction techniques may vary according to the local situation, but the most commonly used technique is dry stone walls, which are usually constructed with the excavator along with the construction of the road formation. Dry stone walls can be constructed on either side of the road relatively quickly by using a skilled excavator operator.

The literature findings regarding the legal framework, the best practice guidelines as well as the technical specifications for designing forest road networks in Austria represent the basis for a sound forest road designing and, consequently, have been taken in consideration in the elaboration of the current project and adapted to the real terrain conditions of the project area.

2.3 Innovative approaches for supporting decision making in road network planning for multiple objectives

Designing the optimal road network is a complex and challenging task because forest road designers must consider several related problems:

- the important amount of terrain and environmental data,
- the lack of explicit constraints
- the unclear and contradictory goals

Computer-aided engineering approaches have been developed for solving these layout problems and their utility has been accelerated by the widespread availability of digital elevation models (Stückelberger, 2006). Initially limited by computing power, they have been improving continuously, resulting in software packages that are supporting the decision making process in road network planning in particular and forest engineering in general.

Starting from PLANS (Twito et al., 1987) and continuing with PLANEX (Epstein et al., 2001) or CPLAN (Chung & Sessions, 2002) these software packages are trying to solve engineering optimization problems inherently multi-objective ones, because they usually have several possibly conflicting goals that must be satisfied simultaneously (Stückelberger, 2006).

PLANS is a software package developed by USDA Forest Service late 1980's which integrates timber harvesting planning using digital terrain models (DTMs) to provide the topographic data needed to fit harvest and transportation designs to specific terrain (Twito et al., 1987). One subcomponent of the software (MAP) was used to construct the digital terrain models required by PLANS, using digitizer-traced contour lines from topographic maps, which are, in turn, processed into an elevation grid and stored in matrix form. MAP builds continuous digital terrain models that can cover large planning areas and builds them to any elevation grid spacing desired. Though the MAP method does not always result in digital terrain models that are a perfect equivalent to the topographic map, they should be adequate for planning. This represents one primary limitation of the MAP program which is the accuracy, relative to the ground, of digital terrain model constructed with it (Twito et al., 1987). Another limitation was represented by the time constraints, explicitly by the time required to construct DTMs with MAP software (manually tracing the contour lines).

PLANEX is a software package designed to support decision making for road network planning and construction, as well as for harvesting planning. The software is based on digitalized information stored in geographic databases and can automatically design the road network (compass step method). Designing a forest road network which should fulfill multiple objectives seems to be a complex process and only few analytic solutions can be analyzed in practice, fact which limits the quality of the obtained solutions (Epstein et al., 2001).

Forest roads must fulfill usually some technical constraints, such as the maximum slope for loaded trucks and the minimum radius of a curve (the road must be wide enough to enable trucks to turn safely along the curve), constraints which make the designing process even more challenging. In the same time, the cost of carrying the logs to the road borders using skidders and towers depends mainly of the distance between the timber and the road. Consequently, a very dense road network will produce smaller harvesting costs, but road construction is expensive and it also negatively affects the environment. Therefore, finding the best technical and economical combination among the location of skidder, harvester – forwarder tandem or cable yarding systems and the road network design is a difficult problem to solve.

In this kind of situations PLANEX can be involved for modeling the problems and requires topographic information of the harvesting areas and timber inventory in digital format (GIS). PLANEX solves the problem using this information together with technical parameters and costs of harvesting and road construction by interacting with GIS and obtaining topological information and timber volumes. A visual solution includes location of cable yarding systems, harvesting areas of each equipment, non-harvested or unreachable areas, existing roads used and new roads to be built. It allows the user to modify several of these elements. The system also gives as output several reports that specify the location of towers in coordinates harvested volumes, average harvesting cost, and cost of road building and timber transport (Epstein et al., 2001).

The general scheme in which the system operates is briefly presented: divide the study area in small cells of 10x10 square meters, which establish the basic unit of analysis. For each potential location of the cable yarding systems, harvesters or skidders the system identifies all the cells reachable (possible to harvest) from that location (see figure 5).

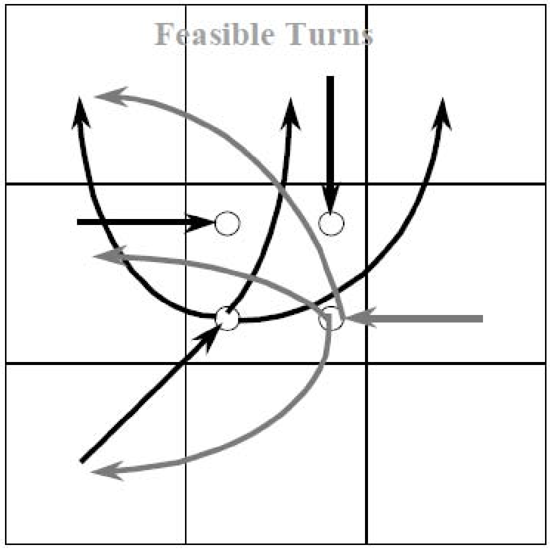

Figure 5. Connection of a cell with the existent road network – PLANEX (Epstein et al., 2001)

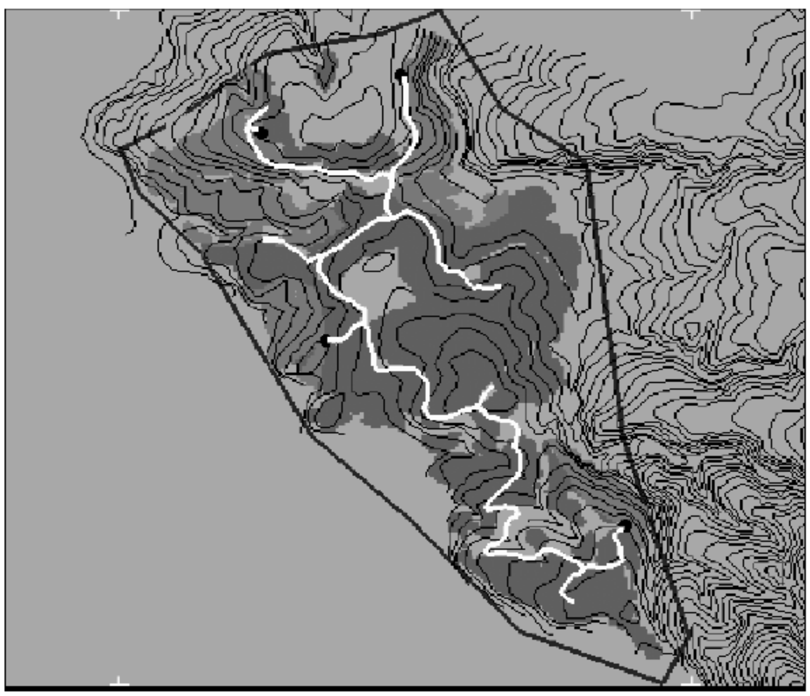

Figure 6. Graphical solution generated by PLANEX (Epstein et al., 2001)

In order to calculate the best way of connecting a harvesting technology with the existent road network, a set of potential roads must be analyzed (alternatives, see Figure 5). For each cell an evaluation of the technical feasibility of building a road segment that links this cell with its adjacent cells has to be done. The level of complexity in decision making increases when the technical constraints for road building are incorporated. This implies the addition of several nodes on each cell to identify the direction in which the cell is accessed. This way, it is possible to identify every feasible turn by eliminating the arcs that produce very close curves. Thus, for a given location, the shortest path between this point and the existent network represent the cost of connection. A possible solution of a given problem can look like in Figure 6 from above.

Although PLANS has been used for developing harvesting and forest road network plans based on large scale topographical maps and PLANEX is able to generate an approximately optimal allocation of equipment and road network based on its heuristic algorithm, none of the mentioned software packages can provide a complete analytic tool which would be able to conduct ground profile analysis while simultaneously optimizing landing and road locations. This problem can be solved by the elaboration of heuristic network algorithm called CPLAN, which is a preliminary computerized model that can assist forest planners in decision making, providing good alternative plans. Solutions for solving the problem of logging equipment assignment and of the road network planning simultaneously can be achieved by using GIS and heuristic optimization techniques (Chung & Sessions, 2002).

CPLAN applies a heuristic network algorithm to solve a cable logging and transportation planning problem. Combined with GIS, the method helps forest planners evaluate a large number of alternative paths in extracting logs from the stump to the mill using cable logging and truck transportation. The logging feasibility and cost analysis modules included in the method provide physically and environmentally feasible alternative timber paths. Nevertheless, some constraints of this method were also identified (Chung & Sessions, 2002). First, since the solutions are determined solely by the logging feasibility and economic analyses, they might not be the best choices from practical perspectives. Second, taking in consideration the fact that the method determines road locations based on a raster grid map and the alignment of roads is not constrained in the method, the proposed roads may include many sharp turns that are inherently produced by connecting a grid cell to one of its adjacent cells. Most of these sharp turns are not feasible for actual road layout and the actual road should be relocated with considerations made to the physical feasibility of the road alignment. Third, a lack of suitable data for the analysis is another problem faced in implementing this method. It is a straightforward fact that low quality data would not produce useful and satisfactory solutions.

Concluding we can note that even the most sophisticated methods and analytic tools designed to support planning and decision making have some shortcomings (Stückelberger, 2006):

- they assume road-building costs to be route-independent
- they limit the number of possible links from a specific network node to its adjacent nodes
- they assume the road centerline to be a chain of consecutive straight lines without considering curve or switchback constraints
- they rarely analyze systematically the trade-offs between different objective functions.

An approach to forest road layout that overcomes the mentioned shortcomings was introduced by Stückelberger et al., 2004 and Stückelberger et al., 2006 which combined the multiple objectives into a single function via the weighted sum of objective functions methods. The defined objective functions were construction and maintenance costs of a forest road network, the negative ecological effects and the suitability (attractiveness) of using cable yarding systems. Moreover the solutions must be physically feasible, economically efficient, environmentally sound and institutionally acceptable (Stückelberger et al., 2006).

The overall model presented by Stückelberger et al., 2006 has five components which altogether aim to solve the problem of minimizing the network that connects the cardinal points in mountainous terrain. These components are:

- a digital elevation model (DEM),
- classification for geotechnical properties of the subsoil,
- the specification of road design parameters,
- unit costs for structural components
- a rock-excavation share model

Minimizing in this context refers to simultaneously solving the objective functions, or other way said to efficiently reduce the life-cycle costs of the forest road network, as well as the disturbances over the habitat, while improving the access for cable yarding systems. Figure 7 shows the interactions in between the mentioned components. The limitation of this approach is that the basic assumption of multi criteria optimization (objective values must be independent) is being violated due to the fact that the negative ecological impact is based on expert knowledge that considers some unclear components, which finally make the approach to be subjective.

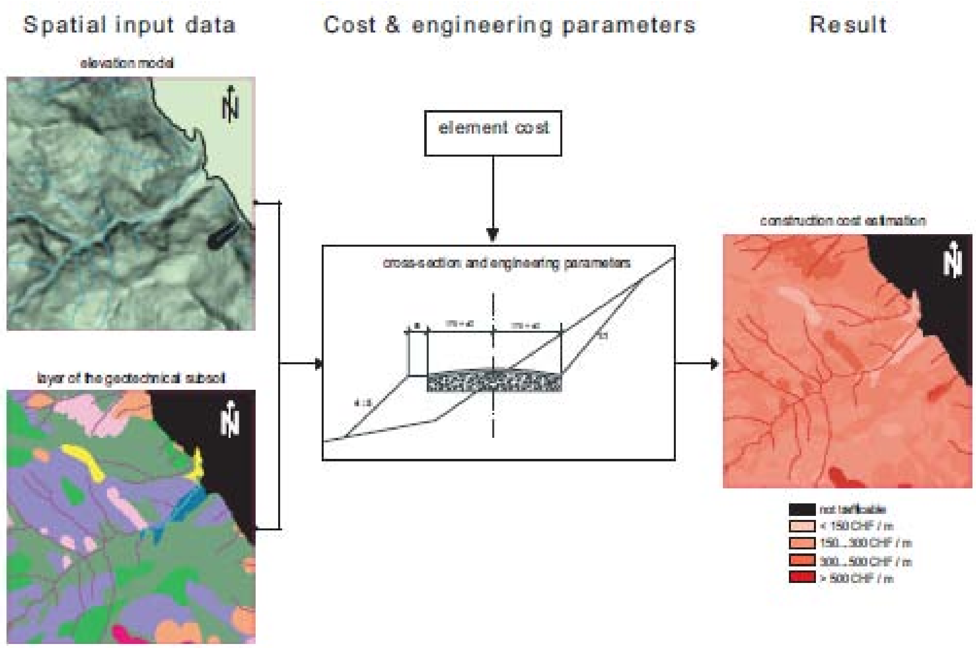

Figure 7. Flow chart for potential road construction estimation using DEM (Stückelberger et al., 2006)

The innovative approaches presented in this subchapter are of tremendous importance for the future development of forest road network planning and especially for improving and understanding of the trade-offs that one forest road planner must make during designing process. The decision making becomes easier when different solutions based on DEM are visually presented to the project (forest) owner and when these alternatives are weighted in terms of their multiple use objectives. In future, the computer aided engineering approaches, which nowadays represent merely a pioneering alternative, can become a state of the art tool for forest road designing and decision making, replacing the classical methods of road network planning.

Chapter 3. OBJECT OF RESEARCH AND METHODOLOGY

3.1 Methodological approach

The methodological approach used for the elaboration of the current project basically followed the fundaments of project management, several steps being undertaken in order to achieve the set of goals and objectives (see *Chapter 1*), as presented in table 3.

First, a kick-off meeting of the stakeholders involved in the project took place. This marked the start of the project. Next steps were the literature research, followed by the 1st survey of the project area. The general planning, consisting of the compass step method and zero line designing followed consequently, as well as the field measurements and data collection phase; these steps took place during the full month of November, 2008. The next step was the office work, marked by the data processing and elaboration of analysis and assessments, using the state-of-the-art tools for forest road network planning (RoadEng software & GIS). The results phase followed, where the achievements of the previous step were gathered and communicated among the stakeholders of the project. Finally, after the experts review of the work, the project was closed down and approved by the project owner team, during the last phase of the project (see table 3).

Table 3. Methodological steps for project elaboration – synthetic overview

Phase	***Goal (tasks)***	***Equipment***
1. Project start	Define problem statement, project team, project objectives, goals and assignments	Map of project area
2. Literature research	Setting the technical and scientific basis for a sound forest road network design	Specialty books, forest engineering journals and publications, internet
3. First survey of the field	Mapping existing roads and access paths, identifying difficulties zones and cardinal points in the project area	Clinometer, forest map of the project area
4. General planning	Elaboration of road network variants on a map	Contour line map, compass
5. Field measurements	Connect starting and ending points of the road network by marking zero plane in the field and filling the data collection protocol in the surveyed points	Data collection protocol, contour line map, clinometer, compass, measuring tape, GPS
6. Data processing	Analysis and assessment of data collected in the field, elaboration of detailed planning and designing of maps, plans, cross section, longitudinal profiles	RoadEng, Arc GIS, CAD, Microsoft Office (Excel)
7. Results	To present the deliverables and findings of the project, such as: maps, plans, profiles, cost estimations, benefits, technical report	Microsoft Office (Word, Excel), Arc GIS
8. Project approval	Obtain the approval of results from the project owner and examination commission	Microsoft Office (PowerPoint)

During the whole period of the project development a continuous communication process within the project team was maintained in order to solve all the sensitive issues encountered in designing and to promote a sound decision making process (e.g. early communication and analysis of possible solutions for different branches, changes in the plan, delays, adaptation of designing solutions to local conditions).

The project started in October 2008 and was planned to end in May 2009, so that the project owner can start building the first sector of the road network in the summer of 2009 (see Figure 6).

Phase	Time frame (2008 - 2009)									
	Oct. 08	Oct. 08	Nov.08	Dec.08	Jan.09	Feb.09	Mar.09	Apr.09	May. 09	Jun. 09
Project start	X									
Literature research	X	X	X	X	X	X	X			
1st survey of the field		X								
General Planning & Field measurements			X							
Data processing (Office work)						X	X	X	X	
Results								X	X	
Project approval										X

Figure 8. Schedule of the project work

As it can be noticed from the figure above, a continuous process of literature research took place from the project starting date up to the ending phases. This was a necessary fact, so that each phase of the project is properly documented and the solutions proposed are the best suited according to the project owner's demands. In the same way, continuous and sound project coordination was insured by the supervisor of this project.

3.2 Methodological steps in detail

3.2.1 Project Start

The preliminary phase of the project is of peculiar importance, as in this phase the fundaments (basis) of the project environment are set: starting from the problem statement and defining the project team, and ending with the project objectives, goals and roles assignment.

Therefore it should be mentioned the stakeholders involved and their roles in the elaboration of the project:

a) Project Owner Team

- *DI Dominik Bancalari* – Forest Manager of „Forstverwaltung Wittgenstein"

The role of the project owner team is essential for the project success as this team defines the problem statement, assigns the project to the project team, establishes the objectives and approves the project close down process. In our case the project owner is the final decision maker in respect of proposed and submitted designing solutions by the project team member. He also has the role to support the project team by providing requested information (e.g. maps, forest data base, etc.) and by giving feedback on the intermediate results or sensitive issues which have been achieved (Gareis, R., 2005). Concluding, one can notice that the role of the project owner team is an active one and involves participation in meetings with team members.

b) Project Coordinator

- *Ao. Univ. Prof. DI Dr. Karl Stampfer* – Head of the Department of Forest and Soil Sciences and of the Institute of Forest Engineering, BOKU

- *DI Thomas Steinmueller* – Department of Forest and Soil Sciences, Institute of Forest Engineering, BOKU

The project coordinator is responsible with the project management and he is directly interested in the progress of the work and in the successful close down of the project (Gareis, R., 2005). His major task is to continuously coordinate and control the project development and also to solve any project discontinuities that might appear from the start until the project close down. The project coordinator cooperates with the project owner team and the project team member, ensuring the respective communication among the project team.

c) Project Team Member

- *DI Adrian Enache* – Mountain Forestry Master Student, BOKU

In this particular case, the role of the project team member is to fulfill the objectives and goals assigned by the project owner, namely to properly develop a project for forest road network planning in Trauch Forest District, "Forstverwaltung Wittgenstein". This task includes among others: literature research, participation at meetings with project owner team and project coordinator, field measurements and data collection, data processing and results communication. Together with the project coordinator he is responsible for the quality of the work and participates also in the project management process. The project team member has the relevant expert competence for the fulfillment of the project objectives.

Although normally the working relationships between the team members (stakeholders) of a project are usually governed by hierarchical means, each member supposing to be responsible and to report in front of the hierarchical superior level, during the kick-off meeting of the project it was established, that the relationship scheme must be adapted accordingly to the small size of the project. This means that during the development of the project there have continuously been direct interactions between all members of the project team, depending on the demands of the project (see Figure 9).

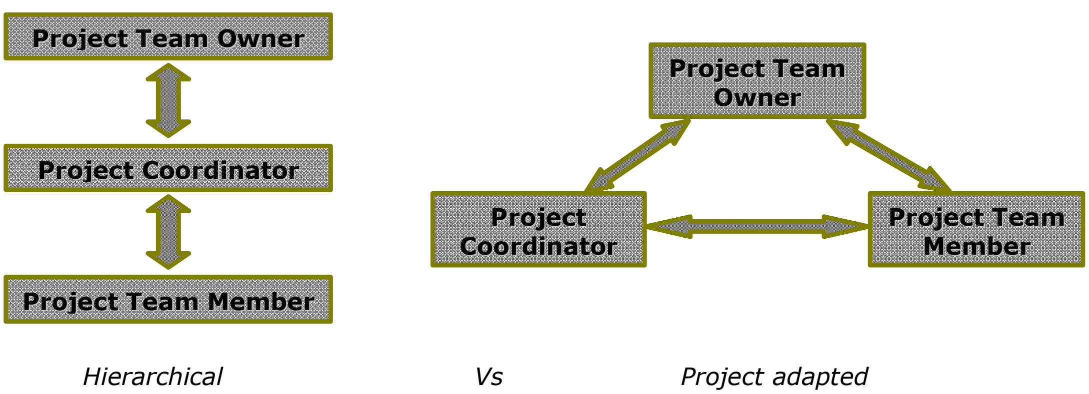

Figure 9. Type of project team communication & interactions

During the inception meeting of the project stakeholders the problem statement was defined together with project goal and objectives, as well as the tasks and responsibilities of the team members were set. Further more, established was that during road network planning, the following expectations of the project owner should be taken in consideration by the project team member:

- Propose different alternatives of forest roads network for the project area
- The road network should connect compartments 21 and 45, using slope roads

- The roads should be conducted to as higher elevation as possible
- Road network should provide availability to use (uphill) cable yarding systems and should result in minimizing harvesting costs
- Expected road density: approximately 30-35 m/ha
- Expected total length of the road network: 10 – 15 km
- Assessment of building costs (CBA or profitability analysis) and scheduling the forest road network building for the next 5 years
- Expected building costs: ~25€/m and more expensive in steeper terrain
- Calculation of harvested timber from the forest road path

During this phase were also defined the proceedings of the road network planning (Figure 10). Each road network planning project should start by defining the borderlines of the project area and by making clear the demands and restrictions set by the project owner.

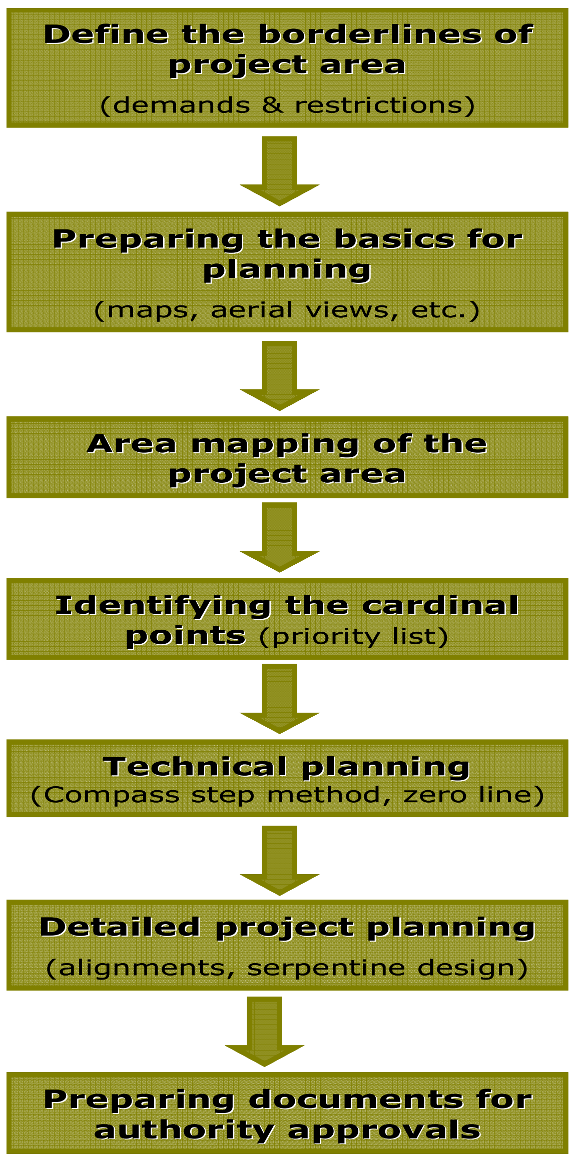

Figure 10. Proceedings of Road Network Planning (Steinmüller, 2008)

The second step of proceeding is to prepare the basics for the planning (e.g. maps, aerial views, terrain models, etc.) that would help the designer in the third step of road designing, respectively mapping out the project area. In this phase, the project area is surveyed and a map of construction difficulties is made. On the map are pointed out the existing roads (e.g. public and hauling roads, skidding tracks, hiking trails) and suitability of those. Also during this phase a rough mapping of slopes, description of local morphology of the terrain and of the geomorphologic and hydrologic characteristics is made. Further on in the field are identified and marked on the map the positive and negative cardinal points and zones. After fulfilling these inception steps the technical planning of different alternatives can start and a general planning with the compass step method is being designed on a contour line map, followed by field measurements and zero plane marking in the field. The project enters then in a processing phase of the data which refers to the detailed project planning, when the horizontal alignments, cross sections, longitudinal profiles and plans will be designed. Finally, the last step in the proceeding list is to prepare the documents for the authority approvals: overview of the project area – map at scale 1:50000, data collection protocols, plan of the forest road network – scale 1:2000, longitudinal profiles, cross sections and technical report (Steinmüller, 2009).

3.2.2 Literature research

Literature research represents a fundamental step in elaboration of a project, being the base upon the respective project is being build on. Therefore specialty technical literature regarding best practices in forest road network planning and construction has been consulted and presented in detail in *Chapter 2 – Literature Research* (see also *Chapter 6 – References*).

3.2.3 First survey of the field

The purpose of this inception phase is to collect basic information from the project area that is useful for the planning of the forest road network. The borderlines of the project area were clearly defined by the project owner and than identified in the field by the project team member. The project owner also prepared and provided the basic tools for the planning process, such as: maps, aerial views and a data base with the technical characteristics/description of the forest stands from the project area.

Making use of a compass, a clinometer and a contour lines map, the project area was surveyed following the next steps:

1. *Mapping of existing roads / access paths* – refers to identification of existing forest roads, skidder roads, hunting trails and other tracks and their suitability for being used in the further planning procedures
2. *Mapping of slopes* (<20%, 20-55%, >55%) – an important step for determining the appropriate harvesting technology that can be used in a given area
3. *Mapping geomorphologic and hydrologic characteristics* – gives important information about the bedrock and soil morphology (creepy soil, slope springs, water courses, etc.)
4. *Identifying and mapping the cardinal points of the project area* is a crucial step during the pre-planning phase. Cardinal points refer to positive (+) or negative (-) aspects that might be encountered on the project area, such as:

- connection to existing roads (+),
- good area for a serpentine (+),
- good point for gravel (+),
- good point for crossing a water course (+),
- steep and rocky terrain (-),
- wildlife habitats (-),
- wet areas (-),
- property borders (-), etc.

The positive cardinal points are points that must be reached and the negative ones should be avoided (as much as possible) by the alignment of the newly designed forest road. The result of this phase of the project is represented by a map with the criteria stated before and with different difficult zones of the project area.

As negative cardinal points were identified the following:

- rocky & steep areas in Schwaig, Mitterriegel, Geisstein and Wurzriegel regions
- chamois goats habitat in Geisstein region
- property border on the main ridge (Wurzriegel – Mitterriegel – Schwaichg)

The main positive cardinal points identified were:

- points A & B drawn on the map, from the compartments 45 and 21 respectively as points to be connected by the road network
- points C & D drawn on the map, as alternative connections of the new designed road network to the existing forest roads (see Figure 11)

3.2.4 General planning

The general planning of a forest road network basically refers to the *Compass Step Method* which is one rough planning method that uses a topographical map and a compass as main tools. The goal of this method is to elaborate two or three variants for the new forest road in a given area, by connecting the starting and ending points of the road network following the next steps (Steinmüller, 2008):

- First, the start and end points of the road must be fixed on the map
- The cardinal points (positive & negative) must also be drawn, in order to know which areas (points) of the forest to achieve and which not
- A scale of the compass step must be drawn on the map, according to the slopes that we would like to use (3% - 12%). The compass step can be calculated with the formula:

$$W = \frac{100 \cdot h}{p} \cdot M$$, where:

W – compass step
h – equidistance
p – average gradient (slope) of the road
M – scale of the map (p)

- After the compass step scale is drawn, calculated must be the difference of altitude in between the first two points we would like to connect and the rough distance in between them, in order to roughly calculate the average slope gradient of the road.
- Drawing the points of the road axis on the map, by using the compass step which best suites the topographical conditions. Each compass step drawn on the map will have the predefined slope gradient.
- Two or more variants of the forest road network on the map can be drawn.

For this respective project area, due to the specific demands of the project owner (e.g. slope roads, roads at as higher elevation as possible – see subchapter 3.2.1), of the already existing valley roads and of the particular topography of the area, basically only one main variant of road network to be designed was possible to be emphasized, and proposal for variants were made only for some certain areas of the project.

The main goal of the designing process was to create access in the project area by achieving an optimum road density (a balance in minimizing the road length & maximizing the forest accessibility). After the first survey of the field and the identification of the cardinal points, the project team member decided to avoid as much as possible the steep areas in order to reduce the volume of mass movement and artworks for the road construction, as well as to keep the road as close as possible to the main and secondary ridges. The idea was to keep the future road on the upper part of the slopes and give access to the valleys by using mobile cable yarding systems, meaning an average distance from the forest road to the valley of about 300 – 400 m. For areas with moderate slopes, the silvicultural operations and logging can be done by harvesters and forwarders and therefore attention was paid to reach such areas by the designed forest road.

As result of applying this procedure resulted a road network represented on a contour lines map consisting of one main road (starting from point B and ending in point D) and of two branches (see figure 11). In this early stage of designing two variants were proposed for opening up the region named “Geisstein” in the project area: first one on the NW side and the second one on the SE side of the Geisstein.

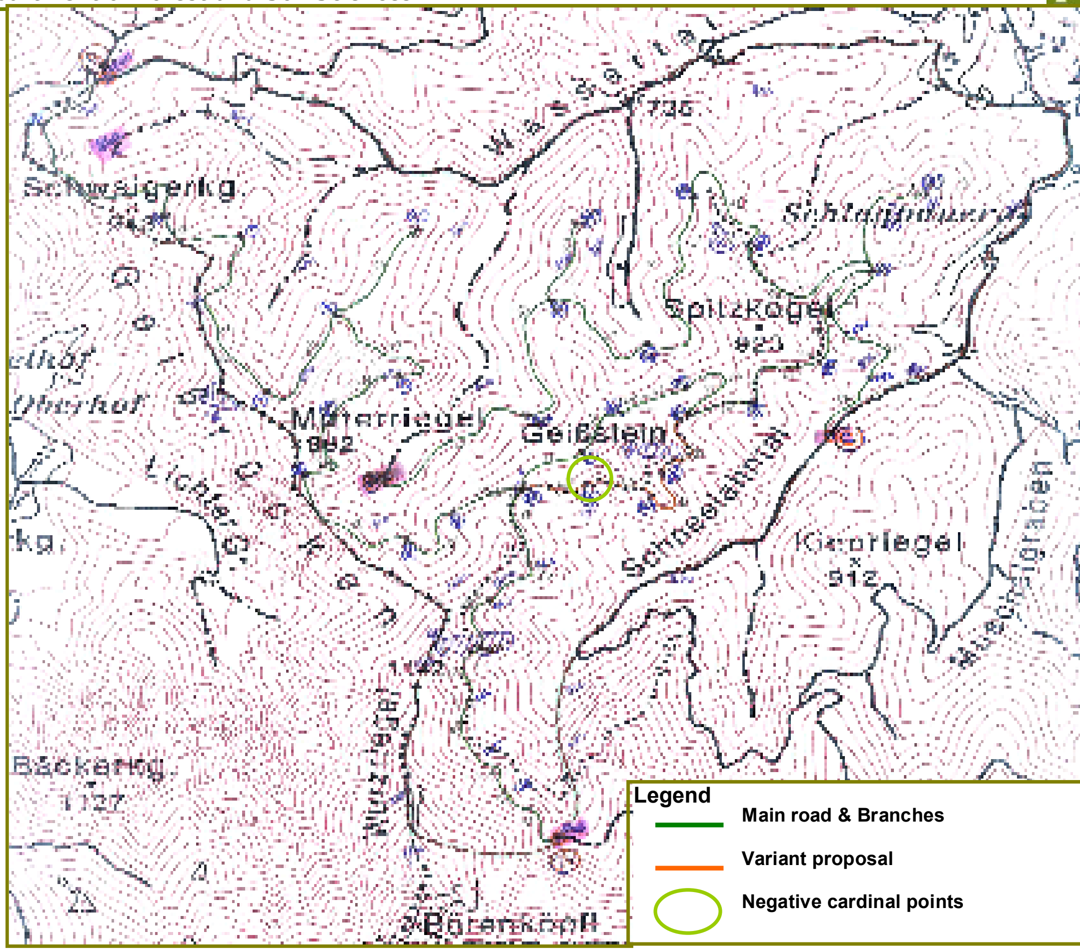

Figure 11. Compass Step Method – First Proposal (Bancalari, 2008)

This first proposal of the road network was presented to the project owner in a meeting when also was mentioned by the project team member that the SE variant for opening up the Geisstein region could be a possible solution, but there were two negative cardinal points which had to be crossed:

- 1st one, the habitat of an important chamois goats family below Geisstein rocks
- 2nd one, the rocky and steep area (see figure above)

During this meeting the project owner decided that the variant proposal (orange line in Figure 11) for crossing the Geisstein region through its SE side is preferred in front of the NW variant, even if the two negative cardinal points had to be crossed. Agreed was to reshape the access to the secondary ridges by surrounding the ridge – tops (e.g. 5-5’ or 21-21’ on the map), as well as the main road in the Geisstein region according to the new situation resulted from the decision to use the SE variant for opening up this region. Taking in consideration the newly made decisions a second map with the road network proposal resulted (see Figure 12).

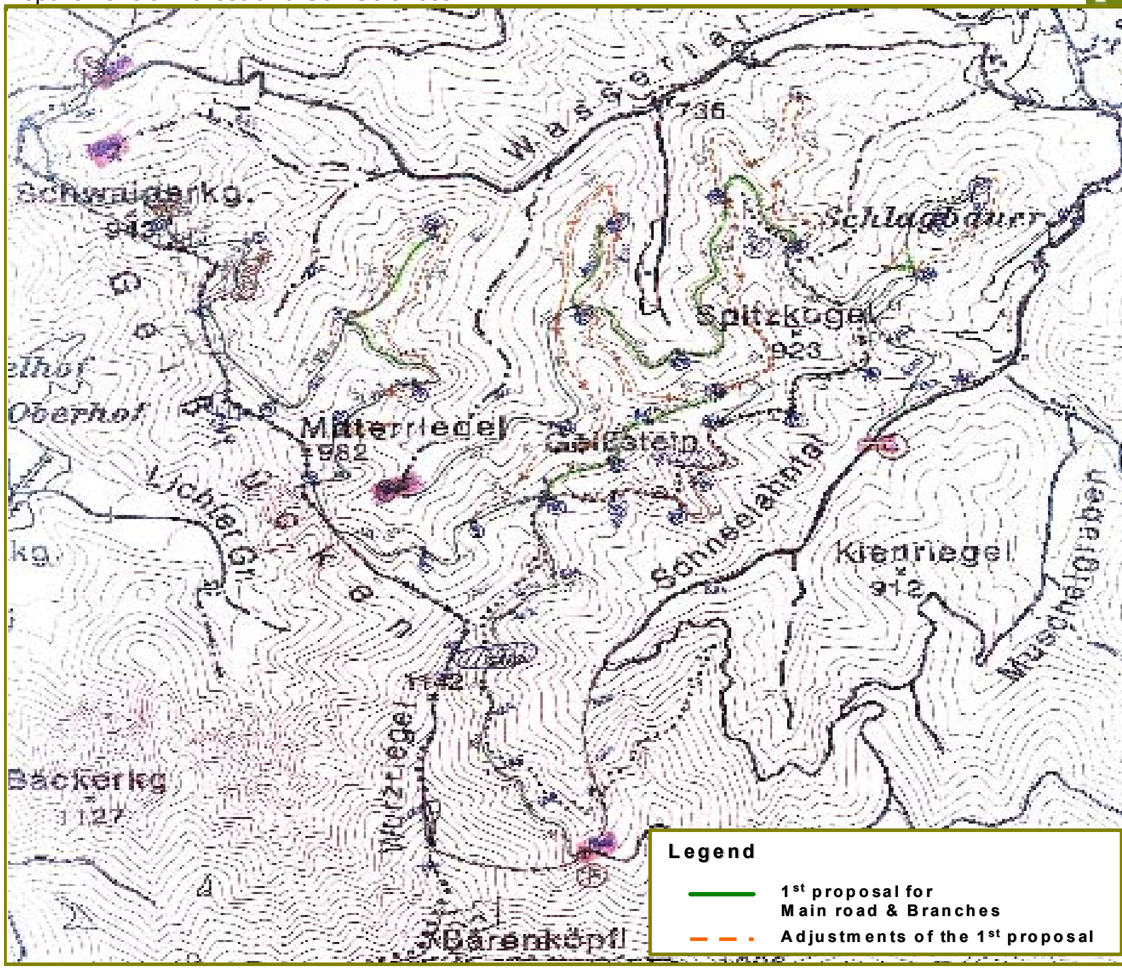

Figure 12. Compass Step Method – Second Proposal (Bancalari, 2008)

The dashed orange lines from above map represent the adjustments made to the first variant of the forest road network according to the agreements from the meeting with the project owner. The map showed in Figure 12 represented also the starting point for the next step of the project: zero plane planning method and field measurements.

3.2.5 Field measurements

This phase of the project is based on the *Zero Plane Method* which is a planning method that uses a meridian-clinometer, compass, a measuring tape, a marking tape and the map resulted in the previous stage of planning for filling a data collection protocol (see Chapter 8 - Appendix) and marking the level (the zero plane) of the new designed road in the field.

The zero plane represents the horizontal plane marked with a tape on the trees standing downhill, pulled out from the point where the road bed hits the terrain and which marks the zero line of the road (see Figure 13).

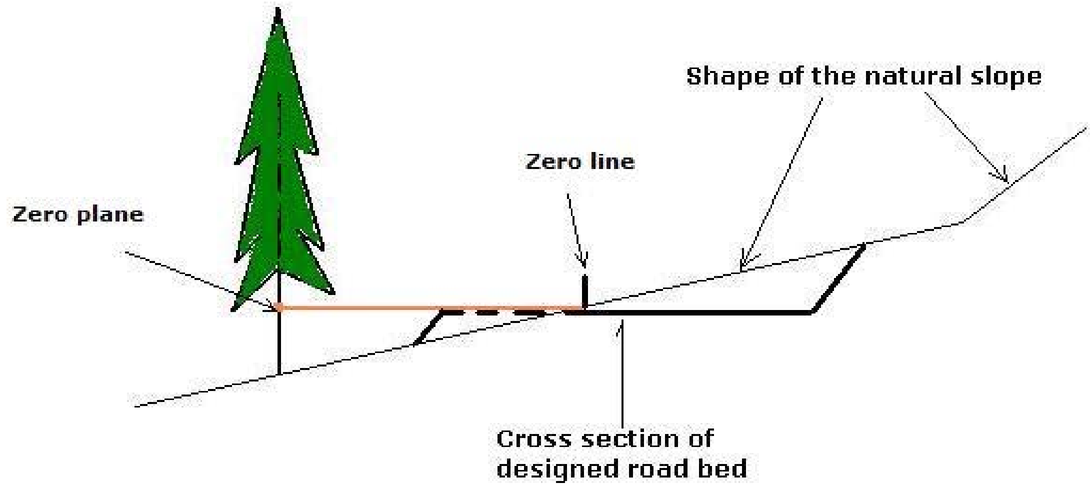

Figure 13. Zero plane details

The main task is to connect the already predefined starting and ending point of the road network by intermediate surveyed points situated at 25-30 m distance one of each other. The zero plane data beginning with the first surveyed has to be collected in the appropriate protocol and the details of the integration area must be measured and noted down (Steinmüller, 2008). Beginning at the integration point of the zero line in the existing road, the project team member defined the zero line route by following the already designed path with the compass step method. At each surveyed point, the following data was collected:

- Current number of the point
- Real distance (m) between the previous and current point
- Longitudinal gradient (%) between the previous and current point
- Longitudinal direction (gon)
- Slope gradient (%, uphill and downhill) in the current point
- Comments and observations about local conditions (creeks, fords, rocks, etc.)
- Centipede (rough sketch of the zero line points, see Figure 14)

During this phase of the project, the following proceeding guidelines were considered when designing the zero line (Steinmüller, 2008):

- Maximum gradient of the road axis: 9 – 12% (16%)
- Minimum gradient of the road axis: 2 – 3%
- Minimum radius of curves (in serpentines or steep terrain): 10 m
- Gradient of the road axis within turns: 5 – 6%
- Longitudinal changes in gradient of successive segments: ±3%
- Consideration of ± 200 gon when measuring different longitudinal direction
- Special consideration of creeks crossing by using fords and concave profiles

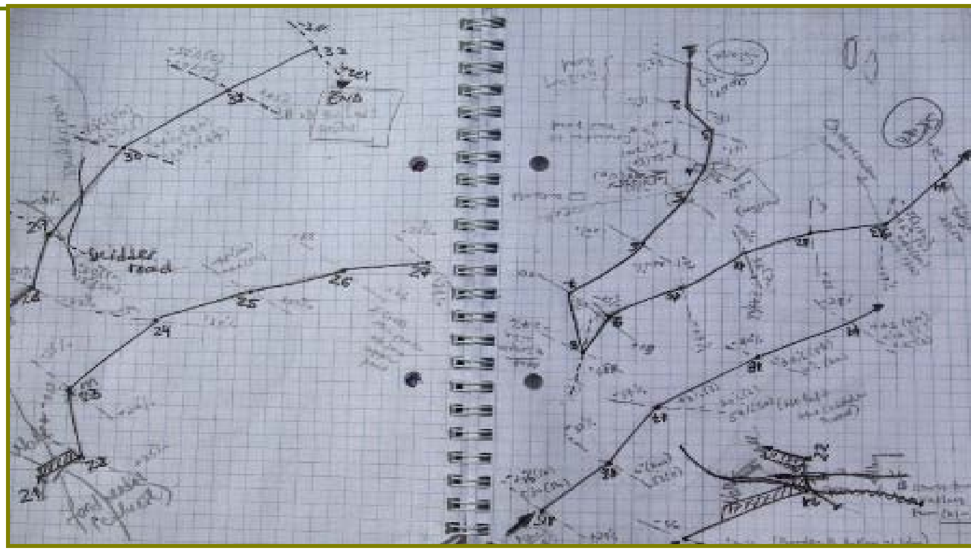

Figure 14. Centipede of Trauch Road Network Planning

The detailed survey of the zero plane brought into light new ideas about some areas to be opened up by the new road network, ideas which were presented and argued in front of the project owner and which finally brought some other changes at the new road network, basically in the N-NW side of the Geisstein region (see Figure 15).

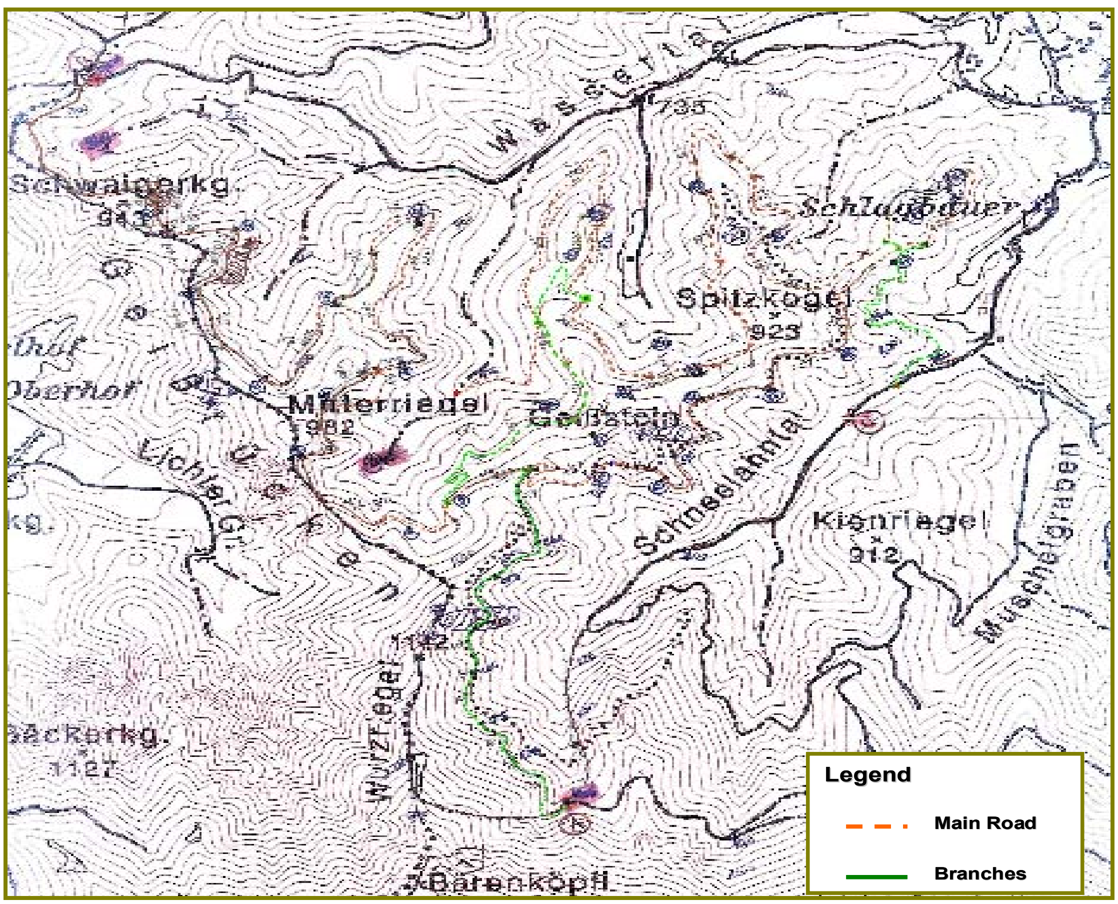

Figure 15. Compass step method – final version (Bancalari, 2008)

The field measurements were realized in November 2008 and concretized in a detailed data collection protocol (see Chapter 9 - Appendix) which represented a base for further data processing and synthetic analyzes (see *Chapter 4 – Results*).

3.2.6 Data processing

The data collected during the field measurements phase have been analyzed and processed by the project team member using the state of the art tools for forest road network planning:

- Excel data sheets and synthetic tables
- RoadEng Software - detailed project planning
  - ✓ calculation of earth mass movements
  - ✓ serpentine design, horizontal & vertical curvature corrections
  - ✓ cross sections design (transversal and longitudinal)
  - ✓ plan of the designed road
  - ✓ longitudinal profile
  - ✓ technical report
- GIS mapping of the new forest road network (orthophotos)
- Cost calculations and rentability analysis

This stage of the project elaboration was a challenging, comprehensive and extensive task in the same time, which lasted from February till end of May 2009. The data collected in the previous phase was first evaluated by means of Microsoft Excel data sheets, resulting synthetic tables giving a rough overview about the newly designed forest road network. By the same means, important information about the project area (forest stands area, species structure, age structure, slopes, etc.) could be analyzed from the data base provided by the project owner.

The following step was the data analysis using the RoadEng tool, Forest Engineer version, especial Canadian software for forest roads designing. RoadEng software consists of three modules (www.softree.com, 23rd April, 2009):

1) ***Survey / Map –*** is a module for data input that provides a complete range of survey data management facilities. Traverses can be entered in the desktop Survey module directly or downloaded from a handheld. Boundaries, tie lines, cable deflection lines, road and site surveys can be entered in a variety of formats. A plan window allows the forest engineer to quickly review one or more traverses (see Figure 16). Cursor tracking in the plan window makes it easy to navigate through the field notes. Traverses can be closed, adjusted, shifted and joined in a variety of ways. Raw data, reduced coordinates, closing errors and areas can be displayed, printed or exported to external software such Microsoft Excel or ArcView. GPS coordinates can also be combined with conventional compass and tape survey (www.softree.com, May 7th, 2009).

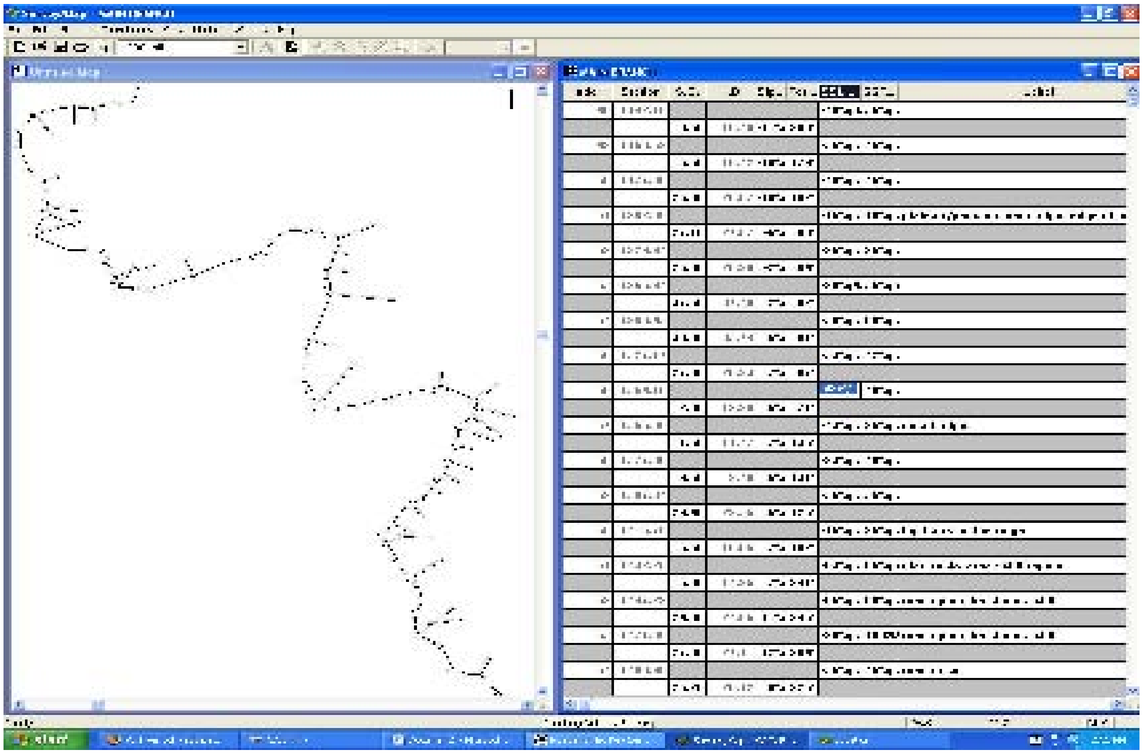

Figure 16 - Survey/Map module of RoadEng Software (www.softree.com)

2) ***Terrain*** – the Terrain module provides a quick and easy mapping package ideally suited for the forest engineer who is not a GIS specialist. Features can be selected, edited, formatted and manipulated by name, coordinate range, property or layer (see Figure 17). Operations are provided to move, scale, rotate, intersect, break, join and offset features. CAD functions are provided for control of color, line type, symbols, hatching, and annotation of distances, bearings, stations etc. Digital images in BMP, JPG or TIF format can be imported and used for reference. Imagery such as orthophotos with georeference information (w*orld file* or *GeoTif* format) can be included. Images can be georeferenced (scaled, rotated, and positioned) and used as a background on which to trace features, calculate areas, distances and angles. 3D terrain models can be created along with smoothed and labeled contours. Cross sections and profiles can be extracted from single or multiple TIN surfaces. Features can be edited in the Profile window allowing for creation of detailed site plans. Output can be directed to a printer or export to CAD or GIS (www.softree.com, May 7th, 2009). Using the outputs of Terrain module, the GPS coordinates collected in certain surveyed points from the project area during field measurements can be assigned in CAD to points on the alignment of the designed road and in this way geo-referencing the plan of the road network. Further on, the geo-referenced plan of the road can be imported in GIS, where together with available orthophotos and forest data base a map of the project area with the designed forest road network can be created.

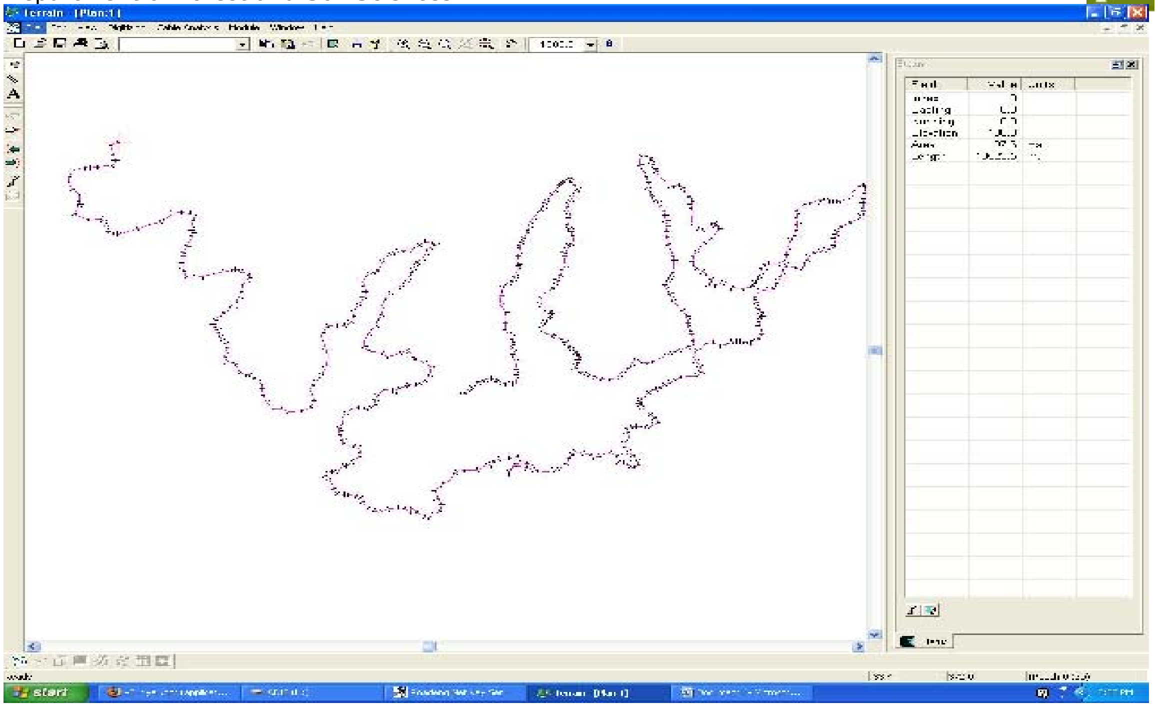

Figure 17. Terrain Module of RoadEng Software (www.softree.com)

3) ***Location –*** is a module using four window types: Plan, Profile, Cross Section and Data (see Figure 18). Each of these windows provides customizable feedback during design. Changes made to your design in one window are instantaneously reflected in all other windows. For example, an adjustment made to the alignment in the cross section window will immediately alter the data window volumes, and the slope stake projections displayed in the profile and plan windows. Creating a vertical or horizontal alignment is quick and easy.

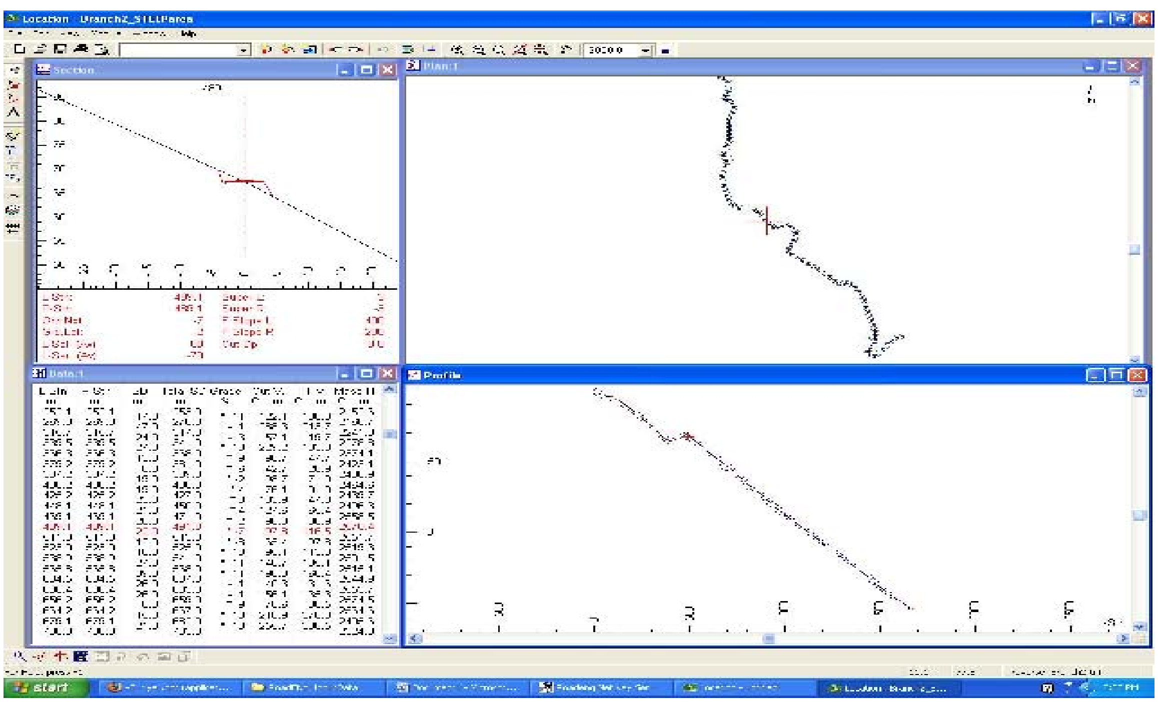

Figure 18. Location Module of the RoadEng Software (www.softree.com)

Working with the mouse in either the plan, profile or section windows you simply point and click and immediate feedback is provided, allowing you to monitor slope stake positions, and grades as you design. A template editor allows you to create turnouts, curve widening, bridges, landings and cut benches. Culverts can be interactively positioned, accounting for size, length, skew and gradient. A configurable data reporting window is provided, allowing the user to display, print or output design information to a spread sheet. Profiles, plans and cross sections can be also output to any Microsoft Windows supported printer or plotter in single page or multiple page formats. Facilities to export drawings to CAD via DWG and DXF are also provided (www.softree.com, May 7th, 2009).

RoadEng software was used for detailed planning of the second branch (Branch 2 – Steep and Rocky Area) of the Trauch forest road network. The field data which has been introduced in the Survey module database was processed in the Location module following the next procedure:

- Defining special templates
    - Earthwork (earthy terrain)
    - Rocky area
    - Culverts
- Assigning the defined templates to certain sectors of the forest road
- Making the final adjustments
    - Horizontal curves alignment
    - Vertical curves alignment
- Printing out the results (e.g. cross sections, situation plan, longitudinal profile, data reports, etc.)

The templates refer to special elements of the road that must be applied during designing, depending on the type and characteristics of subgrade material, slope and difficulty of the terrain and include details regarding the width of the road bed and of the carriageway, details about ditches, side slopes and type of the profiles (mixed, cut, fill). Therefore in case of the rocky area the width of the subgrade (road bed or base of the forest road) was defined to be of 4,50 m (in order to reduce the volume of rock blasting, operation which is very expensive) and in case of the earthy terrain of 5,00 m. In both cases the carriageway is designed in a crown shape with inclination of 3% on each side. The width of the carriageway was defined to 3,50 m for rocky terrain and to 4,00 m for earthy terrain. The slopes of the cutting and filling were defined accordingly with the side slopes of the terrain in the surveyed points: in rocky area the slope used for the uphill side of the road is vertical and 1/3:1 for downhill; in case of earthy terrain the side slopes used for the embankments are 1/3:1 uphill and 1/3:1 for downhill respectively. For the culverts template established were the distance between pipes (70 m), the type and the diameter of the culverts (400 mm for evacuating water from the ditches, and 800 mm for the existing streams). The position of the culverts was manually readjusted according to the longitudinal profile.

After the templates were defined they were applied for the whole branch length according with the characteristics of the terrain (e.g. for the first sector of 269 m was assigned the rocky area template, followed by a sector of 70 m with the earthwork template, etc.). The next step was to manually reshape the zero line following the principle that for terrain with downhill side slopes bigger than 80% the road must be designed in full cut cross section. Therefore, starting from the last surveyed point of the second branch of the road network and going backwards till the first surveyed point each cross section which had downhill side slopes steeper than 80% was dragged (using RoadEng software) towards the slope in the *cross section window*.

The adjustments involve an increased level of attention and care from the designer, as each modification made in this window automatically affects the data from the other windows of the Location module (e.g. the mass movements increases or decreases consequently with the movement of the L-line towards downhill or uphill).

Finally, using the horizontal curves alignment function in the *plan window* was adjusted the most sharpened horizontal curves, so that the project would fulfill the technical specification of the guidelines for forest roads construction. Following the same principles, the vertical curves were adjusted in the longitudinal profile.

One other state of the art tool used in the present project for data analyzing and processing was Arc GIS software. The main application used for all mapping and editing tasks as well as for map-based query and analysis was ArcMap, which represents geographic information as a collection of layers and other elements in a map view. Common map elements include the data frame containing map layers for a given extent plus a scale bar, north arrow, title, descriptive text, and a symbol legend. There are two primary map display panels in ArcMap: the data frame and the layout view. The data frame provides a geographic window, or the map frame, in which you can display and work with geographic information as a series of map layers (orthophotos, existing maps, imported plans from RoadEng, GPS points, etc.). The layout view provides a page view where map elements (such as the data frame, a scale bar, and a map title) are arranged on a page and prepared for printing (www.esri.com, 23rd April, 2009). This software was especially used for creating and adjusting maps using the GIS data base and orthophotos provided by the project owner and importing the results from Road Eng data processing.

3.2.7 Results

In this phase are presented the project deliverables, represented by the main findings of the data processing:

- General planning / Zero line method
    - Synthetic overview of the road network planed (full length of main road and branches, road density, road distance, etc.)
    - Dimensions and number of culverts
    - General observations about the road network (gradients, branches)
    - General cost calculation for building the new forest road network
    - Rentability analysis
    - Schedule Proposal for building the forest road network
- Detailed Planning (only for Branch No. 2 - Steep and rocky area)
    - Technical report
    - Road Eng assessment – printouts of profiles (longitudinal, transversal), details about creeks, fords and culverts
    - Cost Calculation
    - Documents to be filled for the authorities approvals

- Variants and decision making
    - Describe the proposed variants for the road network
    - Point out the advantages and disadvantages of each variant and the recommendations made to the project owner
    - State clearly the decisions made by the forest owner

3.2.8 Project approval

The final phase of the project consists of presenting and defending the project results in front of the project owner and examination commission. The feedback received in this stage by the project team member will be incorporated in the final version of the project and submitted to the project owner. The project will be considered closed after the project owner will approve the results.

3.3 Description of project area

The forest from the project area belongs to Wittgenstein family and is located in the Trauch Forest District from the Wittgenstein Forest Administration (Forstverwaltung Wittgenstein, Figure 19), situated 10 km S of Hohenberg, Lower Austria.

Figure 19. General situation plan of the Forest Administration Wittgenstein (www.forstverwaltung.com, May 7th, 2009)

3.3.1 Geological Data

From the geological point of view, the project area is characterized by the following bed rock types:

- Northern Limestone Alps tectonics (98% of the project area),
- Fluvial and glacial-fluvial deposits (2% of the project area).

The Northern Limestone Alps run from the alpine Rhine to the Viennese basin and were constructed from the remains of life forms in the primeval sea, with a high proportion of reef material and chalky mud. Limestone and dolomite are sedimentary rocks which were deposited in layers during Jurassic and Triassic (www.nationalpark.co.at, May 7th, 2009).

The category of Northern Limestone Alps is represented in the project area (see Figure 20, for the geological map at real scale see Chapter 9 – Appendix) in totality by the upper eastern alpine subcategory, which includes the following types of formation (rock types and deposits):

- Main Dolomites, including Silver limestones
- Wetterstein dolomites
- Wetterstein limestone
- Lunz formation

Fluvial and glacial-fluvial deposits are represented by alluvial deposits in the valleys and young valley soils based on conglomerates and other sediments.

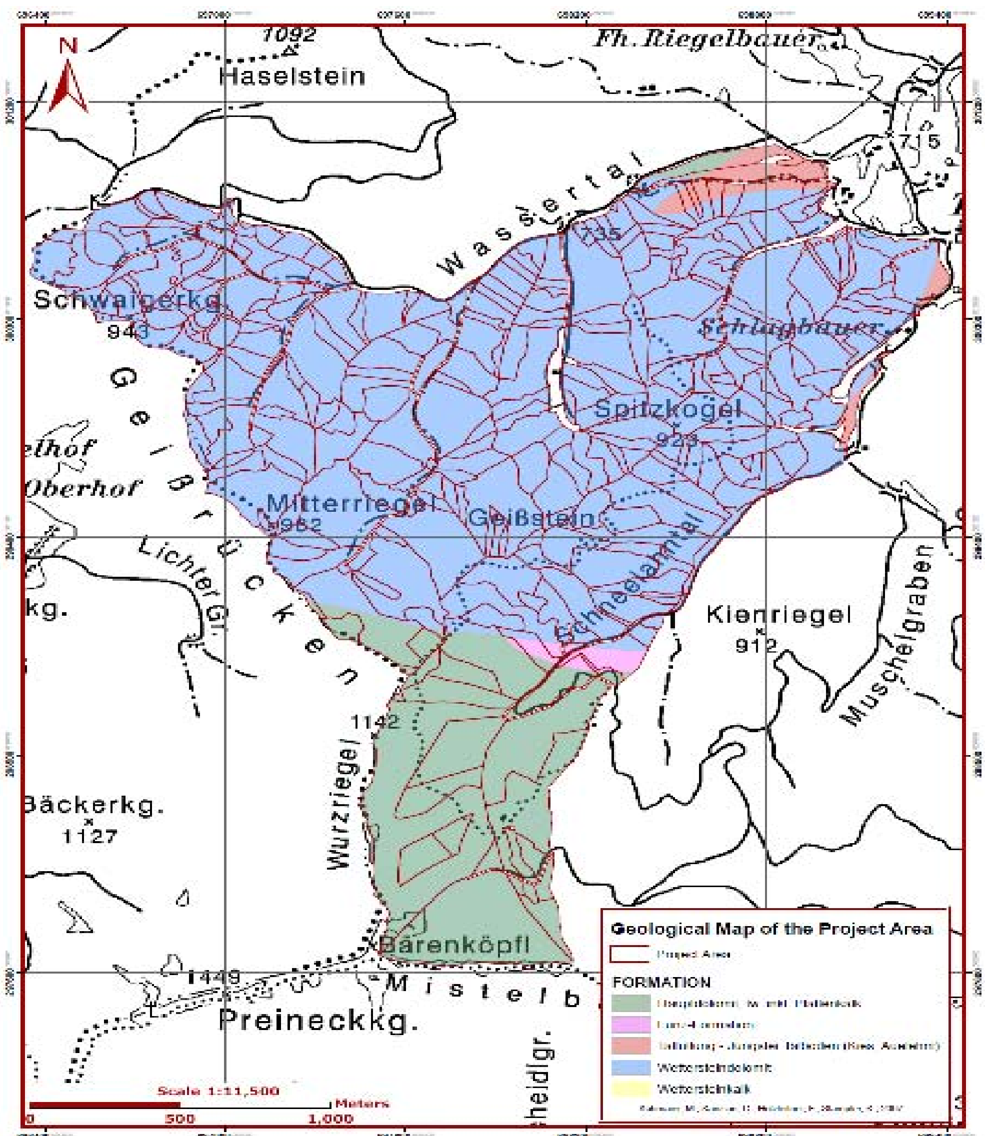

Figure 20. Snapshot of the geological map for the project area (Kuhmaier, M., Stampfer, K., 2007)

3.3.2 Climatic Data

From the geographical point of view the project area is located at the NE extremity of the Outer Alps. The climate data is therefore characterized by temperate continental influences with cold and snowy winters and relatively warm and wet summers. The average yearly temperature is 6,5 °C, the yearly average of the maximum daily temperature is of 13,2°C and the yearly average of the minimum daily temperature is of 1,5°C. The absolute maximum temperature is registered in July and amounts 36,1°C and the absolute minimum temperature is registered in January and amounts -33,5°C (see Figure 21).

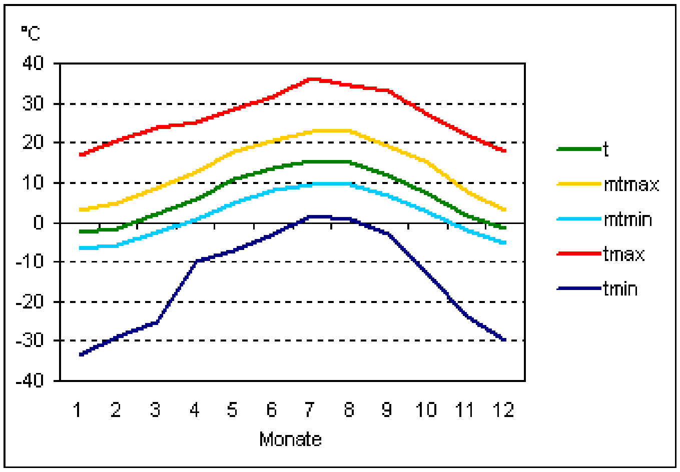

Figure 21. Average and absolute monthly temperatures for the project area (www.zamg.ac.at, 3rd May 2009)

Legend
t – average daily temperature; mtmax – average of the maximum daily temperatures; mtmin - average of the minimum daily temperatures; tmax– absolute maximum temperatures; tmin– absolute minimum temperatures

During one year there are usually 143 days with frost (daily minimum temperatures <0°C), 25 days with ice (daily maximum temperatures <0°C), 243 days with daily average temperatures <12°C and only 36 summer days (daily maximum temperatures >25°C). This means that the vegetation season is quite short, but is being compensated by a rather high amount of yearly precipitation level of 1294,2 mm relatively evenly distributed allover the year (see Figure 22).

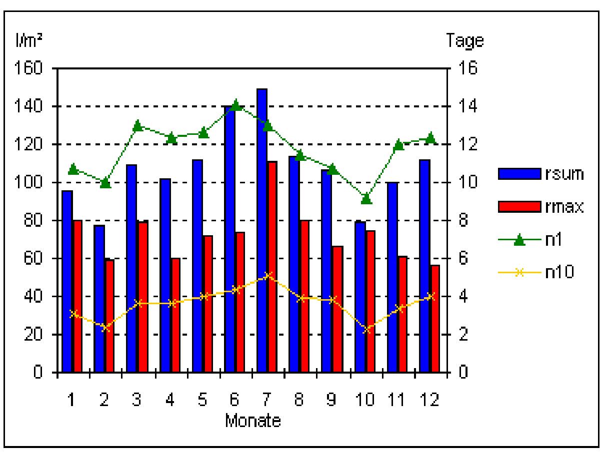

Figure 22. Amount of monthly precipitation in the project area (www.zamg.ac.at, 3rd May 2009)

Legend

rsum – average monthly precipitation amount; rmax – highest precipitation level in 24 hours; n1 – number of days with precipitation amount of > 1 mm; n10 – number of days with precipitation amount of > 10 mm

As it can be noticed from the figure above, the highest precipitation level in 24 hours is of around 110 mm/day and it is registered in July when also the maximum of the monthly average precipitation is reached (148 mm). It is also noticeable a first maximum of the precipitation level during summer (June – July) and a second maximum during winter (December and March). One more important thing to note is that during the vegetation season (April – October) the amount of precipitation is considerably high (800 mm).

Regarding snow levels, it is registered an yearly average deposit of 286,2 cm of new snow, from November till April, with the maximum levels from December till March inclusively (52 – 62 cm of snow each of these months, see Figure 23). The absolute maximum snow deposit is registered in March (108 cm).

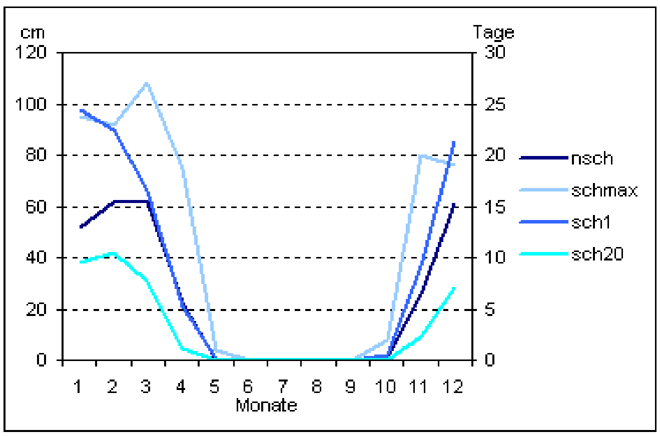

Figure 23. Amount of snow deposits in the project area (www.zamg.ac.at, 3rd May 2009)

Legend

Nsch – sum of new snow deposits; Schmax – maximum snow deposit; Sch1 – number of days with snow deposit > 1 cm; Sch20 – number of days with snow deposit > 20 cm

The huge amount of snow collected in winter represents a real threat for the project area during spring time, especially when the snow melting process happens very fast due to sudden increase of temperatures and can cause important damages to the forest roads and forest stands (e.g. road wash, culverts damage, erosion, etc.).

Another important climatic factor that has an influence over the forest stands, especially in terms of stability, is the wind. The main wind direction is from N (NW – 13,5% and NE – 15,3% of the wind frequency and blowing direction), as the Alpine mountain range acts like a belt in the southern part. Nevertheless, important share do have also the SW winds (see figure 24) which might cause important damages to the forest stands, especially if we take in consideration the fact that the project area is oriented towards N, with the highest elevation point in the southern part (Mistelbacher Hohe ridge) and descending towards N.

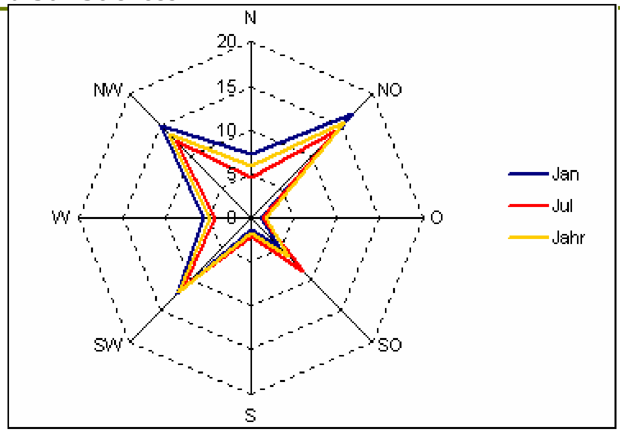

Figure 24. Wind direction in the project area (www.zamg.ac.at, 3rd May 2009)

The climatic data was collected from the Austrian Central Institution for Meteorology and Geodynamics website (www.zamg.ac.at, 3rd May 2009), station Schwarzau im Gebirge situated 6 km south from the project area. The climatic characteristics presented above reflect the propensity of presence in the project area of tree species which prefer high amounts of precipitation, cold temperatures and reduced vegetation season. Therefore, spruce, larch, fir, pines and beech would be in their optimum range from the climatic point of view. One other important aspect to be noted is that, due to the length of the winter season the access in the forests is restricted from December till April and consequently all forest management activities are as well impaired. Therefore the working season for tending operations, harvesting (conifers), road construction and maintenance would be of around six to seven months (late April till end of November).

3.3.3 Forest Data

Wittgenstein Forest Administration is structured in six Forest Districts covering altogether an area of 4043 ha of forests (see Table 4).

Table 4. Structure of the Wittgenstein Forest Administration (www.forstverwaltung.com, May 8th, 2009)

Forest District	**Surface (ha)**
Trauch	1409
Tiefental	1137
Haselstein	146
St. Ayegd	465
Hinterberg	300
Hohenberg	586
TOTAL (ha)	**4043**

As it can be noticed from the table and figure above, Trauch is the biggest forest district among all, covering 1409 ha of forests. The main tree species present in this district are spruce, pine, larch, fir and broadleaves, the share of each one being presented in the following table.

Table 5. Structure of Species in Trauch Forest District (Bancalari, 2008)

Species	Surface	
	(ha)	(%)
Spruce	718.59	51.00%
Fir	21.14	1.50%
Scots Pine	302.94	21.50%
Larch	173.30	12.30%
Broadleaves (Hardwood)	193.03	13.70%
TOTAL	**1409.00**	**100.00%**

The research area for the project covers 401,20 ha and it is located in the SW part of the Trauch Forest District. The main borders of the project area are (see Figure 25):

- "Wassertaal" Valley in N
- "Schneelahntal" Valley in E and SE
- "Geissrucken" ridge (forest property border between Wittgenstein and Rudolf Grafeneder) in SW and W

The project area consists of approximately 91% of commercial forests and 9% of protection forests. The structure of the tree species from research area is presented in the table 6. As it can be noticed from this table, although the main tree species in the whole Trauch forest district is the spruce, the main tree species in the project area are represented by hardwoods (share of ~73% from the total project area): the maple and the beech. The spruce covers cca. 22.5% of the project area.

Table 6. Structure of the forest from the project area by tree species (Bancalari, 2008)

Species	Surface	
	(ha)	(%)
Maple - Acer pseudoplatanus	163.77	**40.8%**
Beech - Fagus sylvatica	128.35	**32.0%**
Ash - Fraxinus excelsior	6.71	**1.7%**
Spruce - Picea abies	90.29	**22.5%**
Scots Pine - Pinus sylvestris	3.38	**0.8%**
Clear cuts & others	8.7	**2.2%**
TOTAL	**401.20**	**100.00%**

The age class structure of the forest stands from the project area is presented in Table 7 (see also Figure 25, for the real scale map see *Chapter 9 – Appendix)*.

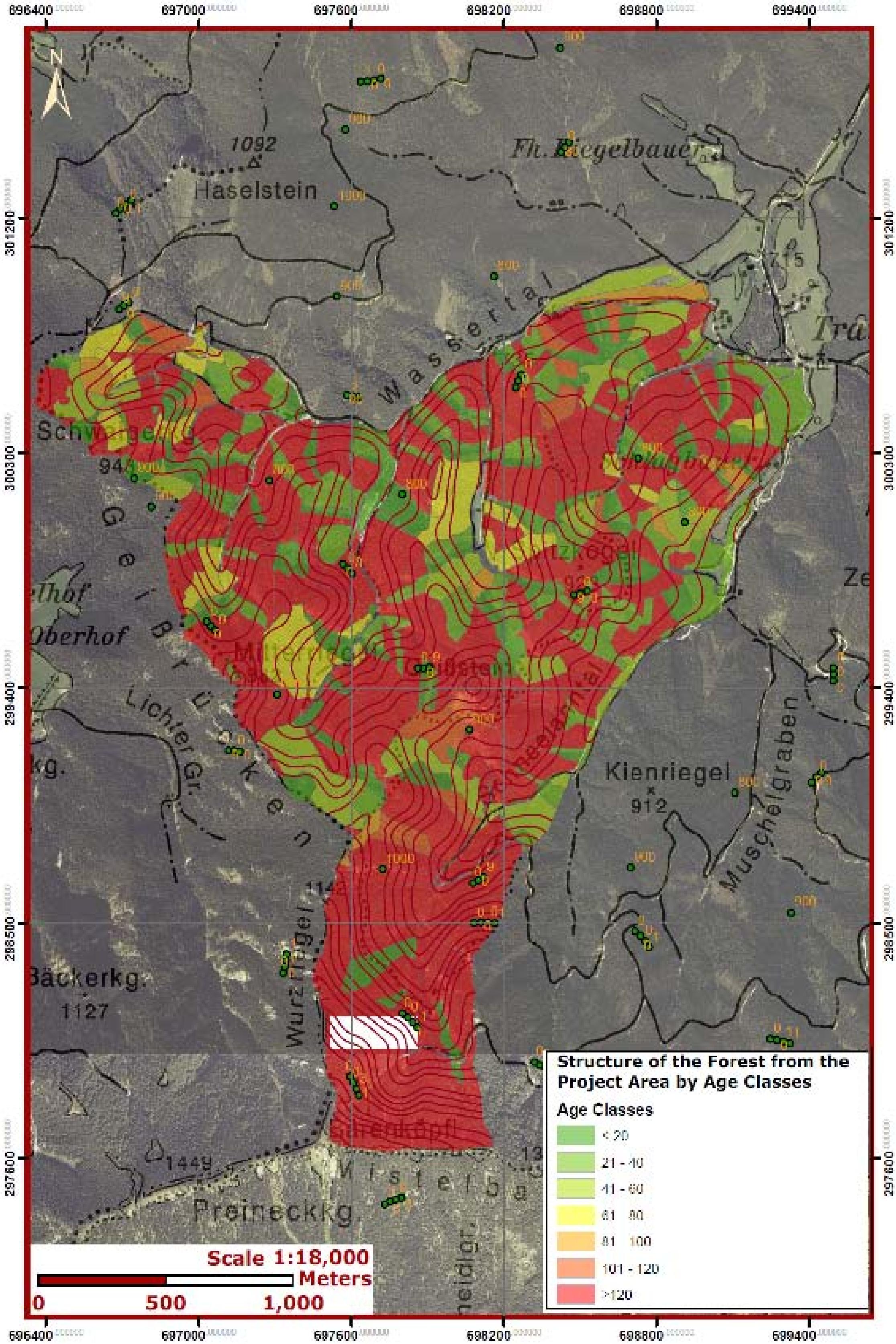

Figure 25. Snapshot of the project area and structure of the forest by age classes (Bancalari, 2008)

Table 7. Age classes of the forest stands from the project area (Bancalari, 2008)

Age Class	**Surface**	
	ha	**%**
I (1-20)	54.32	13.54%
II (21-40)	51.81	12.91%
III (41-60)	32.22	8.03%
IV (61-80)	26.49	6.60%
V (81-100)	7.85	1.96%
VI (101-120)	14.53	3.62%
VII (121-140)	124.92	31.14%
VIII (141-160)	68.84	17.16%
IX (161-180)	20.20	5.04%
TOTAL	**401.20**	**100.00%**

From the table above we can observe that more than 50% of the forest stands from the project area (215 ha) are represented by over-aged forests (more than 120 years old, see Figure 25), which are basically consisting of hardwoods (beech and maple). This fact is a straightforward result of the lack of accessibility to those stands and represents an impediment in the future sustainable development of the project area, due to the following issues that might develop:

- Loss of value by decreasing the timber quality of over-aged stands
- Delaying the natural regeneration of the over-aged forest stands (lack of opening gaps, lack of light for the seedlings)
- Increasing the future harvesting costs due to:
    - long hauling distances
    - high volumes of the logs
    - need of medium – long distance cable yarding systems (operated from downhill)
- Damages brought to the soil and seedlings when logging big volume trees
- Possible wind or snow damages of the older stands (rotten trees)

Therefore an immediate measure to improve the current situation of the project area is to design a forest road network that would create access to these forest stands and which would provide the possibility for valuing the natural resources in a proper, easier and cheaper way. In the same time, sustainable forest development will be promoted by the opportunity of promoting the natural regeneration of the forest stands and the selective cuttings due to an increased road density.

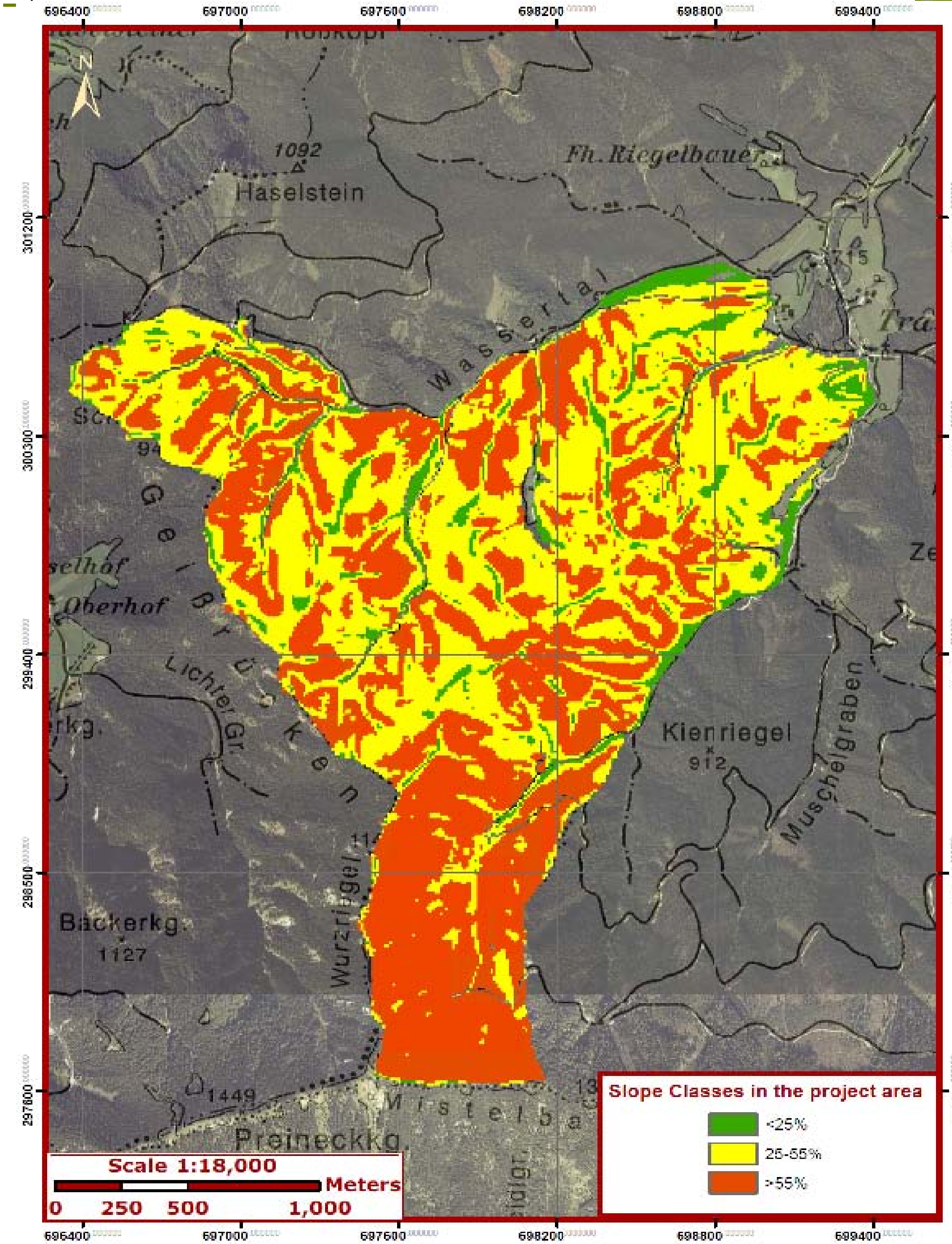

Figure 26. Snapshot of the slope classes in the project area (Bancalari, 2008)

From the above figure (for the real scale map see *Chapter 9 – Appendix)* it can be noted that an important share of the forests are located in steep terrain (>50%). In these areas timber harvesting is possible only by using downhill cable yarding systems, as there are no slope roads in the project area that could allow uphill cable yarding technologies, which are safer and cheaper from the technical point of view. In the table 8 is presented the structure of the project area by slope classes.

Table 8. Structure of the project area by slope classes (Bancalari, 2008)

Slope class	***Area covered (ha)***	***Share (%)***
< 25%	28,72	7,16%
25 – 55%	182,87	45,58%
> 55%	189,61	47,26%
TOTAL	***401,20***	***100 %***

The data from the above table shows that in around 53% the project area (slopes <55%) following harvesting technologies can be used: the skidder and the tandem of harvester and forwarder. As skidding activities might create erosion to the soil and to the forest stands the forest manager (project owner) uses, whenever possible, the tandem of harvester with forwarder which has moderate impact over the soil and the forest stands.

For the rest of 47% of the project area the current harvesting technology possible to be used for bringing the logs at the forest road is downhill cable yarding systems (medium and long distance). This technology is rather expensive, especially in case of long distances and involves an increased level of work complexity and stress for the labor, which is always exposed to risk due to the payloads that are hauled downhill. Any breakdown of the skyline or mainline of the yarding system when loaded with logs might create damages both to the machinery and workers, fact that represents a important issue of the forest management activities. Therefore, a new slope road network would not only reduce the costs of harvesting, but in the same time would reduce the risk of accidents and provide safer work conditions and less stress for the operators and harvesting teams, as the uphill cable yarding systems could be used.

3.4 Cost calculation and rentability analysis (description of methodology)

The data registered in the data collection protocol during zero line planning in the field as well as the unitary costs presented in table 10 have been used for elaborating the general cost calculation of the road network.

Table 9. Unitary costs for material, machinery and labor (Steinmüller, 2008)

Type of cost	Amount (€/unit)
Site preparation	0.7 €/lm
Earthwork – excavator 20 tones	55 €/h
Earthwork – grader 15 tones	68 €/h
Earthwork – roller (compactor) 12 tones	47 €/h
Blasting operations (easy – moderate conditions)	2.50 – 4.00 €/m^3
Blasting operations (moderate – hard conditions)	4.50 – 5.50 €/m^3
Metallic pipes	200 €/piece
Stone walls made of local material	70 €/m^2
Road surface construction (gravel)	9 €/m^3
Engineer	73 €/h
Machine operator (excavator, grader, roller)	28 €/h
Incidentals	10% of total cost

Blasting operation costs include labor and equipment costs (drilling, charging and blasting). Costs inquired with water drainage (pipes) and artworks (stone walls) include material, mounting, fitting, inclusive labor and machine costs. The gravel costs include material, loading, trucking, laying out and compression, including labor and machine costs.

When elaborating the cost calculation, first was taken in consideration the performance of the operation, machinery, work type or labor (e.g. excavator performs in average 80 lm/day) which further was transformed in quantity of the respective item needed to complete the assignments for a respective branch. This last item represented the unitary measures which were assigned a cost per unit according to the cost list stipulated in table 9. Consequently resulted the total cost for a given type of operation and for a given branch. By summing up all the items for a given branch and after applying the incidentals, resulted the total costs of construction for the respective branch (see tables 11-15) as well as the average costs per linear meter.

In order to have a better overview regarding the efficiency of the investment, a rentability (cost/benefit) analysis in respect of timber extraction before and after constructing the forest road network was elaborated and presented in figure 28. The input data is represented by the annual allowable cut (AAC), calculated on an estimative basis depending on the productivity of the forest stands. The total quantity of timber to be harvested each year from the project area was calculated by taking in consideration a harvesting loss of 15% in the timber extraction process.

The costs inquired by the timber extraction process were calculated by taking in consideration the unitary costs provided by the project owner as well as the terrain conditions and type of access (easy / difficult) to the harvesting plots, before and after the road construction. Consequently, due to the improvement of accessibility, the previous extracting costs are higher than the prospective extracting costs, even when we refer to the same extracting technology.

The total costs for building the forest road network were calculated taking in consideration the total investment value of the project, plus the depreciation (calculated on a basis of 30 years lifetime of the road network) and the interest charge. Finally, the Cost – Benefit equation was calculated by deducting the prospective yearly extracting costs from the previously yearly extracting costs (see Figure 28 – *Subchapter 4.1.3 Cost Efficiency Analysis*).

Chapter 4. RESULTS

4.1 General Planning

4.1.1 General description of the forest road network

The general planning of Trauch Forest Road Network consisted in planning and marking in the field the zero line of the future forest road. The main goal of the designing process was to create access in the project area by achieving an optimum road density (a balance in minimizing the road length and maximizing the forest accessibility). The main focus was on keeping the future road on the upper part of the slopes and give access to the valleys by using uphill mobile cable yarding systems (average distance from the forest road to the valley ~ 300 – 400 m). For areas with moderate slopes, the silvicultural operations and logging can be done by harvesters and forwarders and therefore attention was paid to reach such areas by the designed forest road. Focusing on the main aspects presented before resulted a road network with one main branch of 13.35 km length (see Figure 27) and four secondary branches of 0.75 km, 1.68 km, 0.32 km and 1.00 km respectively (see table 9).

Table 10. Synthetic overview of Trauch Forest Road Network

Branch / Specification	***Main Branch***	***Branch B1*** Connection Schneelental	***Branch B2*** Steep & Rocky Area	***Branch B3*** Connection Pass	***Branch B4*** Connection Main Branch - Geisstein Pass	***Total Road Network (m)***
Total Length (m)	13349.95	754.40	1677.20	324.30	1002.70	***17108.55***
Rocky area (m)	1738.93	134.70	650.50	0.00	64.40	***2588.53***
Fords	0.00	99.20	45.00	0.00	8.00	***152.20***
Φ 800 mm culverts	4	1	3	0	2	***10***
Φ 600 mm culverts	2	0	2	0	1	***5***
Stone Walls (m)	3	2	1	0	1	***7***
Segments ≤9% (m)	10532.10	554.20	516.30	324.30	428.20	***12355.10***
Segments 10-12% (m)	2471.65	200.20	1077.90	0.00	399.80	***4149.55***
Segments ≥13% (m)	346.20	0.00	83.00	0.00	174.70	***603.90***

The total length of the designed forest road network is 17.108,55 m, which related to the total surface of the project area (401.20 ha) means a designed road density of 42.77 m/ha and a designed road distance of 234 m. This is an optimum density for achieving the goals of sustainable forest management and for solving the issues mentioned in *Chapter 1 – Introduction* and follows in the same time the patterns of average road density in commercial forests in Austria which is 45 m/ha (Sedlak, 1996).

During designing of the zero line in the field, special attention was paid to the slope gradient of the new forest road, so that the traffic could develop with easiness and the negative impacts of erosion would be reduced to minimum. Due to the same reasons, the slope gradient change in between consecutive designing steps was kept in the range of 3-5%. Consequently resulted a road network which has a slope gradient below 9% for more than 72% of the total length (12.355,10 m).

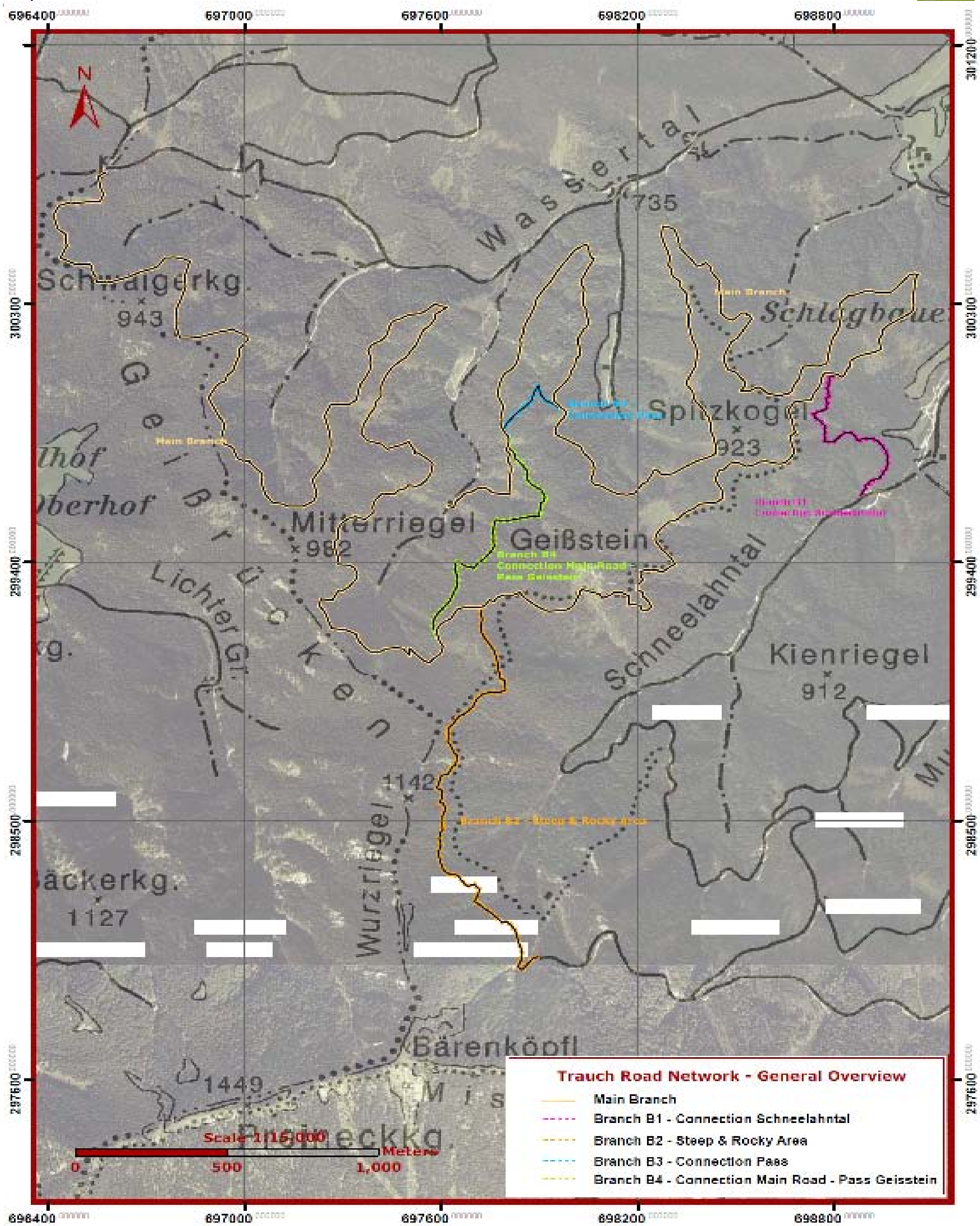

Figure 27 General Overview of Trauch Forest Road Network (snapshot)

The segments with slope gradients between 10 – 12% sum up a length of 4.149,55 m (24% of the total road network). It is to be mentioned that this range of slope gradients was very much used when designing the second branch of the road network (Branch B2 – Steep and rocky area) where the steep terrain conditions, as well as the big difference of altitude (between starting and ending point > 160 m) and the short distance in between the starting and ending point, imposed the use of steeper slopes as unique feasible solution for achieving the goal of connecting the positive cardinal points.

The road segments with slopes steeper than 13% summed up initially only 392,60 m (~2,2% of the total road length). This situation included two serpentines: one designed on the *Main Branch* in Geisstein pass area and another one designed on the last 225 m of the *Branch B4*. Although this solution was agreed in November 2008, after a meeting early May 2009 in between project team owner, project coordinator and project team member, decided was to find other solutions in order to avoid the planning of the serpentines. Consequently, during second half of May, one day field trip to the project area was planned and realized by the project team member in order to redesign the respective areas with serpentines. The solution found was to increase the longitudinal slope gradient over the limit of 12% up to the maximum limit of 16% for short segments.

Following this procedure, resulted a reduction of the *Main Branch* with 210 m than the initial designed one and in the same time the avoidance of the serpentine in the Geisstein Pass area. Nevertheless, it is to be mentioned that this was possible only by adopting longitudinal slopes of 14%-16% for a length of 197 m. The correction sector was marked in the field with white ribbon on the trees. The red ribbons initially used for marking the zero plane in the field were not removed in this case in order to leave to the project owner the possibility of choosing in between the two proposed solutions (with and without serpentine).

In case of *Branch B4* resulted a reduction in total length of 108 m as well as the avoidance of the serpentine by adopting slopes of 12%-13%. The correction sector was marked in the field with white ribbon and in this case, the red ribbons used initially for marking the zero plane on the trees were removed, due to the fact that the correction did not involve such extreme slopes as in the case of the main branch.

Therefore, the length of the segments with slopes steeper than 13% at the level of whole road network increased up to 603.90 m. As mentioned before, the slope gradients > 13% were used only on short segments, in order to avoid important mass movements, rock blasting and serpentines. For detailed data of the zero line designing please consult the data collection protocol of each branch in Chapter 8 – Appendix.

During designing process the planner tried to adapt the zero line of the forest road to the natural contour line as much as possible in order to avoid unnecessary artworks such as bridges or stone walls. Nevertheless, some negative cardinal points were not possible to be crossed without downhill stone wall stabilization. It is the case of branches B1 (99,20 m), B2 (45,00 m) and B4 (8,00 m) that sum up a total length of 152,20 m stone wall needed. As the average height for the stone walls in case of branch B1 was estimated for 2,50 m and 3,00 m for the other two branches, resulted a total surface of the downhill stabilizing stone walls of 407,00 m^2. The big size stones needed in this situation can be easily procured from the construction site (rocky areas) along the road network.

In general terms the designed road passes trough moderate terrain conditions, where approximately 85% (14.520 m) of the total road network length can be built in mixed profile in earthy or terrain with small amounts rock at the surface.

The rest of 15% (2.588 m) is going to be built trough rocky area. From this category about 1762,33 m is represented by soft and moderate rock condition, where hydraulic hammer mounted on excavator can be used to dig through the rocks. In this case, small amounts of blasting might be needed and only occasionally. Only about 826,20 m (5% of the total road network length) is represented by massive hard rock, where the embankments can be built only by making use of explosives and the road will be constructed in full cut profile. In this case, the exceeding resulting rocks can be used for other sectors of the road either for drainage of the water, for building supporting walls or for paving the forest road surface (as gravel, after a mobile crash mill was used).

In order to solve the drainage problem of the newly designed forest road network, the upper layer of the road bed will be cambered in crown shape form with slopes of 2-3% on each side. In the same time, for evacuating the water from the ditches, 250 metallic pipes with diameter of 400 mm will be used. They will be installed at an average distance of 70 m one from each other, taking in consideration the real situation in the field (e.g. points of inflexion of the zero line, concavities, etc.). Normally the length of this type of culverts will be of 5,00 meters, but they can be adapted to the width of the forest road accordingly with the terrain situation (e.g. case of curve widening), up to 6,00 m or more.

For crossing permanent streams metallic pipes of bigger diameter (7 X 600 mm and 5 X 800 mm) were designed for the normal flow of the water, but in combination with fords built according to the size of the water course in order to leave the possibility of high floods to pass over the road without damaging the downhill sectors of the road (see Table 9 and data collection protocol from Chapter 9 – Appendix for details).

4.1.2 General cost calculation

This estimative calculation gives a brief overview of the inquired costs of construction for each branch by types of work employed .The total costs of construction for each branch as well as the average costs per linear meter are presented in the tables 11 to 15.

Table 11. General construction cost calculation for Main Branch

Operation	*Performance*	Unitary Cost (€/unit)	*Road Length (m)*	*Quantity (hour-machine, h-man, m^3)*	*Total cost (€)*
1. Site Preparation		0.70 €	13349.95		***9,334.96 €***
2. Embankments					***145,789.75 €***
2.1 Earthwork - excavator 20 t (m/day)	80	55.00 €	13349.95	1668.70	91,778.50 €
2.2 Rocky area (m^3/lm)			*1738.93*		54,011.25 €
easy (HydHam)	8.5	2.50 €	1251.53	10638.00	26,595.00 €
medium-hard rock (Blastings)	12.5	4.50 €	487.40	6092.50	27,416.25 €
3. Water Drainage & Artworks					***38,200.00 €***
3.1 Mettalic pipes (70 m distance)	70	200.00 €	13349.95	191.00	38,200.00 €
3.2 Road Drainage					
3.3 StoneWalls (local stone) (m^2)		70.00 €	0.00		0.00 €
4. Suprastructure					***108,446.50 €***
4.1 Grader 15 t (m/h)	150	68.00 €	13349.95	89.00	6,052.00 €
4.2 Vibrocompactor 12t (m/h)	100	47.00 €	13349.95	133.50	6,274.50 €
4.3 Gravel layer (20 cm layer)		9.00 €	13349.95	10680.00	96,120.00 €
5. Labour					
5.1 Engineer (h/day)	6	73.00 €	13349.95	48.00	3,504.00 €
5.2 Excavator operator	10	28.00 €	13349.95	1668.70	46,723.60 €
5.3 Grader operator	10	28.00 €	13349.95	89.00	2,492.00 €
5.4 Roller operator	10	28.00 €	13349.95	133.50	3,738.00 €
Total Cost					358,238.82 €
Incidentals (10%)					35,823.88 €
TOTAL COST MAIN BRANCH (€ / Road Length)					***394,062.70 €***
AVERAGE COST MAIN BRANCH (€ / lm)					***29.52 €***

Table 12. General construction cost calculation Branch B1 – Connection Schneelahntal

Operation	Performance	Unitary Cost (€/unit)	Road Length (m)	Quantity (hour-machine, h-man, m^3, piece)	Total cost (€)
1. Site Preparation		0.70 €	754.40		**528.08 €**
2. Embankments					**10,597.00 €**
2.1 Earthwork - excavator 20 t (m/day)	80	55.00 €	754.40	94.30	5,186.50 €
2.2 Rocky area (m^3/lm)			134.70		5,410.50 €
easy (HydHam)	8.5	2.50 €	61.90	526.20	1,315.50 €
medium-hard rock (Blastings)	12.5	4.50 €	72.80	910.00	4,095.00 €
3. Water Drainage & Artworks					**12,945.20 €**
3.1 Mettalic pipes (70 m distance)	70	200.00 €	754.40	11.00	2,200.00 €
3.2 Road Drainage		10.00 €	99.20	133.92	945.00 €
3.3 StoneWalls (local stone) (m^2)		70.00 €	99.20	248	9,800.00 €
4. Suprastructure					**6,124.00 €**
4.1 Grader 15 t (m/h)	150	68.00 €	754.40	5.00	340.00 €
4.2 Vibrocompactor 12t (m/h)	100	47.00 €	754.40	7.50	352.50 €
4.3 Gravel layer (20 cm layer)		9.00 €	754.40	603.50	5,431.50 €
5. Labour					**3,428.40 €**
5.1 Engineer (h/day)	6	73.00 €	754.40	6.00	438.00 €
5.2 Excavator operator	10	28.00 €	754.40	94.30	2,640.40 €
5.3 Grader operator	10	28.00 €	754.40	5.00	140.00 €
5.4 Roller operator	10	28.00 €	754.40	7.50	210.00 €
Total Cost					33,622.48 €
Incidentals (10%)					3,362.25 €
TOTAL COST BRANCH B1 (€ / Road Length)					**36,984.73 €**
AVERAGE COST BRANCH B1 (€ / lm)					**49.03 €**

Table 13. General construction cost calculation Branch B2 – Steep and rocky area

Operation	Performance	Unitary Cost (€/unit)	Road Length (m)	Quantity (hour-machine, h-man, m^3, piece)	Total cost (€)
1. Site Preparation		0.70 €	1677.20		**1,174.04 €**
2. Embankments					**56,173.50 €**
2.1 Earthwork - excavator 20 t (m/day)	80	55.00 €	1677.20	209.70	11,533.50 €
2.2 Rocky area (m^3/lm)			650.50		44,640.00 €
easy – medium (Hydraulic Hammer)	10	4.00 €	384.50	3845.00	15,380.00 €
medium-hard rock (Blasting)	20	5.50 €	266.00	5320.00	29,260.00 €
3. Water Drainage & Artworks					**14,857.50 €**
3.1 Metallic pipes (70 m distance)	70	200.00 €	1677.20	24.00	4,800.00 €
3.2 Road Drainage		10.00 €	45.00	60.75	607.50 €
3.3 Stone Walls (local stone) (m^2)		70.00 €	45.00	135	9,450.00 €
4. Suprastructure					**15,136.70 €**
4.1 Grader 15 t (m/h)	150	68.00 €	1677.20	11.20	761.60 €
4.2 Compactor 12t (m/h)	100	47.00 €	1677.20	16.80	789.60 €
4.3 Gravel layer (20 cm layer)		9.00 €	1677.20	1509.50	13,585.50 €
5. Labor					**7,969.60 €**
5.1 Engineer (h/day)	6	73.00 €	1677.20	18.00	1,314.00 €
5.2 Excavator operator	10	28.00 €	1677.20	209.70	5,871.60 €
5.3 Grader operator	10	28.00 €	1677.20	11.20	313.60 €
5.4 Roller operator	10	28.00 €	1677.20	16.80	470.40 €
Total Cost					95,311.34 €
Incidentals (10%)					9,531.13 €
TOTAL COST BRANCH B2 (€ / Road Length)					**104,842.47 €**
AVERAGE COST BRANCH B2 (€ / lm)					**62.51 €**

Table 14. General construction cost calculation Branch B3 – Connection Pass

Operation	*Performance*	Unitary Cost (€/unit)	*Road Length (m)*	*Quantity (hour-machine, h-man, m^3, piece)*	*Total cost (€)*
1. Site Preparation		0.70 €	324.30		***277.01 €***
2. Embankments					***2,227.50 €***
2.1 Earthwork - excavator 20 t (m/day)	80	55.00 €	324.30	40.50	2,227.50 €
2.2 Rocky area (m^3/lm)			*0.00*		0.00 €
easy (HydHam)	8.5	2.50 €	0.00	0.00	0.00 €
medium-hard rock (Blastings)	12.5	4.50 €	0.00	0.00	0.00 €
3. Water Drainage & Artworks					***1,000.00 €***
3.1 Mettalic pipes (70 m distance)	70	200.00 €	324.30	5.00	1,000.00 €
3.2 Road Drainage		10.00 €	0.00	0.00	0.00 €
3.3 StoneWalls (local stone) (m^2)		70.00 €	0.00	0	0.00 €
4. Suprastructure					***2,634.60 €***
4.1 Grader 15 t (m/h)	150	68.00 €	324.30	2.20	149.60 €
4.2 Vibrocompactor 12t (m/h)	100	47.00 €	324.30	3.20	150.40 €
4.3 Gravel layer (20 cm layer)		9.00 €	324.30	259.40	2,334.60 €
5. Labour					***1,416.60 €***
5.1 Engineer (h/day)	6	73.00 €	324.30	1.80	131.40 €
5.2 Excavator operator	10	28.00 €	324.30	40.50	1,134.00 €
5.3 Grader operator	10	28.00 €	324.30	2.20	61.60 €
5.4 Roller operator	10	28.00 €	324.30	3.20	89.60 €
Total Cost					7,505.71 €
Incidentals (10%)					750.57 €
TOTAL COST BRANCH B3 (€ / Road Length)					***8,256.28 €***
AVERAGE COST BRANCH B3 (€ / lm)					***25.46 €***

Table 15. General construction cost calculation Branch B4 – Connection Main Road – Pass Geisstein

Operation	*Performance*	Unitary Cost (€/unit)	*Road Length (m)*	*Quantity (hour-machine, h-man, m^3, piece)*	*Total cost (€)*
1. Site Preparation		0.70 €	1002.70		***701.89 €***
2. Embankments					***8,807.40 €***
2.1 Earthwork - excavator 20 t (m/day)	80	55.00 €	1002.70	125.30	6,891.50 €
2.2 Rocky area (m^3/lm)			*64.40*		1,915.90 €
easy (HydHam)	8.5	3.50 €	64.40	547.40	1,915.90 €
medium-hard rock (Blastings)	12.5	4.50 €	0.00	0.00	0.00 €
3. Water Drainage & Artworks					***4,588.00 €***
3.1 Mettalic pipes (70 m distance)	70	200.00 €	1002.70	14.00	2,800.00 €
3.2 Road Drainage		10.00 €	8.00	10.80	108.00 €
3.3 StoneWalls (local stone) (m^2)		70.00 €	8.00	24	1,680.00 €
4. Suprastructure					***8,145.40 €***
4.1 Grader 15 t (m/h)	150	68.00 €	1002.70	6.70	455.60 €
4.2 Vibrocompactor 12t (m/h)	100	47.00 €	1002.70	10.00	470.00 €
4.3 Gravel layer (20 cm layer)		9.00 €	1002.70	802.20	7,219.80 €
5. Labour					***4,414.00 €***
5.1 Engineer (h/day)	6	73.00 €	1002.70	6.00	438.00 €
5.2 Excavator operator	10	28.00 €	1002.70	125.30	3,508.40 €
5.3 Grader operator	10	28.00 €	1002.70	6.70	187.60 €
5.4 Roller operator	10	28.00 €	1002.70	10.00	280.00 €
Total Cost					26,656.69 €
Incidentals (10%)					2,665.67 €
TOTAL COST BRANCH B3 (€ / Road Length)					***29,322.36 €***
AVERAGE COST BRANCH B3 (€ / lm)					***29.24 €***

A general observation to be noticed from the tables above (table 11 – table 15) is that for moderate difficulty level and terrain conditions, such as the case for the main branch, branches B3 and B4 respectively, the construction costs are in range of 25 – 30 €/lm. Where difficult terrain is encountered, the construction costs increase considerably as in the case of branches B1 – Connection to Schneelahntal (49.0 €/m) and B2 – Steep and Rocky Area (62.5 €/m).

If for the *Branch B2 – Steep and Rocky Area* the reason of the increased construction costs is obvious from the very name of the branch, having to deal with steep terrain conditions and massive rocks that need important quantities of explosives, in the case of the *Branch B3 – Connection Schneelahntal* the main reason of the increased costs is represented by a moist and steep area of approximately 100 meters which needs both road bed drainage and downhill slope stabilization with stone walls. From this point of view and given the fact that the reason of designing branch B3 was merely to connect the newly designed main road with the *Schneelahntal* Forest Road, it appears that this branch is not a reasonable solution from the economical point of view. The sensitive situation of this branch was presented to the project owner from the early phase of designing (field measurements) when the project team member observed the negative cardinal point mentioned above, but nevertheless the decision was to use this solution for connecting the main road with the *Schneelahntal* valley. Therefore the project team member designed and marked the zero line of this branch in the field and considered it in further analysis and calculations in the project, according to project owner's decision.

The overall construction costs of the Trauch Road Network are presented in table 16.

Table 16. General construction cost calculation – Synthetic overview of Trauch Forest road Network

Operation	**Unitary Cost (€/unit)**	***Road Length (m)***	***Quantity (hour-machine, h-man, m^3, piece)***	***Total cost (€)***
1. Site Preparation	0.70 €	*17108.55*	*17108.55*	***11,975.99 €***
2. Embankments				***223,595.15 €***
2.1 Earthwork - excavator 20 t (m/day)	55.00 €	*17108.55*	*2138.50*	*117,617.50 €*
2.2 Rocky area (m^3/lm)		*2588.53*	*27879.10*	*105,977.65 €*
easy (Hydraulic Hammer)	3.50 €	*1762.33*	*15556.60*	*45,206.40 €*
medium-hard rock (Blasting)	4.50 €	*826.20*	*12322.50*	*60,771.25 €*
3. Water Drainage & Artworks				***71,590.50 €***
3.1 Metallic pipes (70 m distance)	200.00 €	*17108.55*	*245.00*	*49,000.00 €*
3.2 Road Drainage	10.00 €	*152.20*	*205.47*	*1,660.50 €*
3.3 Stonewalls (local stone) (m^2)	70.00 €	*152.20*	*407.00*	*20,930.00 €*
4. Suprastructure				***140,487.20 €***
4.1 Grader 15 t (m/h)	68.00 €	*17108.55*	*114.10*	*7,758.80 €*
4.2 Vibro-compactor 12t (m/h)	47.00 €	*17108.55*	*171.00*	*8,037.00 €*
4.3 Gravel layer (20 cm layer)	10.00 €	*17108.55*	*16243.40*	*124,691.40 €*
5. Labor		-	*2503.40*	***73,686.20 €***
5.1 Engineer (h/day)	73.00 €	-	*79.80*	*5,825.40 €*
5.2 Excavator operator	28.00 €	-	*2138.50*	*59,878.00 €*
5.3 Grader operator	28.00 €	-	*114.10*	*3,194.80 €*
5.4 Roller operator	28.00 €	-	*171.00*	*4,788.00 €*
Total Cost				521,335.04 €
Incidentals (10%)				52,133.50 €
TOTAL COST Trauch Road Network (€ / Road Length)				***573,468.54 €***
AVERAGE COST Trauch Road Network (€ / lm)				***33.52 €***

The total investments needed for the construction of Trauch Forest Road Network (17.11 km) would rise to 573,468.54 €, which means an average value of 33.52 € per linear meter of new road built. Being given the overall terrain conditions of the project area specified in Chapter 3, this figure represents a feasible economical solution for opening the accessibility in the specified forests. The most costly intensive operations in the construction process are:

- *Embankments* - in value of 223,595.15 € (39% of the total project value)
- *Suprastructure* - in value of 140,487.20 € (25% of the total project value)
- *Water drainage and artworks* – rises up to 71,590.50 € (12% of the total project value)
- *Labor* – in value of 73,686.20 € (13% of the total project value)

The costs presented above are calculated based on estimative quantities deducted from the data field collection protocol. Therefore, the final costs of construction might suffer a slight variation according to the real quantities inquired (gravel, hour machinery, etc.). For example, the costs for gravel layering were calculated with an average value of 9 €/m^3 of gravel, but taking in consideration the increased availability of gravel in the area the total costs of this operation might decrease. In the same time it is possible that the values calculated for explosives and blasting operations to slightly increase in reality (e.g. blasting volumes are estimated), but in overall terms these costs might be compensated by the decrease in value of gravel layering operations. Being given the fact that for the total construction costs were taken in consideration as well the externalities/incidentals that might occur (10% of the project value), the estimative cost calculations are considered consistent and close to reality.

The investment effort for building Trauch Forest Road Network is significant enough (573,468.54 €) and therefore not justifiable from the cash – flow point of view to be made in only one year. Consequently, the construction of the forest road network was planned and scheduled for a period of five years (2009 – 2013, see table 17), taking in consideration the priorities defined by the project owner in the first place and the functionality of branch connections and equity of annual investments in the second place.

Table 17 Schedule of investments (2009 – 2013) for Trauch Forest Road Network

Year	***Branch/Road Sector***	***Length (m)***	***Investments value***		***Realised from total project(%)***	
			Total (€)	***Average (€/lm)***	***Quantity (lm)***	***Value (€)***
2009	B1 + B2	2431.60	141,827.20 €	58.33 €/lm	14.00%	24.73%
2010	B4 + Main branch (Hm 52+921 » 77+134; Hm 129+285 » 133+499)	3845.50	113,235.89 €	29.45 €/lm	22.00%	19.75%
2011	Main Branch (Hm 12+049 » 52+921)	4087.20	120,645.62 €	29.52 €/lm	24.00%	21.04%
2012	Main Branch (Hm 0+000 » 12+049; Hm 129+285 » 100+586)	4074.75	120,278.13 €	29.52 €/lm	24.00%	20.97%
2013	Main Branch (Hm 77+134 » 100+586) + B3	2669.50	77,481.70 €	29.02 €/lm	16.00%	13.51%
TOTAL		***17108.55***	***573,468.54 €***	***-***	***100.00%***	***100.00%***

As main priority the project owner set the construction of Branch B2 (Steep and Rocky area) in the first year, in order to create access to the most inaccessible part of the project area, which in the same time is represented by the biggest share of over-aged forests. Following then a functional approach of branch connections within the newly designed road network or with the existing forest roads, the designer set up the following schedule:

- 1st year – construction of Branch B2 + Branch B1 (Connection to Schneelahntal Valley)

- 2nd year – connection of Branch B2 with Branch B1 (Main Road from Hm 52+921 till Hm. 77+134) and connection of Branch B2 with Branch B4 and the end part of the main road (Hm 129+285 till Hm 133+499) in order to facilitate the downhill transport of the logs from the steep and rocky area.
- 3rd year – continuing the construction of Main Road from Hm 52+921 till Hm 12+049
- 4th year - continuing the construction of Main Road from Hm 12+049 till Hm 0+000 and from Hm 129+285 until Hm 100+586
- 5th year – finalizing the main road (Hm 77+134 till Hm 100+586) and building branch B3

During the scheduling phase, the project team member strived for maintaining equity of effort investment among each of the five years foreseen for building the road network. Nevertheless, as table 17 shows it was not possible to keep a complete balance in between the value and quantity of realized work for all years. The biggest difference in between effort investment (25% of the total project value) and quantity (linear meters of road network built, 14% of the total road length) is registered in the first year (see table 17), but this is an expected fact if we note that also in this year we have to deal with the most difficult part of the forest road network (branches B1 and B2). The following years are more balanced from this point of view and the last year from the scheduled plan is the one with the smallest investment amount (13% of the project value and 16% of the road length). Depending on the availability of investment funds, interests and willingness of the project owner, the construction of the forest road network might be also finished in only four years instead of five, by rescheduling the constructions foreseen in the fifth year for the period from 2nd until the 4th year.

4.1.3 Cost Efficiency Analysis

A very important aspect of building the designed forest road network is the efficiency analysis or other way said the benefits the forest owner will earn by implementing this project. From the very beginning is to be specified that although the economical benefits are prevailing, they are not the only ones which are taken into account, the access to forest plots compartments realizing tending operations and thinnings or access to the forest in case of calamities (e.g. wind throws, massive insects attack, etc.), as well as the safety of the working conditions are equally important for weighting the overall benefits of the investment.

As specified in *table 8* (Chapter 3 – Methodology) around 52% (211.59 ha) of the project area is represented by slopes below 55%, which from a theoretical point of view means that harvesting technologies such as skidder or the tandem of harvester and forwarder could be used. Nevertheless, due to the complex topography of terrain and not direct road access to the plots situated in this range of slopes, the reality is totally different: only 14% (56.18 ha) of the project area can be harvested by the named technologies, the rest of 86% of the area (345.02 ha) needing the employment of cable yarding systems (see table 18). Out of this last amount, only 5.86 ha can be harvested by uphill cable yarding systems, the rest being possible to be harvested by downhill cable yarding systems. In the following table are presented the current harvesting technologies used in the project area.

Table 18. Harvesting technologies used in the project area from Trauch Forest District (Bancalari, 2008)

Harvesting Technology	Harvesting costs	Slope Classes	Surface (ha)
Skidder	24 €/ m^3	<25%; share of 10% (wind throws)	5.52
Harvester + Forwarder	23 €/ m^3	22-55%	49.68
Cable Yarder Uphill	26 €/ m^3	>55%	5.86
Cable Yarder Downhill	31 €/ m^3	>55%	340.14
TOTAL			**401.20**

As it is noticeable from the table above the average harvesting cost per type of harvesting technology varies between in the range of 23-31 €/m^3, being the downhill cable yarding the most feasible and expensive technology in the same time, and the tandem harvester – forwarder the cheapest one. Nevertheless the harvesting cost information provided by the project owner could not be used directly in calculations of total harvesting costs and needed to be adapted according to the previously mentioned local terrain conditions, calculating an average harvesting cost per slope class as presented in the following table (e.g. mixed harvesting technology in one slope class is possible). In this way an average harvesting cost of 27.9 € per m^3 and slope class was calculated.

Table 19. Calculation of actual harvesting costs per m^3 and slope class

Slope class	Area covered (ha)	Harvesting technology	Harvesting costs per m^3 and slope class
< 25%	28.72	Skidder (SKD) - 10%, Harvester + Forwarder (HV + FWD) - 90%	23.1 €/m^3
25 – 55%	182.87	SKD + HV+FWD – 14%, DCY – 86%	27.8 €/m^3
> 55%	189.61	Downhill Cable Yarder (DCY)	31.0 €/m^3
TOTAL	**401.20**	***Average cost per m^3 and slope class***	***27.9 €/m^3***

Being given the fact that the forest data base provided by the project owner was not complete in terms of information regarding the project area, the total standing volume had to be estimated. Consequently, first was calculated the average volume per hectare by age classes and then, knowing the area each age class covers the total standing volume per age class was easily calculated. By summing up each age class' standing volume results the total estimated standing volume from the project area as it is presented in table 20. The forest compartments where the data was missing (standing volume) were excluded from the calculation of the average standing volume per hectare and age class, but their occupied area was included in the final calculation of the total standing volume. Results in this way a total estimated standing volume in the project area of 52193.61 m^3.

Table 20. Calculation of standing volume by age classes in project area

Age Class	Average Volume (m^3/ha)	Area Covered by Age Class (ha)	Total Estimated Volume (m^3)
I (0 – 20)	23.62	54.32	1283.15
II (21 – 40)	130.35	51.81	6753.71
III (41 – 60)	558.80	32.22	18007.26
IV (61 – 80)	138.35	26.49	3664.26
V (81 – 100)	69.68	7.85	546.98
VI (101 – 120)	62.39	14.53	906.66
VII (121 – 140)	101.55	124.92	12685.82
VIII (141 – 160)	105.43	68.84	7258.06
IX (161 – 180)	53.84	20.20	1087.70
Total	***130.10 m^3/ha***	***401.20 ha***	***52193.61 m^3***

The total standing volume was then divided at the total surface that the project area covers and result an average value of 130.10 m^3 per hectare of forest irrespective of age class. This volume was further on used in calculation of the standing volume per slope class as it appears in the following table.

Table 21. Calculation of standing volume per slope class in the project area

Slope class	***Area covered (ha)***	***Share (%)***	***Standing Volume by Slope classes (m^3)***
< 25%	28.72	7,16%	3736.33
25 – 55%	182.87	45,58%	23790.47
> 55%	189.61	47,26%	24666.81
TOTAL	***401.20***	***100%***	**52193.61**

The calculated standing volume per slope classes was used in the efficiency analysis in terms of calculating which the expected harvesting costs are before and after the construction of the forest road network, as shown in the following table.

Table 22. Efficiency analysis of building Trauch Forest Road Network

Slope class	***Standing Volume (m^3)***	***Current Situation***			***After Road Network Construction***		
		Harvesting technology	***Harvesting costs***	***Total HV Costs***	***Harvesting technology***	***Harvesting costs***	***Total HV Costs***
< 25%	3,736.33	SKD 10%, HV+FWD 90%	23.1 €/m^3	79,210.16€	SKD 10%; HV+FWD 90%	*21.2* €/m^3	79,210.16€
25 – 55%	23,790.47	SKD + HV+FWD – 14%, DCY – 86%	29.5 €/m^3	662,077.22€	HV+FWD	*21.0* €/m^3	499,599.94€
> 55%	24,666.81	Downhill Cable Yarding (DCY)	31.0 €/m^3	715,352.09€	Uphill Cable Yarding (UCY)	*25.0* €/m^3	641,350.15€
TOTAL	***52,193.61***	***Average HV cost***	***27.9 €/m^3***	***1,553,113.29€***	***Average HV cost***	***22.6 €/m^3***	***1,227,259.28€***

The designed forest road network seems to be interesting in terms of profitability, if we take in consideration the fact that the average harvesting costs would be reduced in the project area from 27.9 €/m^3 to 22.6 €/m^3 after the road network will have been constructed. This fact can be translated in a total added value to the forest resources from the project area of 325,854 €, which represents approximately 57% from the total value of the investments (573,468.54 €).

The maintenance costs of the forest road network represent more or less the value of the total investment equally distributed on the life time of the road (30 years). This means each year approximately 17,109 € (1 € per linear meter) has to be considered as maintenance costs of the entire forest road network (reshaping the carriageway, replacing damaged culverts, etc.)

The corridor of the future road network that must be cleared before starting the construction has an average width of 12 m. Correlated with the total length of the road network of 17.11 km, results in an area of 20.53 ha of forest that has to be clear cut before the road will be built. In table 23 is presented the economic assessment of clearing the road bed of the designed forest road network.

Table 23. Economic assessment of opening the corridor of the designed road network

Opening (clearing) road bed area	20.53 ha
Volume to harvest	***2670.88 m³***
Average price	60 €/m³
Average Extracting Costs	25 €/m³
Average Benefit	35 €/m³
Total benefit of opening the road bed corridor	***92,813.23 €***

The project owner can recover approximately 16% (92,813.23 €) from the total investment effort by opening up the platform of the designed forest road network, which is another important argument that would make the road network economically feasible. The figures presented in the table above are estimative and were calculated on the basis of the average price (for different assortments of conifers and broadleaves) for timber sold at the road side; the real benefit from opening up the road bed corridor might vary according to the quality and quantity of the harvested timber.

In order to have a better overview regarding the efficiency of the investment, a rentability (cost/benefit) analysis in respect of timber extraction before and after constructing the forest road network was elaborated. As it is presented in figure 28, building Trauch Forest Road Network has an overall yearly benefit of *1,423 €*, which means that the project worth while investing. The difference between the previous and prospective extraction costs (approximately 12 € per m^3 gained after constructing the road network, see figure 28) is a straight forward fact that supports the decision of investing in this project. It is to be mentioned that the rentability analysis of the timber extracting process took in consideration all the costs inquired by the newly designed forest road network, including building costs, financing costs, as well as the maintenance costs of the road network.

Besides the economic benefits, if we take in consideration the other non – monetary benefits created by opening up the access to the forest, we can admit that Trauch Road Network Project brings multiple improvements in the project area. Intrinsic values such as opened access to young forest stands for realizing tending and thinning operations, improved access in the forest in case of natural calamities or reduction of risk of accidents during logging operations are important benefits promoting a sustainable forest management and have a more ecological and social perspective. In the same time, the access for game management has been improved, the forest managers being able to create new observation points and feeding places for winter season. In this way the existing and further plantations are being better protected, by reducing the pressure from the wild animals. On the other hand, we have to take in considerations the benefits brought by the nee road network for the development of a sound eco-tourism, because activities like hiking, biking, birds and animal watching will be easier to be realized in the project area and surrounded areas. The new road network intersects with several hiking trails and provides easier access to them and better connections with other existing hiking trails.

These facts represent important arguments that should encourage the project owner to apply for co-financing the execution of the forest road network by the regional forest authorities.

Rentability Analysis for Trauch Forest Road Network

1. Input Data

a. Accessibilized Forest Area (ha) 401.2

b. Annual Allowable Cut (AAC)

Productivity level: good	12	x	174.7	Area (ha) =	2096.4	m^3/Year
Productivity level: average	10	x	189.3	Area (ha) =	1893	m^3/Year
Productivity level: poor	8	x	37.2	Area (ha) =	297.6	m^3/Year
	SUMM =		401.2	ha	**4287**	**m^3/Year**

c. Harvested timber

AAC (fm) 4287 - 15% Harvesting loss = **3644** **m^3/Year**

2. Previous Extracting Costs

Previous Extracting Technologies	Cost (€)	x	Share	=	Cost x Share
1. Downhill Cable Yarding System - long distance	31.0	x	0.68	=	21.08
2. Not extractable	55.0	x	0.20	=	11.00
3. Uphill Yarding System - long distance (>300 m)	26.0	x	0.00	=	-
4. Skidder (long hauling distance)	24.0	x	0.02	=	0.48
5. Forwarder - Harvester	23.0	x	0.10	=	2.30
Average Extracting Costs	**SUMM**		**1.0**		**34.86**

Previous Yearly Extracting Costs

Average extracting costs 34.86 x quantity 3644 = **127,029.84**

3. Total Costs of Building the Forest Road Network per Year

Length of the designed forest road network 17109 m

Average construction cost per linear meter 33.52 €

Total Construction Costs m 17109 x € 33.52 = **573,478.60**

a. Depreciation for 30 Years

Total Construction Costs 573478.60 : **30** = **19,115.95**

b. Interest Charge

30% of Total Construction Costs 172043.58 **x 0,04 (4%)** = **6,882.00**

c. Maintenance Costs

Length of the road network (m) 17109 **1 € / meter** = **17,108.55**

d. Total Costs

a. + b. + c. = **43,106.50**

4. Prospective Extracting Costs (after road construction)

future Harvesting Technology	Cost	x	Share	=	Cost X Share
1. Downhill Cable Yarding System - long distance	31.0	x	0.00	=	-
2. Uphill Yarding System - short distance (300 m)	25.0	x	0.40	=	10.00
3. Skidder (long hauling distance)	23.0	x	0.02	=	0.46
4. Forwarder - Harvester	21.0	x	0.58	=	12.18
Average future Harvesting Costs	**SUMM**		**1.0**		**22.64**

Future Yearly Harvesting Costs

Average prospective Extracting Costs (€) 22.64 x quantity 3644 = **82,500.16**

5. Prospective Extracting Costs including Costs of constructing the forest road network (Sum 3 and 4)

Average prospective extracting costs	82,500.16
+ **Total Costs of the Forest Road Network**	43,106.50
Future Total Harvesting Costs	**125,606.66**

6. Cost (2. Previous Extracting Costs) - Benefit (5. Prospective Extracting Costs) equation

Previous Yearly Extracting Costs **minus**	127,029.84
Prospective Yearly Extracting Costs	125,606.66
= Cost Savings / Year (€)	**1,423.18**

Figure 28 Rentability Analysis for building Trauch Forest Road Network

4.2 Detailed Planning

As agreed with the project owner in the inception phase of the project, the detailed planning will refer to *Branch B2 – Steep and Rocky Area*, in length of 1677.20 m which will create access in the most difficult part of the project area. For this branch first a technical report will be presented, followed by details of situation plan (map), cross section and longitudinal profile description.

4.2.1 Technical Report

Branch B2 starts at Hm 0+00, by connecting to the end point of the existing forest road situated approximately 400 m below Bärenköpfl main ridge and will descend up to the connection with the newly designed main road situated in the proximity of Geisstein Pass. The road is north – south oriented and will generally have a mixed profile, with the left side slope in cut and the right side slope in fill and with the ditches for the water evacuation on the left side (towards the slope). Nevertheless, for difficult terrain conditions (downhill side slopes > 80% and rocky sectors) the road is designed in full cut profile. For the evacuation of the water from the ditches 400 mm diameter metallic pipes will be used set up at an average interval of 70 m.

At Hm 0+14 the road turns left and enters in to a very steep and stony sector up to Hm 2+69 and consequently it will be executed in full cut profile. Important amount of explosives will be needed for digging through the rocks in this sector.

At Hm 0+67 road turns right and enters in a succession of two right curves (the second one at Hm 0+84) where also two important deep ditch crossings will take place; therefore construction of fords over Φ800 mm and Φ600 mm pipes respectively will be needed in both specified positions (hectometers 0+67 and 0+84), as well as downhill stone walls of 20-25 m^2 to stabilize the pipe-ford construction and the road base. This bucket shaped area actually represents the start of Schneelahntal Valley, both ditches having small permanent water streams, but the main reason of the fords and pipes setting is the water run-off during spring time after snow melting and during heavy precipitation, when the ditches might behave as torrents. After crossing this critical point, the road will continue in cut profile through massive rock up to Hm 1+76, from where the cross section will change to mixed profile as the slopes become more moderate and the terrain less rocky up to Hm 2+30. For this sector only hydraulic hammer diggings and some explosives would be employed for building the embankment. From Hm 2+30 till Hm 2+69 the road enters again in a steeper area, where the cut profile will be a necessity.

From Hm 2+69 the road enters into a clear-cut area and continues to descend following the natural contour lines, through moderate terrain conditions (mixed profile) up to Hm 3+79 where a ditch is crossed before a curve to right. In this point a Φ600 mm pipe and a downhill stonewall of circa 20 m^2 are needed. The road will continue descending in mixed profile (moderate terrain conditions) up to Hm 4+06 when the slope gradient of the road will start increasing up to Hm 4+69 in order to avoid a difficult stony area, which will be crossed through a small pass on its uphill side. From Hm 4+48 till Hm 4+69 the road will be in cut profile through rocks, therefore explosives will be needed.

From Hm 4+69 till Hm 6+30 the road goes smoothly in mixed profile through moderate terrain conditions crossing through an old forest and a clear cut area. After the clear cut area ends, at

Hm 6+30, a sliding sector starts and therefore cut profile will be used till Hm 6+56. In this point, after a curve to the left, the road enters in a very difficult sector of about 100 m length with massive blocks of stones. Consequently, from Hm 6+56 till Hm 7+59 the road is to be executed in full cut profile, by making use of important amounts of explosives. For two thirds of the length of this difficult rocky sector the road will be situated on a cliff with the bottom part of the foot at 20-25 m downhill.

After a slight curve to right which starts at Hm 7+59 the road enters in a moderate rocky sector, where some explosives as well as hydraulic hammer (excavator) will be employed for digging through the rocks. This rocky sector is less difficult to be crossed (softer rock) than the previous one and it ends up at Hm 9+85. At Hm 8+18 a ditch must be crossed (start of a small valley) and consequently a small ford over a Φ400 mm pipe should be installed and at Hm 9+48 the roads the road connects with a hiking trail.

From Hm 9+85 till Hm 13+59 the road goes through a relatively easy sector with moderate terrain conditions where the road can be executed in mixed profile. From Hm 13+59, another rocky sector starts which ends up at Hm 14+73, at the edge of young forest (first age class). Through this rocky sector, some explosives and mainly the hydraulic hammer of the excavator could be used for building the road in cut profile. At Hm 14+07 a valley starts and a downhill stabilizing stonewall is needed for a length of approximately 8-10 m (24-30 m^2 of stonewall).

From Hm 14+73 till the end of the Branch B2 the side slopes become moderate and the road can be again executed in mixed profile up to Hm 16+69, where *Branch B2 – Steep and rocky area* connects to the newly designed main branch (at Hm 56+63) of the Trauch road network, in the vicinity of Pass Geisstein.

4.2.2 Road Eng Assessment

RoadEng software (Forest Engineer version, see www.softree.com) is a state-of-the-art designing tool which was used for detailed planning of *Branch B2 – Steep and Rocky Area*. After being introduced in Survey / Map module the data collected from the field was processed in *Location* module, where for window types make possible the adjustments of road plan, cross sections and longitudinal profile (see *Chapter 3 – Subchapter 3.2.6 Data processing* for details).

A first step in data processing was to define one template for steep and rocky area, and one template for moderate conditions area (earth mass movements). These templates were assigned to the whole length of the *Branch B2* according to the data collection protocol and specified observation regarding the type of terrain (rocky, moderate and earthy). In this way results at the end a surplus of material of about 100 m^3.

The next step in data processing was to adjust the cross section of the road where the downhill side slopes exceeded 80%, so that the road would be executed in full cut profile. In this way, after assessing the full length of the branch B2, the quantity of surplus material (rocks) increased to 5853 m^3. Although this is quite a big quantity of material that must be transported we can consider it as a normal one, given the steep conditions of the terrain.

The third step in data processing was to adjust the most sharpened horizontal curves, using the horizontal curves alignment function in the *plan window*, in order to fulfill the technical specification of the guidelines for forest roads designing and construction. Following the same principles, the vertical curves were adjusted in the longitudinal profile. In this way, a number of 29 horizontal curves with radius between 10 and 100 meters were adjusted and result the total quantity of surplus material which rises to 7758 m^3. One other important aspect to be mentioned is that during curves adjustments process a compromise had to be made: in case of some areas where the downhill side slopes exceeded 80% the cross section could not be realized in full cut profile, due to the minimum radius constraints (which in current case is 10 m) and of the curve tangents and therefore, these areas were designed in mixed profile (80% cut and 20% fill). In these situations the safety and comfort of driving on the future road prevails. Another positive aspect of this compromise is that there is enough filling material available from neighboring sectors that can be used and consequently the final material resulted from mass movements would be reduced.

Following the process described above, in Section window of RoadEng – Location module, the cross sections of the Branch B2 were designed (see *Figure 29* and *Chapter 9 – Appendix*, for details and complete list of cross sections).

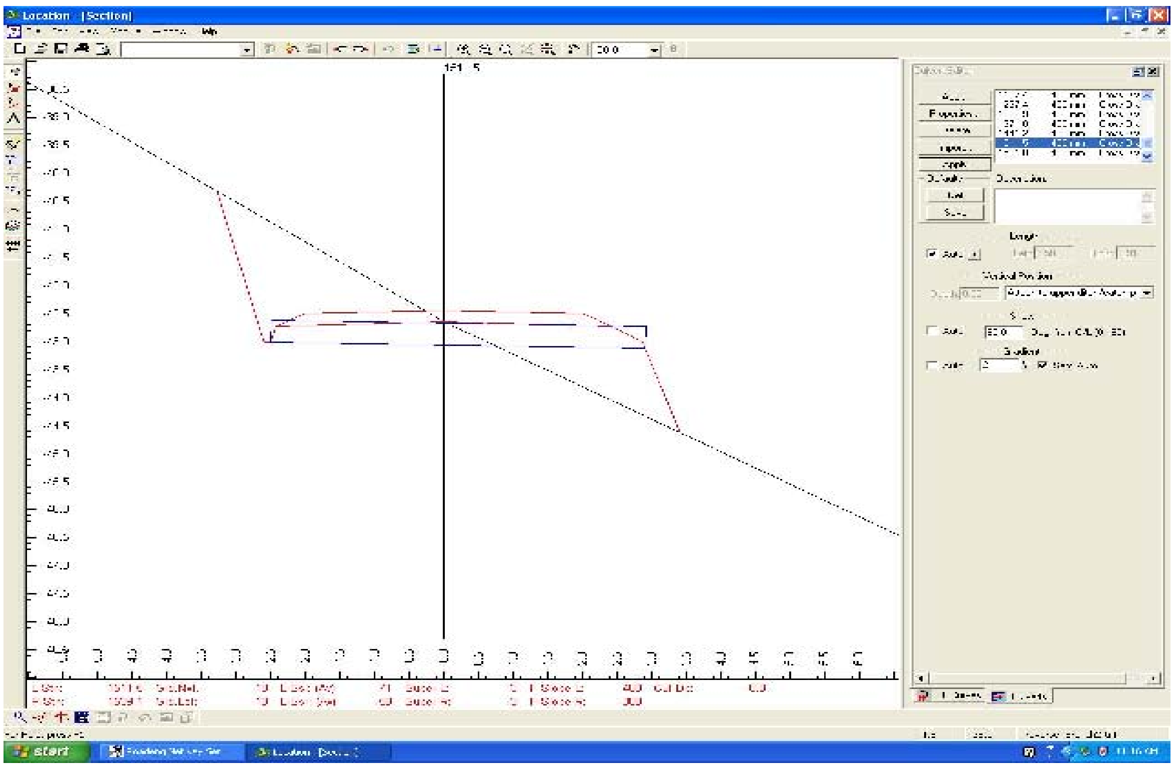

Figure 29. Snapshot of mixed profile cross section in Branch B2 - RoadEng designing

The *Plan* window of Location module for branch B2 shows the details regarding the alignments and horizontal curves as shown in figure 30 (for the complete plan of Branch B2 at real scale please consult *Chapter 9 – Appendix*).

In plan window the details of alignments, curves, culverts positioning and earth mass movements are easy to be identified at scale 1:2000 (see *Chapter 9 – Appendix*). The black line in this window represents the zero plane marked in the field and the red doted line represents the alignment of the road after adjustments in RoadEng have been made. Each curve has specified the starting and ending point, as well its center point and radius. A total of 29 curves where adjusted in *Location module – Plan window*, each one of them being marked on the plan.

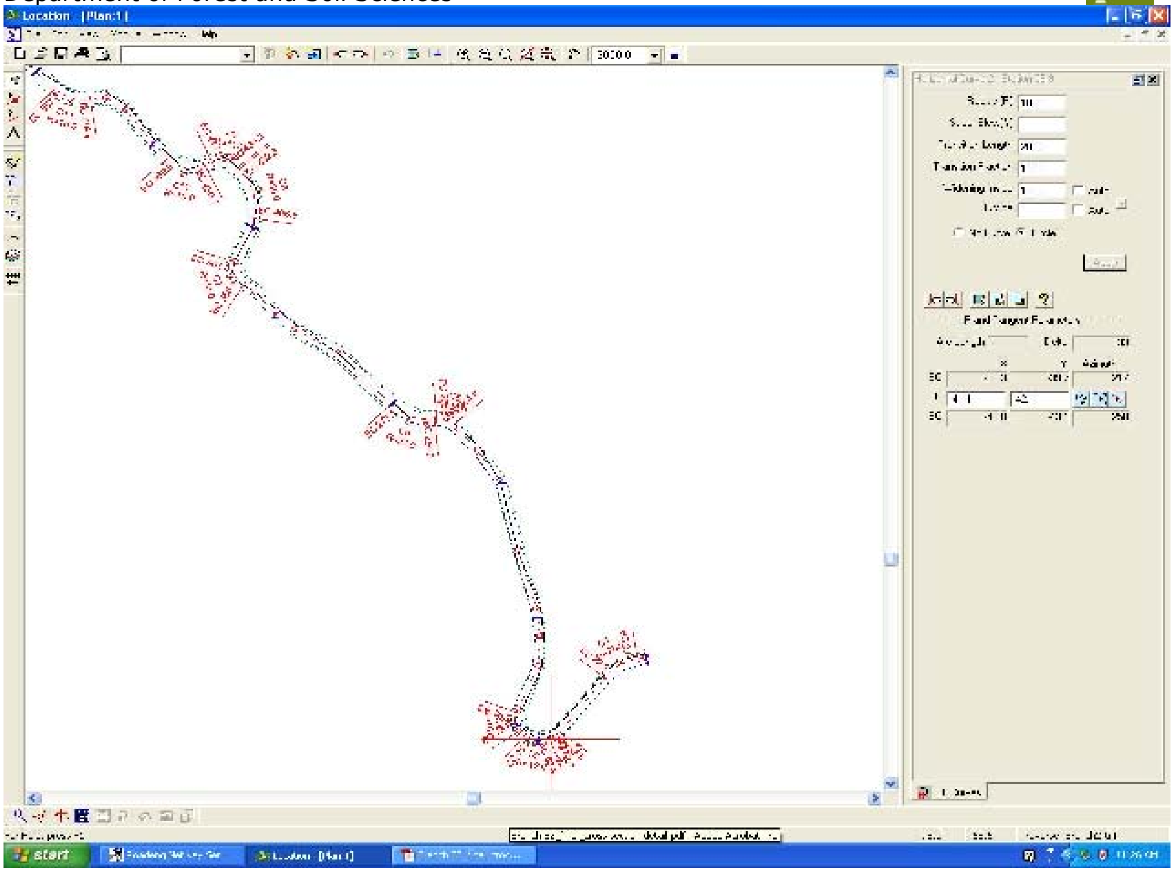

Figure 30 Snapshot of plan window for Branch B2 – Location module, RoadEng

Regarding longitudinal profile, one can notice that *Branch B2* has a decreasing profile up to Hm 4+02 where the road increases in altitude up to Hm 4+70 in order to avoid a big stony area (see Figure 31 and *Chapter 9 – Appendix* for details). The culverts position was also adapted to this, meaning that one 400 mm pipe was designed to be installed exactly in Hm 4+02 where a concave profile is being created due to the change in slope (from positive to negative). From Hm 4+70 the road continuously decreases up to Hm 16+69, where branch B2 connects with the main branch of *Trauch Forest Road Netwo*rk, in the vicinity of Geisstein Pass.

One other important result of RoadEng assessment is the data report of Branch B2 which provides detailed information regarding longitudinal and side slope gradients, direction, distance between surveyed points (stations), the positioning of curves and their radius and about the earth mass movements (see Figure 32 and *Chapter 9 – Appendix* for details).

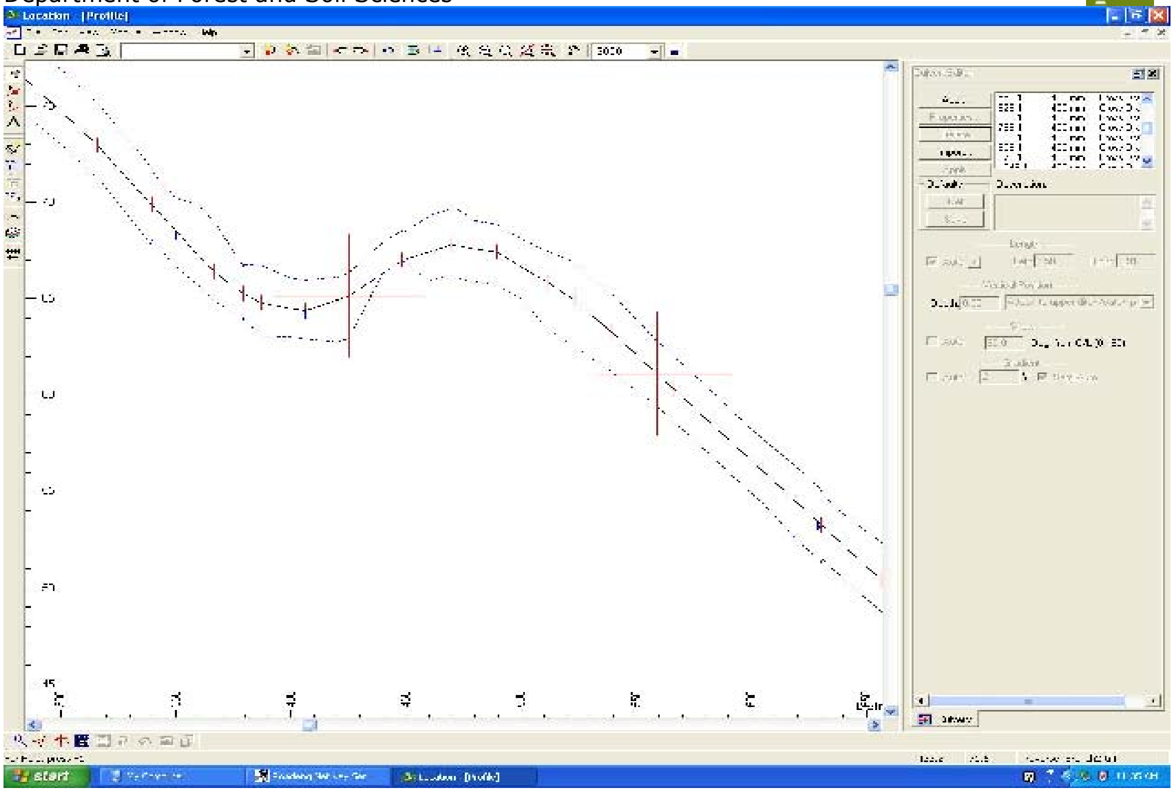

Figure 31 Snapshot of longitudinal profile of Branch B2 – RoadEng designing

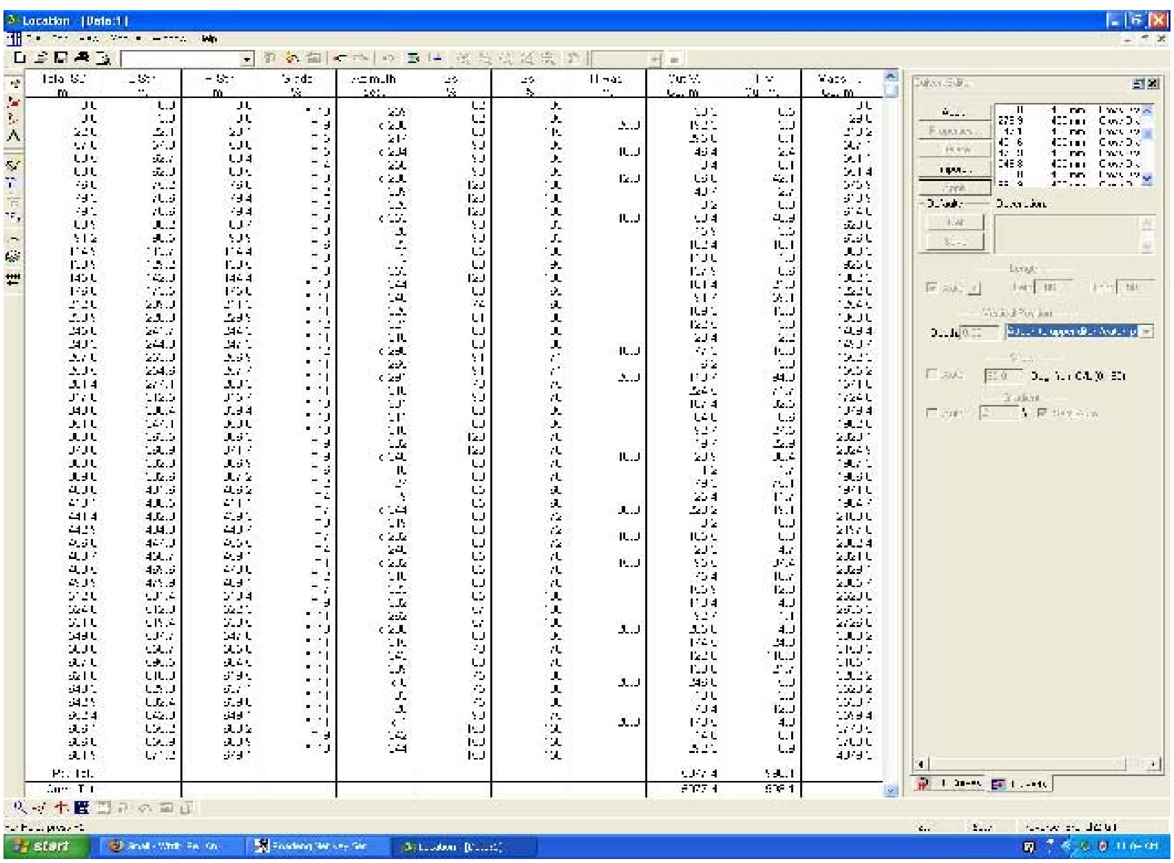

Figure 32 Snapshot of data window for Branch B2 – RoadEng assessment

The data included in this report represented the basis for the elaboration of the technical report (see *Subchapter 4.2.1 - Technical report*) as well as for the cost calculation assessment for Branch B2. The surplus material (7758 m^3) resulted from the mass movements is not equally distributed on the total length of the branch (see Chapter 9 – Appendix, *Branch B2-Data Report*), the most important surplus of material (5990 m^3) resulting from the first 1000 m of the branch. This is an expected outcome, if we take in consideration that this part of the road is the rockiest and the steepest one from the entire *Branch B2*. For this sector of the road, the project owner needs to establish intermediate deposits of surplus material at the road side. From these deposits, the rocks can be crushed using mobile crashing machines and used as gravel for realizing the carriageway (pavement) of branch B2 as well as for the other branches of the road network. The last 650 – 700 m of the branch B2 are more balanced from the point of view of mass movements, around 3450 m^3 resulting from cut profiles and half compensated by the necessity of around 1700 m^3 of fill profiles. Consequently, other intermediate places for the storage of surplus material (~1750 m^3) have to be established. In the same way, the surplus material can be later on used for paving the other branches or for road maintenance activities.

The assessment made using state-of-the-art RoadEng software has an essential importance for the successful achievement of the project objectives, as it provides sound details regarding type of cross sections, culverts, horizontal curves and longitudinal profile. These details also represent the basis for other assessments that have been done (e.g. technical report and estimative cost calculations).

In the end has to be pointed out that the detailed project for building *Branch B2* is included in *Chapter 9 – Appendix* and includes the following:

- Overview – Map of the project area (scale 1:20000, GIS)
- Data collection protocol (output from Survey/Map module – RoadEng Software)
- Plan of the Branch B2 – Steep & Rocky Area (scale 1:2000 – RoadEng Software)
- Longitudinal Profile (scale 1:500 vertical, 1:5000 horizontal – RoadEng Software)
- Cross sections of the surveyed points (scale 1:150 – RoadEng Software)
- Data report (output of RoadEng Software)
- Technical report (Subchapter 4.2.1)

The detailed project of *Branch B2 – Steep & Rocky Area* follows the Austrian requirements for the construction of a forest road and can be submitted to regional forest authorities for approval.

Chapter 5. CONCLUSIONS

The goal of the present project was to design a forest road network in Trauch Forest District from Wittgenstein Forest Administration in order to improve the access to the forest, to facilitate and promote the implementation of sustainable forest management activities, to reduce the actual harvesting costs and the risk of accidents among forest workers.

The forest road network designed has a total length of 17.11 km and consists mainly of forest roads conducted in the third upper part of the slopes. The main advantage of this fact is that the road building and maintenance costs are going to be cheaper than in the case of existing valley roads, due to the fact that the road network is not exposed at the risk of being eroded or damaged by the water course and spring/summer flooding. Therefore no important protection measures of the road bed are needed (e.g. concrete walls, dams, etc.). In the same time the increased road density and the opened access to the third upper part of the slope makes thinnings, tending operations and other forest management activities easier, cheaper and in safer conditions to be realized.

An important aspect to be mentioned is that the total value of the investments needed for the construction of the forest road network rises to approximately 573,500 €, amount which represents an important financial effort that the project owner has to support. Consequently, in order to make the project feasible also from the cash flow point of view, the project implementation was scheduled for a timeframe of 5 years (2009 till 2013, see *subchapter 4.1. - General Planning*), focusing on balancing as much as possible the investments made each year. The scheduling also gives the possibility to recover part of the investment costs before year 2013, by the opened access to sources of income such as the old stands that are in row for regeneration or final cuts, as well as by harvesting the trees which are in the alignment of the designed road.

The general planning provides sound information for the project owner to start building the road network. In the same time the cross sections, longitudinal profile and earth mass movement calculation resulted from the RoadEng detailed planning of the *Branch B2 – Steep and Rocky Area* (first branch in row to be built in 2009) provide even more details for the project implementation and can be a considered as model of level of detail in which the other forest road's branches (including main branch) could be designed. The project team member opines that detailed planning of the entire road network would be of essential importance for the construction phase, giving consistent and sound information regarding the cross sections, leveling and profiles that the constructor has to use. Nevertheless it is project owner's decision to continue or not this project with another one for planning in detail all other branches (15.44 km) using the state-of-the-art RoadEng designing tool.

Finally it can be concluded that the goals and objectives set up in the inception phase of the project (see *Chapter 1 – Introduction*) were fulfilled in integrity by designing the *Trauch Forest Road Network*.

Chapter 6. ABSTRACT

In Trauch Forest District from Wittgenstein Forest Administration, Hohenberg, Austria was identified an area of 401,20 ha of forest where the access is restricted, basically being insured only via valley roads. Besides the fact these roads are exposed to damages at an interval of 2-3 years by the snow melting and precipitation, increasing the costs of maintenance as such, the harvesting costs in this area are relatively high and forest management activities are difficult to realize due to restricted access to the forest.

In these peculiar circumstances, the project owner was looking for solutions to improve the current situation in the project area. The goal of the present master thesis was to design a forest road network in order to improve the access to the forest, to facilitate and promote the implementation of sustainable forest management activities, to reduce the actual harvesting costs and the amount of risk of accidents among forest workers. The main objectives were:

- To assess different possible alternatives for the new road network
- To open the access to the forests from the third upper parts of the slopes (possibility for using uphill cable yarding systems, harvester and forwarder)
- To elaborate a general planning for the whole road network
- To elaborate a detailed planning for the branch to be built in the first year
- To assess the construction costs of the road network and to schedule the project implementation for a period of 5 years (2009 – 2013)

The forest road network designed has a total length of 17.11 km, consists of one main branch (13.35 km) and four secondary branches (B1 – 0.75 km, B2 – 1.68 km, B3 – 0.32 km, B4 – 1.00 km), and is represented by slope forest roads conducted in the third upper part of the slopes. Therefore, no important protection measures of the road bed are needed (e.g. stonewalls, bridges, etc.). The designed road density in the project area is 42.77 m/ha and the designed road distance is 234 m. This is an optimum density for achieving the objectives set by the project owner and the goals of sustainable forest management.

The total value of the investments needed for building the forest road network is approximately 573,500 € (an average of 33.50 €/m), which represents an important financial effort for the project owner. Consequently, the project implementation was scheduled for a timeframe of 5 years (2009 till 2013), focusing on the priorities set by the project owner and on balancing as much as possible the investments made each year. The project owner can recover part of the investment costs before year 2013, by the opened access to sources of income such as the old stands that are in row for regeneration or final cuts, as well as by harvesting the trees which are in the alignment of the designed road.

The general planning provides sound information (e.g. marked zero line in the field, the data collection protocols, map with the situation plan of the road network and the construction cost calculation) for the project owner to start building the forest road network. Moreover, the cross sections, longitudinal profile and earth mass movement calculation resulted from the RoadEng assessment of the *Branch B2 – Steep and Rocky Area* provide even more details for the project implementation in the first year. The goals and objectives set up in the inception phase of the project were fulfilled in integrity by the elaboration of the Trauch forest road network planning.

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