Deliverable Number D.1.04

Technical Requirement Report

WP 1 – Definition of requirements and system analysis
Task 1.2 – Hardware and equipment definition

Revision: Final

Authors: Giulio Panizzoni, Daniele Magliocchetti, Federico Prandi, Martin Kuehmaier

Author name (Partner name): Graphitech, Boku

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Statement of originality

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<td>WP</td>
<td>Work Package</td>
</tr>
<tr>
<td>HMI</td>
<td>Human-Machine Interface</td>
</tr>
<tr>
<td>HCI</td>
<td>Human Computer Interaction</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>CG</td>
<td>Computer graphic</td>
</tr>
<tr>
<td>VR</td>
<td>Virtual reality</td>
</tr>
<tr>
<td>RFID</td>
<td>Radio frequency Identification</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>---------</td>
<td>----------------------------------</td>
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<tr>
<td>UHF</td>
<td>Ultra high frequency</td>
</tr>
<tr>
<td>HF</td>
<td>High Frequency</td>
</tr>
<tr>
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<td>Near Field Communication</td>
</tr>
<tr>
<td>FMS</td>
<td>Fleet Management System</td>
</tr>
<tr>
<td>OBU</td>
<td>Onboard Unit</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<td>GSM</td>
<td>Global System for Mobile Commun.</td>
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<td>GPRS</td>
<td>General packet radio service</td>
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<tr>
<td>CAN</td>
<td>Controller area network</td>
</tr>
<tr>
<td>FRC</td>
<td>Functional Road Class</td>
</tr>
<tr>
<td>SQL</td>
<td>Structured Query Language</td>
</tr>
<tr>
<td>PASW</td>
<td>Predictive Analytics Software</td>
</tr>
<tr>
<td>UAV</td>
<td>Unmanned Aircraft Vehicle</td>
</tr>
<tr>
<td>RTK</td>
<td>Real Time Kinematic</td>
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INTRODUCTION

The following document constitutes a reference for the hardware and software equipment detected in the first phase of the project among all the involved partners and recognized as the most suitable to achieve the objectives of the project. Considering the experimental and research nature of the project this list has to be considered as the main reference for the final platform deployment being aware that some requirements might change in the future.

The SLOPE system is very complex and composed by several different hardware and software components which communicate between them so a detailed analysis of the single part have to be carried out in order to full fill the project requirements.

The different parts can be classified in three main categories namely:

- Instruments and tools to collect forest information before harvesting;
- System to plan the harvesting;
- Instrument and tools to collect timber information during the harvesting;
- Instrument and tools for resources tracking;
- System to manage the harvested resources.

In the first category we can include all those HW/SW components for the forest survey including topographic survey (laser scanner, GPS) as well as remote sensing system (UAV, satellite). Measurement instruments, each with own specific characteristics that will be investigated during the WP2, are included in this category. Furthermore coupled with the instrument should be considered even the software system used to process the raw data. These software can be own or open sources and generally are used to extract useful information from images or point cloud information.

The second category includes the ITC solution supporting the harvesting planning including the localization of the area, the available timber and biomass stock and the cable crane installation simulation. The main purpose of this component is to access the information contained on the Forest Information System including the data provided by the abovementioned tools and perform a simulation of the harvest collection. This component will be defined on the system architecture and during task 2.5.

The third block is the core component of the SLOPE hardware. The intelligent processor head that will be designed and implemented during WP3 and WP4 composes it. In this document will be defined the system requirements of the
processor as well as of the all sensor that should be mounted on it. Furthermore the document will include the specifications of the systems for the information collection and for communication between the on field and remote components.

The tracking framework is constituted by the instruments and tools to ensure the identification of the trees starting from the marking propaedeutic the cut to the log sent to the sawmill. This includes the RFID tag, antenna and writer specification as well as the truck tracking system.

Finally the system for harvest resources is a software framework to manage the information collected on field about the log stock. The data should be made available via web for all the SLOPE users.

### 1.1 Organization of the document

The document is organized as follows: chapter 2 provides an overview of forest survey technological requirements, chapter 3 a specification of the forestry machine requirements, chapter 4 the requirements for monitoring and tracking technologies and finally chapter 5 provides a set of conclusions for the correct deployment of the slope platform.

### 1.2 Additional notes

Considering the delays encountered for the writing of the current document due to an inactivity of some partners in the first months of work package 1, it cannot be considered in its final version. For this reason a review is planned within 3 months from the delivery of the report in order to update it with potential new requirements coming after the definition of the system architecture.
2 Overview of supply chain processes and SLOPE hardware and equipment

The integration of all information that can be collected before and during the harvesting operation allows the analysis of tree and log characteristics and the traceability of the produced timber. The integration of all data in one single system is the key to analyse and provide with valuable information along the supply chain. The combination of the processes and the collected data will provide more valuable information, which can be used by the stakeholders along the supply chain to increase efficiency of the wood supply.

Figure 2-1: Supply chain processes in steep terrain

Figure 2-1 shows supply chain processes that are typical for timber harvesting in steep terrain. The trees are felled manually by chain saw. The extraction of the trees from the forest to the landing is executed by whole-length-method by a cable yarder. Processing includes debranching, crosscutting and sorting and is executed by an excavator with a harvester head. Transportation of the logs can be carried out by trucks or tractor and trailer. Harvesting residues are often chipped and also transported by trucks and container.

SLOPE includes some additional processes to provide information about terrain, trees and logs and to assure monitoring of the supply chain and the traceability of the wood flow (Table 2-1):
Table 2-1: Additional processes within the SLOPE scenario

| Characterisation of the terrain and forest inventory by satellite images, UAV and TLS |
| Characteristics of each log measured by laser scan and sensors |
| RFID tag on each tree |
| Tree by tree traceability must be kept and integrated into the platform |
| Harvester information updated on real time |

The processes of collecting data for the forest survey, marking the trees, felling, extracting and transporting are normally executed one after another. The information generated during this processes is also used for tracking the wood flow, which is a process that is executed permanently. To carry out all these processes, specific hardware and equipment is needed (Figure 2-2).

Each processed log will be measured and recorded on real time. A fixed RFID reader/writer integrated in the harvester head, a GPS receiver in the base machine (excavator) and a marking system in the harvester head. For demonstrating the SLOPE system forests dominated by Norway spruce will be selected.
Figure 2-2: Processes and hardware within the SLOPE supply chain
3 Forest Survey Technological Requirements

3.1 UAV: Technical Specification and typology of flight

Unmanned Aircraft Vehicles (UAV’s) come in a variety of shapes and sizes, developed by the military for reconnaissance purposes. Their use has spread to numerous industries from traffic management, crop management to search and rescue in extreme environments.

With their development comes the development of a variety of payloads from standard High Definition & Infrared cameras to NDVI (Normalized Difference Vegetation Index lenses).

These developments have enable the development of an accurate simple graphical indicator that can be used to analyse remote sensing measurements which previously were carried out from satellites with varying accuracies.

Key to the success of their development is the development of an Auto Pilot control system that can be operated in conjunction with standard VRS GPS surveying systems or with RTK (Real Time Kinematic) systems transmitting signals over the UHF radio band. Furthermore key to their success is safety whilst operating in airspace populated by civilian and military traffic.

Governments throughout the world have set limitations on size, engine power, weight, payload weight, and the altitude at which civilian UAV’s UAS’s can be operated.

Restrictions also require the operator to be trained to a high level and to issue a flight plan to the local or national Air Traffic Controller.

Forestry will benefit massively from UAV development as large areas can be surveyed from a single location delivering numerous data streams from topographical survey data to soil erosion and plant health data.

The current method of surveying forestry involves counting and marking trees whilst trekking through the forest on foot, this process is slow and time consuming especially in mountainous areas as access is always a problem where no roads or trails exist.
Coastway have chosen a lightweight UAV that is suitable for use in mountainous areas, it is launched by hand carries a variety of payloads and can fly in winds up to 30kmph.

The UAV fail-safe includes a transponder which emits a radio signal should it taken by the wind or encounter mechanical problems.

### 3.1.1 Aircraft Technical Description

#### 3.1.1.1 Manufacturer information
Sensefly is an offshoot of the Laboratory of Intelligent Systems at EPFL - an organization at the cutting edge of research into collective aerial robotics, vision-based flight control for mini UAV and smart locomotion.

- Incorporated end of 2009
- Autopilot, Airframe and Software development and production
- Leading Technology in miniature Autopilot Systems (Prof. Dr. Dario Floreano of the EPFL LIS is one of the company founders)
- Web Address: http://www.sensefly.com

#### 3.1.1.2 Designation and Type

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<td>The Grainstore Singleton Way Bagenalstown Co. Carlow Ireland</td>
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<tr>
<td>Manufacturer</td>
<td>Sensefly Ltd</td>
<td>Sensefly LLC Route de la Brûlée 4B 1024 Ecublens Switzerland</td>
</tr>
<tr>
<td>Distributor</td>
<td>Korec</td>
<td>Precise Construction Instruments T/a KORECB7 Riverview Business Park Nangor Road, Dublin 12 Ireland</td>
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<td>Airframe Model</td>
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### 3.1.1.3 AIRCRAFT, CONTROL SYSTEM AND COMMUNICATIONS SPECIFICATION

#### Table 3-2: UAV technical specifications

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<td>Length</td>
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<td>Weight</td>
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<td>Battery</td>
<td>3-cell Lithium-Polymer</td>
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<td>Capacity</td>
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<td>Endurance¹</td>
<td>Approx. 30 minutes</td>
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<td>Range²</td>
<td>Up to 20 km</td>
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<td>Propulsion</td>
<td>Electric brushless motor</td>
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<td>Nominal static thrust</td>
<td>0.45 kgf (4.4 N)</td>
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</tr>
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<td>Flight speed</td>
<td>Nominal cruise speed: 10 m/s</td>
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<td>Communication link³</td>
<td>35 MHz, range: approx. 1 km (s/n: up to SC-03-xxx)</td>
<td>2.4 GHz, range: approx. 1 km (s/n: SC-04-xxx and higher)</td>
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<td>Telemetry Link / Radio Modem</td>
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<td>MAC: 0013A200408D7BE9</td>
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<td>ISM 2.4 GHz operating</td>
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<td></td>
<td>250Kbaud rate</td>
<td>60mW (18 dBm) 100mW EIRP</td>
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<tr>
<td></td>
<td>power output</td>
<td>RS-232 interfacing port,</td>
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<tr>
<td></td>
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<td>or, USB interface port</td>
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<tr>
<td></td>
<td></td>
<td>RPSMA antenna connector</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industrial (-40° to – 85° C)</td>
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<td>Data:</td>
<td>2.4 GHz, range: approx. 1.5 km</td>
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<tr>
<td>Navigation</td>
<td>up to 20 waypoints</td>
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<tr>
<td>Photos</td>
<td>up to 5 photo locations</td>
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<td>Ground Station Type</td>
<td>Active</td>
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<td>Payload</td>
<td>Cannon Ixus 220 HS</td>
<td>Effective Pixels Approx. 12.1M</td>
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<td></td>
<td></td>
<td>Focal Length 4.3 – 21.5 mm</td>
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<td>(35 mm equivalent: 24 – 120 mm)</td>
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<td></td>
<td></td>
<td>Zoom Optical 5x.</td>
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<td></td>
<td></td>
<td>Operating Environment 0 – 40</td>
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<td></td>
<td></td>
<td>°C, 10 – 90% humidity</td>
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<td></td>
<td></td>
<td>Dimensions (WxHxD) 92.2 x</td>
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<td></td>
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<td>55.9 x 19.5 mm</td>
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<tr>
<td></td>
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<td>Weight Approx. 141 g</td>
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<td><strong>Endurance</strong></td>
<td><strong>Range</strong></td>
<td><strong>Range</strong></td>
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<td>Endurance can vary greatly depending on external factors such as wind, altitude change and temperature.</td>
<td>Range can vary greatly depending on external factors such as wind, altitude change and temperature.</td>
<td>Range of communication can vary greatly depending on external factors such as cruise altitude, presence of obstacles and radio-frequency interferences.</td>
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Figure 3-1 Sensefly Ebee UAV
3.1.1.4 EMOTION2 (SOFTWARE) MINIMUM REQUIREMENTS

Table 3-3: Hardware requirements of the base station

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</tr>
<tr>
<td>Hardware</td>
<td>1 GHz processor, 1 GB RAM</td>
</tr>
<tr>
<td>Free space</td>
<td>500 MB</td>
</tr>
<tr>
<td>Screen min. resolution</td>
<td>1280_900 (1024_768 with the compact cockpit)</td>
</tr>
<tr>
<td></td>
<td>Visible outdoors</td>
</tr>
</tbody>
</table>

3.1.1.5 OPERATING LIMITATIONS AND CONDITIONS

Table 3-4: Operating limitations

<table>
<thead>
<tr>
<th>Item</th>
<th>Limit</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Ceiling</td>
<td>15,400ft</td>
<td>Maximum Take-off altitude + 400ft at MTOM or other stated</td>
</tr>
</tbody>
</table>
### 3.1.1.6 Data Acquisition requirements

3D reconstruction from images of the forest canopy is difficult due to the repetitive texture of the canopy, and leaf and branch movement, this greatly effects the process of matching trees in scans and aerial imagery. Here are listed some operational requirements in order to ensure suitable results from the survey.

#### Table 3-5: Operation requirements to be followed during the data acquisition

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Operational Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Endurance</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Maximum Speed</td>
<td>36kmh or 19.4kts</td>
</tr>
<tr>
<td>Maximum Wind Speed</td>
<td>25kmh or 13.5knots</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>0-40 deg C</td>
</tr>
<tr>
<td>Maximum Flight Length</td>
<td>10 km maximum distance (go and back)</td>
</tr>
<tr>
<td>Radio Lock Maximum Range</td>
<td>Up to 2km range of radio lock to UAV than autonomous mode</td>
</tr>
<tr>
<td>Other Manufacturer Restrictions</td>
<td>Does Not fly in the rain</td>
</tr>
</tbody>
</table>

The UAV will be flown in low wind conditions.

High amounts of image overlap (at least 70% frontal overlap and 85% side
Must be flown high, as this improves the results as it reduces the visual complexity of the canopy.

Must be flown at a constant height above the canopy especially on mountain sides or steep slopes.

Visible ground survey control must be spread evenly throughout the survey area.

Data recorded will be combined with LiDAR data recorded by laser scanners at ground level in the test areas.

- Areo Triangulation is carried out by the software for each Tie Point by the means of Bundle Block Adjustments
- Bundle Block Adjustments compute the tie point position and camera position and orientation.
- Multiview dense matching operates on each pixels and results in a dense point cloud being created
3.1.2 Forest Survey Mission Planning

In a simulation of the survey we used a combination of traditional GPS surveying & Laser Scanning and Aerial Mapping using the UAV and were joined by Treemetrics.

Surveyors placed 23 no. ground targets around the forest and recorded the GPS coordinates of each point; several Surveyors commenced laser-scanning stands of trees approximately 100mx100m in size to help create a digital terrain model (DTM), a Digital Surface Model (DSM) and a digital canopy model (DCM).

The UAV Pilot and Commander made their way to a mountain top located approximately 1km from the laser scanning sites, communications were maintained by radio at all times. EMotion 2 Software was used by the pilot to locate the forest stand on a tablet device.

The recorded coordinates of the 23no. Targets were entered into the software and a safety flight buffer zone placed approximately 500m around the outside of the survey area. The safety buffer zone is used as a return to base barrier should the UAV be taken off course by the wind.

Wind Speed to be taken into account when scanning if above 10km at ground level blurring will occur in point cloud. The wind at test flight time was over 30km per hour so the pilot was placed on standby as he did not receive flight clearance from Air Traffic Control in Dublin.

The wind dropped, all Surveyors and Spotters were informed by the Commander that the flight was about to begin.

Take off, flight duration 45minutes.
Several test flights/emergency landings/loss of control/ and find the UAV scenarios were practiced.

In the table below are reported the characteristics of the mission:

**Table 3-6: Technical specification of the flight**

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take-off weight</td>
<td>630g</td>
</tr>
<tr>
<td>Wingspan</td>
<td>96cm</td>
</tr>
<tr>
<td>Wind resistance</td>
<td>Up to 45km/h</td>
</tr>
<tr>
<td>Cruise speed</td>
<td>36 – 57km/h</td>
</tr>
<tr>
<td>Camera</td>
<td>16MP (RGB or NIR)</td>
</tr>
<tr>
<td>Radio coverage link</td>
<td>Up to 3km</td>
</tr>
<tr>
<td>Coverage</td>
<td>1-10km²</td>
</tr>
<tr>
<td>Landing</td>
<td>Hand launched</td>
</tr>
<tr>
<td>Other</td>
<td>On board data logging</td>
</tr>
</tbody>
</table>

**Table 3-7: Operational characteristics of the test flight**

- Flight Planning completed on eMotion Software
- Pre-Flight checks by Pilot & Commander
- Second Landing zone identified as backup
- 80% overlap of images required
- Wind Speed to be taken into account
- Spotters and Back up equipment tested
- 45 minute Flight Time set up to cover the forest
- Ground crews sent to the forest
- 23no. Targets used over 3km of forest
<table>
<thead>
<tr>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS Target marked in forest clearing</td>
</tr>
<tr>
<td>Regular Radio checks with all team members maintained.</td>
</tr>
<tr>
<td>Surveyors in the forest act as spotters during the flight</td>
</tr>
<tr>
<td>Local property and land owners informed of the survey teams presence</td>
</tr>
<tr>
<td>Contact with Air Traffic Control for flight clearance maintained due to the</td>
</tr>
<tr>
<td>overhead flight corridor for commercial flights.</td>
</tr>
<tr>
<td>Wind speed over 30kmph / flight set to standby</td>
</tr>
</tbody>
</table>

### 3.2 Ground LiDAR for Forest Survey

The laser scanner predominantly used by TreeMetrics is the FARO Focus 3D. This lightweight (5kg) portable laser scanner collects a hemi-spherical scan with approximately 40 million data points in 3.5 minutes with a file size of approx. 145MB at its default setting. It contains its own battery supply, which will provide enough power for 8hrs working. A replacement battery can be inserted for longer working periods.

The scanner is operated by a user-friendly touch-screen interface and data is stored on a removable SD card. Each scan is given a unique ID with a date and time stamp. This method facilitates easy data transfer from the operator to TreeMetrics processing servers.

![Figure 3-4: Terrestrial Laser Scanner](image-url)
This scanner works on a phased shift method, which means that it analyses the wavelength of the laser beam to generate a 3D point cloud. The TLS can record information to 70m in distance but the general maximum radius plot used by TreeMetrics is 15m.

![Figure 3-5: Image of a Terrestrial Laser Scan](image)

The default settings on the scanner for forest inventory are ¼ resolution and 2x quality. This provides a laser point reading every 6mm at a 10m distance from the scanner. For timber taller than 30m it is recommended to increase the resolution setting to ½ resolution and 2x quality. This setting provides laser point readings every 3mm at 10m distance.

Upon completion of each scan the scanner stores the scans onto a removable SD card. This is similar to that on any digital camera. To download these scans the SD card is removed from the scanner and connected to a PC or laptop. A directory opens up on the PC with a folder displaying the scans by their unique ID. A batch file transfer is activated and automatic download from the SD card to the PC takes approximately 20 sec per scan. This should be done at the end of each day to ensure good work practices. The specific scan number ID’s assigned to each scan makes it easy to match the relevant scan with a particular plot location.

The AutoStem Forest™ software developed by TreeMetrics can process data from any terrestrial laser scanner currently on the market.

AutoStem Forest™ is an innovative software product developed by TreeMetrics, designed to detect and create a 3D profile model of each tree from Terrestrial Laser Scanning (TLS) scan data Figure 3-6. It is the first system in the world that automatically measures stem straightness and individual stem taper.
Figure 3-6: TreeMetrics 3D Stemfile

AutoStem Forest™ provides accurate stem information for hundreds of stems in a forest stand that can be used to estimate the actual status of the stand and provides compelling data for forecast and growth models. AutoStem Forest™ software developed by TreeMetrics operates under different forest conditions to accurately capture pre-harvest timber measurement data. Collected field data is analyzed using this automated, which uses each tree shape to estimate the tree volume and timber products (saw log, pallet, pulp and waste).

This individual tree data is combined with remote sensing information to estimate the total volume and products included in each stratum. The field survey data can also be used to update the remote sensing information. Additionally using high density ALS data, models based on single tree methods could be applied to determine each individual tree volume and products based on the relationship between TLS estimations and ALS parameters.

**Technology Description of TLS:**

TLS is based on Light Detection and Ranging (LiDAR), and is an active system whereby laser pulses emitted by the sensor are used to scan the surface of surrounding objects in a raster-wise manner, Figure 3-7. A laser beam is emitted from a laser light source and when it finds an object or surface in its trajectory, the beam is reflected back to the scanner. The time taken for the beam of light to return back to the scanner depends on the distance of the object.

The angle of laser pulse emission and reflection, together with the time between laser pulse emission and return are used to record highly accurate X, Y and Z coordinates for each point of reflection. The accuracy of distance measurements depends mainly on the intensity of the reflected laser light and therefore directly on the reflectivity of the object surface. Distance is automatically calculated as the half of the total time between pulse emission and pulse detection by the speed of light.
Distance = 0.5 \* t \* v

**Distance:** The distance from the scanner to the object

T: Total time between pulse emissions and pulse detection

V: The speed of Light

The intensity value is a measure of the return signal strength. It measures the peak amplitude of return pulses as they are reflected back from the target to the detector of the LiDAR system. Intensity values are relative rather than absolute and vary with the distance to the sensor, atmospheric conditions, directional reflectance properties, and the reflectivity of the target. Because these values are relative, the process of creating images from vector intensity data requires the exercise of judgment.

Sometimes a beam could be partially reflected on a surface (e.g. object edge and border), some instruments are capable of measuring multiple returns or even the full waveform of the reflected pulse. This property is very important in Airborne Laser Scanning (ALS), where the beam footprint can be large.

A larger number of beams are emitted by a TLS system. This is achieved using a moving mirror (sweeping and rotating) that reflects the laser beam. Scan swath width depends on the mirror’s angle of oscillation, and the number of points collected depends on speed and mirror oscillation rate. About 40 million reflection points can be collected in a 360° scan, collectively referred to as a point cloud.

![Figure 3-7: LiDAR operation scheme](image)

A 3D image from LASER is projected in one-color, using the intensity values it is possible to obtain gray-scale image where the objects can be recognized. Additionally, the latest TLS devices have an integrated camera that allow it take pictures in multispectral bands (RGB) and afterwards colorize the point cloud data. This is a revolutionary development that enables new analysis such as the potential for species recognition.
4 Harvesting Planning System

The harvesting planning system should be able to manage and presents all the information needed by the forest operator for the management of the harvesting operation. This information include all the relevant geographical information (slope, road, cadastral) as well as the 3D information model collected and generated using the technologies described on chapter 2.

Table 4-1 Requirements of the harvesting planning system

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>To visualize the 2D map of the area of interest.</td>
<td></td>
</tr>
<tr>
<td>To access the OCG web services provided by SLOPE platform.</td>
<td></td>
</tr>
<tr>
<td>To access the Forest Information System data for a selected area.</td>
<td>Visualizing the information about full forest inventory estimation, including graphs, pie diagram etc.</td>
</tr>
<tr>
<td>To identify road and landing area for a selected harvesting zone.</td>
<td></td>
</tr>
<tr>
<td>To visualize the 3D model of a selected harvesting area.</td>
<td>The system should visualize a 3D model of the forest, visualizing trees by trees features as produced by the combination of chapter2 surveys.</td>
</tr>
<tr>
<td>To access to available information of each single tree</td>
<td>The system should access to the forest Information system retrieving the single tree information (species, height, diameter etc.)</td>
</tr>
<tr>
<td>To highlight the trees marked for the cut</td>
<td>The system should be able to highlight the selected tree based on the tree ID</td>
</tr>
<tr>
<td>To simulate the installation of a cable crane corridor</td>
<td>The system should be allow the insertion of the cable crane features and visualize a virtual model of the cable crane.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------------------------</td>
<td>-----------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>To evaluate the size and location of potential landings.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>To estimate the total amount of timber to be harvested.</strong></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4-1 Example of 2D paper map of a forest area of interest.
5 Hardware Forestry Machine Specification

5.1 Harvester Head

5.1.1 Requirements

The integration of all information that can be collected during the harvesting operation will allow for the analysis on log characteristics. The integration of all data in one single system is the key to analyse and provide with valuable information along the procurement chain. The combination on the described data will provide more information and that information we will have to decide how and which information is transferred (Bluetooth, wireless, by colour marking, print, USB, other...).

In the following table are instead listed some of the Working assumptions in the SLOPE scenario:

<table>
<thead>
<tr>
<th>Table 5-1: Harvesting head working assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics of each log</td>
</tr>
<tr>
<td>RFID tag on each tree</td>
</tr>
<tr>
<td>Tree cut by chainsaw</td>
</tr>
<tr>
<td>Whole length transport by cable to a landing zone</td>
</tr>
<tr>
<td>Landing zone with Excavator + Harvester Head</td>
</tr>
<tr>
<td>Tree by tree traceability must be kept and integrated into the platform</td>
</tr>
<tr>
<td>Harvester information updated on real time</td>
</tr>
<tr>
<td>Tree species is Norway spruce</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 5-2: list of requirements for the intelligent head processor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each processed log will be measured and recorded on real time.</td>
</tr>
<tr>
<td>A fixed RFID reader/writer integrated in the Harvester Head</td>
</tr>
<tr>
<td>GPS receiver in the base machine</td>
</tr>
</tbody>
</table>
Marking system log by log

Base machine logs

For instance for that Scenario the possible combinations Kesla Harvester Head + Base machine are:

A.1. Kesla 25RHS-II + Excavator

Figure 5-1: Kesla 25RHS-II + Excavator

Table 5-3: Excavator requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>14 to 17 Tones</td>
</tr>
<tr>
<td>Oil Pressure</td>
<td>210-240 bar (3045-3480 PSI)</td>
</tr>
<tr>
<td>Oil Flow</td>
<td>170-210 l/min (45-55 rpm US)</td>
</tr>
<tr>
<td>Engine Power</td>
<td>60-85 kW (80 – 115 hp)</td>
</tr>
</tbody>
</table>

A.2. Kesla 25RHS-II + Rubber wheel
Table 5-4: Excavator Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight from 13 to 20 Tones</td>
<td></td>
</tr>
<tr>
<td>Oil Pressure</td>
<td>210-240 bar (3045-3480 PSI)</td>
</tr>
<tr>
<td>Oil flow</td>
<td>200-250 l/min (53-66 rpm US)</td>
</tr>
<tr>
<td>Engine power</td>
<td>75-100 kW (100 – 135 hp)</td>
</tr>
</tbody>
</table>

Equipment Limitations for modifications introduced in the Harvester head:

- Size
- Weight
- Protected against Shock
- Protected against Dirt
- Protected against Moist
- Protected against High temperatures
- Protected against Vibrations

5.1.2 Harvester Heads

At present over 20 manufacturers of commercial processors are active in the world, mainly in Sweden and Finland, the remaining located in other EU countries, USA, Canada and New Zealand. The models, over 60, differ for size (maximum diameter of the log), type of prime mover (dedicated machine or multiple machine such as excavators or tractors), cutting system and other aspects.
One of the main differences among processors is the feeding system, meaning the method for dragging the tree into the debranching knives embrace. Two main systems are in use: rollers and stroke movement.

- Rollers (or crawler tracks) are by far the most common system, being fast and reliable. With this system, the rotation of the teethed rollers makes slid the tree into the processor, debranching the plant. An additional rolling sensor measures the length, in order to cross-cut at the desired final log size. This method proved often unreliable in measuring the length of alpine trees, since the resistance of the bigger branches leads the processor to slip on the bark.

![Figure 5-3: Example of Rollers processor head](image)

- Stroke movement, is less common being slower and for this reason less productive. Nevertheless stroke processors are more simple, light and require less hydraulic pressure, thus being adaptable to relatively inexpensive and smaller prime movers.
The former partner Kesla manufactures both roller and stroke processors, thus the choice was open to the two working systems. Theoretically a stroke processor could be more suitable for the purpose of SLOPE, because it could be better adapted to isolate the delimbing resistance and determine the branch index, nevertheless the Kesla 25 SH operates moving the whole tree in the stroke movement (similar to roll processors), thus the hydraulic resistance is related to an excessive number of factors (branches, weight of the tree, inclination, friction with ground) and due to the variability of working conditions it would be almost impossible to isolate the resistance due to branches.

The analysis focused first on the few manufacturer providing stroke processors for the abovementioned potential benefits. The survey over 22 makers worldwide highlights that just two makers provide stroke processors: Arbro and Tapio, both Finnish.
The products of the first manufacturer, ARBRO, seem to be particularly suitable for the purposes of SLOPE. Both stroke models, the ARBRO 400 S and 1000 S, feature a stroke movement opposite to that described for the Kesla 25 SH: the processor body holds firmly the tree, kept still, and the debranching arm moves forward. With this system the factors determining the hydraulic demand (the resistance to advance) are the density/size of branches and the friction of the knives against the bark. Those two factors are relatively easy to identify and disaggregate, allowing for an effective definition of the “branch index” as hydraulic effort (by mean of a sensing hydraulic valve in the distribution system).
Working coupled with a cable crane the stroke processor may present further benefits:

- The absence of rollers, makes easier to use the very processors for a first rough piling of timber, thus this machine could use the idle time to organize the stacks of different commercial classes;
- The lower productivity compared to roll processors is not influent, since the extraction of trees by cable crane is relatively slow. On the contrary, roll processors under this conditions present higher idle time than stroke processors, furthermore stroke processors can perform the same activity (process trees of the same diameter) requiring smaller prime movers compared to roll processors. This means lower fixed and variable costs and a much lower overall operative cost for the simpler stroke machines (Magagnotti et al. 2012);
- The relatively simple structure and electronics (already capable of measuring length and diameter) is particularly suitable for the modifies and integrations foreseen in SLOPE (WP3 and WP4). The more complex and performing control systems installed on most of processors, such as Motomit installed on Kesla (www.en.productsupport.tarjoaa.fi) and Epec (www.epec.fi) are much more troublesome to modify or integrate. Furthermore software generally does not belong to the processor producer but to a third company, which in previous experiences of SLOPE partner Treemetrics proved always unavailable to modify the program or provide access to the script.

Under these premises the ARBRO 1000 S is regarded as the most suitable machine for the development of the project (tasks 3.4, 4.1, 4.2, 4.3 and 4.4). The operative capacity (maximum tree diameter 45 cm) is somehow close to the lower limit, meaning that the
machine cannot handle mature spruce trees from close-to-nature silviculture. It will be still possible to test the system in commercial harvest operations by choosing accordingly the demonstration site(s). In fact the system proposed will be capable of coping with about 80% of the plants typically extracted in the Alpine forest operations. Furthermore, if necessary in a following commercial phase, it will be rather straightforward to upscale the prototype processor to a larger size capable of handling larger trees.

Figure 5-7: The processor will not modify in its structure, but several sensors will be installed on the existing frame as shown in the picture.

The processor is designed for being installed on the boom of excavators, farm tractors, forwarders or small sized forester harvesters. Minimum hydraulic requirements of the prime mover are shown in table 8. The installation requires a rotator joining the head to the boom and wiring connecting the processor to the cockpit where CPU, interfaces and controls are installed.

**Table 5-5: Technical requirements of the ARBRO stroke processor models**

<table>
<thead>
<tr>
<th>ARBRO Harvesting head specifications</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>400S</td>
<td>1000S</td>
</tr>
<tr>
<td>Weight</td>
<td>330 kg</td>
<td>450 kg</td>
</tr>
</tbody>
</table>
Max. opening of delimming knives | 730lbs | 990 lbs.  
---|---|---  
360 mm | 450 mm  
14.2" | 17.7"  
430 mm | 550 mm  
16.9" | 21.7"  
Number of knives | 4 (3 moving ones) | 4 (3 moving ones)  
Feed Force | 22kN | 34kN  
4900lbs | 7800lbs  
Saw Bar Type 404" | 16" | 20"  
Oil Flow required | 45-80l/min | 80-120l/min  
Oil pressure nominal | 175 bar | 180 bar  
2500 PSI | 2600 PSI  
Deliming speed | 0.3-0.5 m/s | 0.3-0.5 m/s  
Carrier weight | 6-8 ton | 8-12 ton  
Saw motor | F11-5 | F11-10/F11-19**)  
Stroke | 660 mm | 660 mm  
Measuring Options | Length, Length & Diameter  
**| optional  

Pilots will be designed and planned accordingly, focusing on stands with an average diameter not exceeding a DBH value of 50 cm, thus allowing full operative demonstration of the system. For future commercial development very likely the ARBRO 400 and 1000 models would be integrated with a further machine (different just for the size) capable of handling trees with a diameter up to 55 cm, thus providing a full coverage of the operative requirements and the market demand. Offering the same processor type in several models differing basically for the size is the typical commercial strategy of most makers.

### 5.1.3 Control systems

**SYSTEM ARCHITECTURE**

It is possible to use sophisticated control systems such as Motomit (www.en.productsupport.tarjoaa.fi) and Epec (www.epec.fi). The first system is also adopted by Kesla for its processors. These system feature functions such as bucking to value, priority bucking, volume calculation and operator-specific settings.
In alternative due to its structural simplicity and operability (e.g. closed-center valves) it is possible to operate the processor with simpler control systems such as IFM hardware with Eco mat-mobile or Codesys software. Using this programming system the company developed its own control system for the process automation (with no bucking optimization, just adjustable cut length).

The owner has expressed the willingness to collaborate with the SLOPE project by providing the original program installed in the processors as open script. Thus, the software would be available as a starting point for the development of a more complex control software integrating the inputs provided by the FIS and the quality sensors foreseen by SLOPE.

In order to integrate the control system for the machine and sensors operability, as well as the inputs provided in a unique hardware platform, the IFM Central Processing Unit (CPU) will be substituted by a National Instruments CPU.

Figure 5-8: Concept of the data flow between SLOPE system components.

The whole control system of the SLOPE forest hardware is presented Figure 5-8 in and consists of:

1. The smartphone/tablet of the forester; marking the tree, inserting RFID tag and providing first information related to the tree quality into database. The data are downloaded to the central server at home of the
forester by means of home network (Wi-Fi, Bluetooth) and ADSL connection

2. The smartphone/tablet of the forest worker; cutting the tree, inserting RFID tags in case of cross cutting, and optionally providing information related to the tree/log quality into database. The data are downloaded to the central server at home of the forest worker by means of home network (Wi-Fi, Bluetooth) and ADSL connection.

3. The information extracted by Treemetrics are downloaded to the central server from the company office after processing raw data.

4. The Techno of Graffenberg is equipped with its own control system adapted for the SLOPE project by additional sensors (RFID reader, load cell). The custom system communicates with the central computer installed on the processor. The data are transmitted by using WiFi and are stored in the database.

5. The track may be also communicating with the central computer by means of WiFi. It may be necessary in case if the weight of logs can be measured while loading truck (in order to unable estimation of the green biomass quantity).

6. The central server stores all the proceeding data related to the log quality and provided by means of all operations. It is communicating with the central computer installed on the processor by means of cellular phone network or read the data from a backup hard disk uploaded by the processor operator before work.

7. The “black box” is a backup system storing all data (including optionally raw images, quality indicators, etc.). The hardware is composed of hard disk, to be connected with internet every day after work in the forest in order to download data to the central server.

8. The control system of the processor head is most complex and will be described in more details as follows:

   The control system of the prototype processor head may be:

   A. Hybrid of the standard control system provided by the processor head producer and quality grading (optimization) control system developed within WP4. In that case the communication between both systems may be necessary in order to assure safe operation of scanning (stopping all processor activities during scanning phase) as well as providing some log characteristics (such as diameter and length). The schematic of such configuration is presented in Figure 5-11.

   B. A unique control system supervising both kinematics of the processor head and scanning module. The schematic of such configuration is presented in Figure 5-10.
Figure 5-9: Schema of the processor head control system in scenario A (separate systems for controlling kinematics of the machine and quality of logs)

Figure 5-10: Schema of the processor head control system in scenario B (unique systems for controlling kinematics of the machine and quality of logs)

The solution A is relatively easy for implementation as no integration in to control of machine kinematics is necessary. The only troublesome may be related to the connection of both control systems. However, assuming ARBRO processor head as a SLOPE choice, it will be possible to edit the control system software as the source code will be available. The transmission protocol is unknown at this
moment. Even if the simplicity of scenario A is a great advantage, there are several important constrains:

- Impossible to automate of the log optimization
- The user interface requires several displays in order to project all important data
- Impossible to interact to the process kinematics while processing logs
- Two independent software codes necessary for full operation

The preferred solution is scenario B, where single control system manages the kinematics of the processor head (set of hydraulic valves), signals from standard sensors installed on the processor head (ex. encoders, proximity sensors) as well as all sensors developed within SLOPE WP4 quality grading system. Single software code will be necessary in that case, allowing real-time control and simple integration of all electronic/mechanic components. The signals transfer (both input and output) will be managed by dedicated modules to be selected on the base of the final technical requirements and selected sensors characteristics.

The software environment recommended for development of the control system is LabView. It allows simple code development including implementation of sophisticated data processing algorithms and decision making expert systems. It is possible to use same real-time environment and combine the whole set of tasks, including reading input from sensors/controllers/keyboard/joystick, pre-processing of signals, signal analysis/processing, decision making and sending commands to actuators. It is also important to mention that the system abovementioned allows analysis not only analog/digital signals but also images of various types to be implemented in the prototype. Finally, the system may be upgraded by means of WIFI (and/or GPRMS) module(s) simplifying integration of the software with other instruments/machines.

Consequently to the choice of software platform, it is recommended to apply the hardware solution provided by National Instruments. Several options are available here including CompaCrio, CompactDaq\(^1\) + PC, industrial PC + extension PCI boards, PXI. The final solution should be selected on the base of detailed description of the input/output configurations, computational power required and cost.

\(^{1}\) More details regarding the software and hardware can be found in the website www.ni.com.
5.1.4 Harvesting Head Analysis Equipment

The User requirements (task 1.1) as well as hardware and equipment definitions (task 1.2) are the base for appropriate selection of necessary sensors and to start the purchasing process for task 3.4.

The development of the intelligent processor will imply the installation of several sensors, as planned in the DOW of the project. Possibly not all of the tested sensors will be installed in the final prototype, but all of the proposed will be considered and, in case of overlapping of information provided, contrasted for the best ratio quality-of-data/cost-reliability.

Figure 5-11: Overall view of the processor with the positioning of sensors and additional elements (such as the RFID tag stapler).

The following set of sensors and related complements (cables, computers, etc.) are foreseen for the development of the processor:

1) The new actuator bar for scanners scanning the cross section of log
2) Chain sawing module for sensing cutting forces and optimization of the cross-cut
3) Feed power sensor
4) Camera/3D vision sensor
5) Colour camera(s) scanning side of the log
6) Ultrasound stress wave velocity scanner
7) RFID reading system
8) Data fusion/control unit
A brief description of the above modules is presented as follows:

Ad #1: It is proposed to develop a scanner bar 🚀 hosting the selected sensors, to be later integrated within log grading/optimization system developed within WP4. The kinematics of the bar will be very simple and similar to that of the chain saw🪓. The additional parts will include encoder (monitoring the rotation angle of the bar), control system (integrated with control unit #7). The challenge is to develop a robust structure able to host sensors, assuring their protection and capable of measurement all the properties of interest. The bar will be directly controlled by the unit #7 and integrated with the User Interface developed within the SLOPE. The set of sensors/special equipment to be integrated with the bar includes:

- **Position sensor**: (encoder or rotation sensor) is used for monitoring/controlling position of the bar + triggering data acquisition by sensors

- **Linear camera**: (CCD, CMOS or hyperspectral detector) is used for acquisition of the RGB images of the log cross section

- **NIR sensor(s)**: (miniaturized sensor, rigid capable for measurement of the wide range of spectra in the NIR band) is used for acquisition of the NIR spectra along the arc on the log’s cross section

- **Free vibration sensor**: (miniature sensor, without contact, resistant for electrical noise, capable of measuring acoustic effect of mechanical excitation or capable of measurement of vibrations) is used for acquisition of the FFT spectra of the exited vibration of the log in order to estimate mechanical properties/qualities

Log marking module and/or inserting RFID tags as well as bar code/color code printing module for logs marking will be tested in addition to the scanning capacity of the bar #1. The schematic of the module is presented on Figure 5-12.
Figure 5-12: The scanning bar #1  in the working position (please notice that the chain saw  will be in its park position during scanning).

Ad #2: The system for monitoring cross cutting of logs will be used for four purposes:

- Monitoring of the cutting force of the chainsaw’s cutting edges
- Monitoring of the pushing force of the chainsaw toward log
- To clean the surface before scanning by means of bar #1
- To optimize the cross cutting position of logs on the base of scanning info

The novel crosscutting system is used for estimation of the cutting resistance, fracture toughness, density, and quality as well as for monitoring of the innovative sharpness.

The proposed sensor is a load cell measuring directly cutting force. Alternatively, sensor measuring energetic effects of the cutting (e.g. W*h, oil consumption l/s, etc.) or tensiometer measuring deformation of the holding system due to cutting forces is considered. The module #2 will be also used for optimization of the products, adjusting the log length according to production plans and actual quality of logs (as predicted by the sensor set developed within SLOPE. The schematic of the cross cutting module is presented on Figure 6, assuming that the scanning bar #1 is in the park position during cross cutting.

Ad #3: The novel system for monitoring feeding of logs will be used for estimation of the branch(ing) quality index; one of the quality indexes crucial for sorting and cross cut optimization. The working principles of the selected processor head (ARBRO 1000) allows direct measurement of the cutting/feed force as related to (just) the cutting-out branches. The sensor proposed is a set of load cells (tensionmeters) measuring directly the cutting force on each delimming knife.
However, even more suitable is to use a sensor measuring energetic effects of debranching (e.g. pressure of oil and/or oil consumption of the piston). The schematic representation of the feed system is presented in Figure 5-13.

![Figure 5-13: Schematic of the de-branching system; cutting knives and hydraulic actuator.](image)

Ad #4 the multisensory vision system acquiring information on the side of logs will be used for the following purposes:

- Acquiring 3D surface maps of the log sides (for detection of defects related to the log shape and for measurement of detailed dimensions)
- Acquiring 3D surface color texture of the log sides (for detection of visible defects on log surface)

The multisensory camera is used for detailed description of each log geometry, detection of log defects related to the geometrical defects or surface roughness. The sensors involved include 3D vision camera (or) time of flight or triangulation sensor, array of microphones and color vision camera. The inspiration for the scanning module is low cost multi sensor device MS KINECT (http://www.microsoft.com/en-us/kinectforwindows/) or similar devices available on the market. The schematic representation of the sensor and its installation on the processor head is presented in Figure 5-14.
Figure 5-14: Multisensor system for 3D/color mapping of logs.

Ad #5 Colour camera(s) scanning side of the log will be used for the following purposes:

- For scanning (colour imaging) of the side of each log in order to detect all wood defects related to colour pattern;
- For precise measurement of the log length.

The sensors will be low cost compact digital camera(s) including a simple illumination with LED. The installation of sensor will assure its protection and easy maintenance and eventual cleaning. The image processing will be performed in real-time by the CPU of the control system. The proposed location of two cameras is shown on Figure 5-15.

Figure 5-15: Color cameras for color mapping of log’s sides.
Ad #6 Ultrasound stress wave velocity scanner will be used for characterization of the log’s mechanical properties along its length. It can be used for detection of the internal/no-visible defects. Such system will be capable of pre-sorting of high quality logs suitable for further conversion into structural wood elements. The system measures the velocity of the ultrasound propagation through wood by measuring distance (transducer to receiver) and time of ultrasound pulse propagation. By combining the velocity with other parameters (such as dimensions and density) it will be possible to grade the wood according to dynamic mechanical properties. The transducer will be installed within the main body of the processor head, when the receiver will be fixed to the moving arm. In such configuration, at least two scans will be possible in the extreme position(s) of the piston. The schematic of the ultrasound sensors and measurement is presented in Figure 5-16.

![Figure 5-16: The stress wave velocity measuring system for determination of the mechanical properties of the log; ultrasound transducer and ultrasound receiver.](image)

Ad #7 – RFID reading system will be used for determination of the log/tree code and using it for supplying information already available in the cloud data base. The details of the antenna selection, installation, access, and control will be developed in close collaboration with ITENE.

Ad #8 Data fusion/control unit will be used for the purpose of:

- Integrating all the sensors installed on the processor head (collecting raw signals from each sensor, pre-process it, determine quality indicator, combine all available data)
- Quality grade processed logs
• Optimize the cross-cutting of the log (log length for the highest value)
• The control system will be modular, flexible, easily programmable, and compatible with existing control systems of ARBRO and MHG (as well as Greifenberg cable crane, track and data backup system). All the sensors described above have to be connected directly to the control system by means of dedicated modules. The hardware platform to be used for development of the control system based on the one offered by National instruments. Two optional architectures are considered:
  • CompactRIO
  • Industrial PC working in real time

The final hardware configuration (the selection of CPU, modules, and signal conditioners) has to be designed in collaboration with other SLOPE partners in order to assure optimal hardware selection.

The prototype software dedicated to the quality grading of logs will be developed in LabView. Assuming the collaboration of other SLOPE partners, this software can include all aspects of the control system (including sensors management, signal acquisition, processing data mining, quality sorting, length optimization, data base management, communication and backup). Additional module within the CRio/PC may be optionally used for gprs/umts/3G/wireless communication, as described in DoW.

5.2 Cable Way and Self Propelled Carriage

5.2.1 Tecno: self-propelled carriage

Tecno is Greifenberg’s self-propelled carriage, in the cableway sector, which combines ergonomics, simplicity and high productivity. Tecno brings about in the cableway sector a revolution touch due to the absence of the main unit (slide winch). Tecno can work independently with different slopes (up to 40°) on the cable. It presents many advantages: it can work on a level land, unlimited long lines, workers reduction (2 out of 4) and handling directly by the user, without the intervention by radio of another user. In addition, Tecno can work in every slope condition thanks to the direct control of the cable by the motorized undercarriage. It is not necessary to use the carrying cable; it allows operations on every different line and ensures user’s safety by employing a remote control. Tecno can operate with the presence of two users and it does not require any cable, making the machine more economical while maintaining the same carriage safety standards. The integrated software sets the parameters of the line by
setting the points for the slowdown, charge and discharge. The machine can work automatically along the line and save repetitive operations.

5.2.2 Interface Specifications

Commands sent by the user through the radio control panel are received by the radio receiver connected by a CAN BUS, which collects input commands ordered by the user and connects them while processing other incoming data sent by the sensors on the machine (pickup, encoder, feelers, inclinometers, transducers, pressure switches, capacitive sensors, diesel engine diagnostics, etc.).

The control software creates output signals, which are delivered by CAN BUS to the diesel engine, by PWM signals to the two hydraulic transmissions and by digital signals to the valves of the braking system.

5.2.2.1 Peripheral Hardware

In the implementation of this project, several data-detecting systems interact and connect to the PLC through one unique protocol. On this basis, at first a system for carrying data with CAN BUS was chosen, as it is fast and allows to connect nodes in the network leaving space for further expansions.

Choices for hardware components are based on technical needs like type and quality of the data to be collected but most of all on the reliability of the components in difficult weather conditions.

The TECNO software can move automatically with continuously variable loads and slopes. Each load has different weight and structure and although the machine is
moving on the same line, the carrying cable might lead to different catenaries needing real time evaluation.

The following components have been chosen because of their excellent reliability, their ability to connect to the CAN BUS, their suitability for PLC CR0303 and because they have resolution and speed suitable for working in real time.

![Figure 18: PLC IFM Specifications](image)

### 5.2.2.2 Main Device list

**PLC IFM CR0303**: chosen for its number of inputs and outputs, for the possibility of managing the four hydraulic transmission control PWMs and for its mechanical features, including stress and temperature resistance, in line with requirements in the automotive field.

**Radio receiver Autec FJM**: as CAN BUS data transmission system due to the wide range, reliability and compliance to current standards that make it a complete device.

**Pickup IFM**: for carriage speed and position detection. Two of them are on the idle pulley to avoid anomalous readings caused by slipping. Their position is shifted in a way that they can detect the working direction and are equipped with redundant logic to detect possible damages.

**Encoder IFM**: for lifting cable speed and position detection, chosen because of its high precision work (500 impulses/revolution).

**Feelers Omron**: for detecting the impact of the carriage at the end of the line. This system raises the safety of the machine as it stops the carriage in the very moment the feeler detects the end of the line position. This can happen only in
case of pick up breaking (there are two with redundant control logic) or in case of damage of the PLC (negative breaks become operative and will stop the machine).

Inclinometer IFM: able to detect the maximum tilt on two axis. It manages the balance between the diesel engine torque and the hydraulic system oil flow while the carriage starts uphill or downhill. In both axis, it signals the maximum tilt limit to protect the diesel engine. It is chosen for its reliability, strength and connectivity with CAN BUS.

Transducer IFM: to detect instantaneous pressure of the circuit.

Pressure switches IFM: used to manage opening and closing of the shifting and transfer hydraulic motor negative break. They are chosen for the stability over time, absolute precision, and the possibility to be set through one computer, setting the difference between the brake opening pressure and the brake closing pressure. There is also the possibility to set a delay on the closing time and the detection of pressure peaks during the work.

Diesel engine CAN BUS: chosen because it is equipped with self-diagnosis and connects better with PLC IFM working through CAN BUS with protocol J1939.
6 Monitoring and Tracking Technologies

6.1 RFID Technologies

There are five main RFID technologies for radio frequency identification. They are:

6.1.1 High Frequency (HF)

High Frequency RFID work at 13.56MHz. This frequency only allow working at a very close distance, in example 1-2 cm. This means that basically direct contact is done between tags and readers. The antenna for this frequency has a spiral type, and it needs a size similar to a credit card. Typical applications for this technology are bus cards or building accessing.

This RFID tag is not a priori interesting for the SLOPE project since it has too low reading distance, and because it needs a specific reader.

6.1.2 Near Field communication (NFC)

Near Field Communication technologies are a modification of RFID HF technologies. They work at the same frequency, 13.56MHz, which means that they have the same short reading distance (1-2 cm), credit card size and spiral antenna. The main difference between HF and NFC tags is that NFC includes specific protocols for data exchange, being interesting contactless payments and other data transaction. This is becoming widely used in smartphones (mainly Android, iOS phones do not use it yet).

NFC tags could be interesting for the SLOPE project because they can be read with smartphones. However, a priori they will not be used because of their short range, and because it is more adequate to work in all stages with the same technology trying to reduce the number of tags / readers needed.
6.1.3 **Ultra High Frequency (UHF)**

Ultra High Frequency RFID tags work at 868-902MHz. They are the standard for logistics and storage applications. Their frequency allows easily for a reading distance up to 4-5 meters. The antennas have a dipole layout, and sizes usually below 11 cm wide. Although the tag and reader model can change, all are compatibles between themselves since they comply with the standard ISO 18000 and gen2. There are several kind of tags in the market (encapsulated, adhesive, etc.) and types of readers (manual readers, fixed, portals, etc.).

This is initially the selected technology for the SLOPE project due to the long reading range. A tag compatible with wood applications will be used.

6.1.4 **Ultra High Frequency Near field communication (NFC UHF)**

Near Field Communication UHF are a hybrid between HF and UHF dequencies. These tags are compatible with all UHF readers, but they have a short reading range (1-2 cm). They are used for applications where UHF technology is preferred for compatibility, but the usual reading range of the UHF tags is too big (i.e. building accesses).

This technology is a priori interesting for the project, in case near contact identification is needed.

6.1.5 **Microwave RFID tags**

Microwave tags work at frequencies bigger than 3 GHz. They have a very long reading range, i.e. 200 meters. They are expensive and big devices, which incorporate a battery to power the communication waves. This battery needs to...
be replaced once it has been used. They usually include other elements, like sensors, to measure and communicate different information.

This technology is a priorly not selected for the project, since it is expensive, the devices have considerable size and they need maintenance.

### 6.2 RFID Components

An RFID system is comprised of various elements, mainly a RFID transponder or tag, a RFID reader, and an antenna.

#### 6.2.1 RFID tags.

An RFID tags is small device usually oriented for low-cost which includes an antenna and a microcontroller with memory. It receives energy through its antenna, powers the microcontroller, reads or saves data, and sends the response also through its antenna. Reading range and form in which the information is coded (induction – backscattering) is dependent on the tag technology.

In the most basic form, an RFID inlay is just an antenna with the attached chip and a substrate made of paper or plastic. For more difficult environments encapsulated tags are used, so that they can withstand hits, rain, etc.

The tags usually receive energy from the antenna, and therefore they do not need batteries to work. This type of tags is called passive tags. However, when the tags are combined with sensors or they need to work at long distances, active tags are used which include a battery.

#### SLOPE tags

UHF technology has been identified as the most adapted to the SLOPE project requirements, due mainly to the low cost (passive tags) and long reading range (4-5 meters).

The first tag will be introduced in the tree marking process, and will accompany the tree in all the processing steps. When the tree is split in separate logs, all logs will also be tagged, to identify them.

Once the logs are stored in a landing, they are tagged with RFID devices if they are still without tag. The tags selected for this are UHF gen 2 frequency RFID tag. UHF frequency is able to have a long reading range (in example 4-6 meters) without the need of battery, which implies lower cost.

Some RFID UHF tags for wood applications are shown next.
Table 6-1: RFID UHF tags for wood applications

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
</table>
| Intermec Large Rigid UHF RFID Tag² | Rugged encapsulation for harsh environments
Consistent UHF range performance worldwide
Available with Gen 2 and ISO 18000-6B silicon |
| Confidex Ironside micro³   | EPC Class1 Gen2 (ISO 18000-6C) compliant passive on-metal tag
Read range: up to 5m / 16 ft. Memory: 128bit EPC + 512 bit.
Dimensions: 27 x 27 x 5,5 mm
1,06 x 1,06 x 0,22 inch. Ambient temperature: -35°C to +85°C. -31°F to +185°F |
| Confidex Ironside⁴         | PC Class1 Gen2 (ISO 18000-6C) compliant passive on-metal tag
Read range: up to 9m / 30 ft. Memory: 128bit EPC + 512bit.
Dimensions: 51,5 x 47,5 x 10 mm.
2,03 x 1,87 x 0,39 inch. Ambient temperature: -55°C to +105°C. -67°F to +221°F.
Peak 1h duration:+125°C to +257°F |

6.2.2 RFID readers and antennas.

The RFID reader is a device which includes or can be connected to one antenna. It sends the primary RF wave, listens for the response from the tags near the antenna, and decodes the information included in the received RF wave.

There are several constructive variations for this device:

- Fixed Reader with integrated antenna. The reader and one antenna are integrated in a unique device.
- Fixed Reader with external antennas. The reader has 4 external parts where different antennas can be connected. This allow placing the antennas in specific pattern, in example in a portal, where the reader reads all tags that go through the portal.
- Portable reader with integrated antenna. Handheld readers are small and portable. The usually can send less energy that fixed readers, and therefore have a smaller reading range.

SLOPE Readers and antennas


All readers and antennas in the project will use UHF technology, in order to be compatible with UHF tags. Depending on the application (tree marking, processor, crane, truck) a specific model will be selected according to the constructive requirements of the application.

Some of the identified compatible RFID readers are:

Table 6-2: RFID UHF readers

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1240I-qID5</td>
<td>Fully integrated <strong>handheld UHF RFID USB/Bluetooth reader</strong></td>
</tr>
<tr>
<td>Intermec IF2 reader6</td>
<td>EPCglobal UHF Class 1 Gen 2, ISO 18000-6C, ISO 18000-6B, IP53 sealing Die cast magnesium base, Lexan plastic cover, DC power input (12 VDC +/-5%, 30W), 10/100 BaseT Ethernet RS-232 and USB for configuration, 4 external antennas</td>
</tr>
<tr>
<td>Motorola FX95007</td>
<td>UHF band, 902-928 MHz, 865-868 MHz, RS232 Serial Console – DB9, USB Client – USB Type B, 10/100 BaseT Ethernet – RJ45, +24v Vdc,</td>
</tr>
</tbody>
</table>

6.2.3 **RFID Technology Selected**

UHF RFID technology has been selected for use in the project. The main reasons are the RFID tags are passive (without battery, less expensive) and because they have an appropriate reading distance (up to 4-5 meters).

Hardware specifications are summarized in next table.

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
</table>

5 http://www.caenrfid.it/en/CaenProd.jsp?idmod=801

6 http://www.intermec.es/products/ridif2a/index.aspx

6.3 Smart Truck Hardware Specifications

Task 3.5 of the SLOPE project will design and develop an intelligent transport truck. The aim of the task is to add intelligence to trucks and transport vehicles to move timber and biomass between the processing area and the end users and/or the storage areas. The position of the trucks and their load need to be accessible in real time to the SLOPE platform users.


9 http://www.intermec.es/products/rfidif2a/index.aspx

10 http://www.intermec.com/products/ip30a/
Several hardware options have been identified at this stage of the project to provide this functionality. Those options are detailed next.

### 6.3.1 Option 1. Handheld Reader

The first option uses an RFID handled reader to read placed tags into the logs. This option is easy to implement, and it has low cost since it only uses a handheld device. It is an excellent option for pilot testing and field trials, as required in the slope project.

![Option 1 Handheld Reader option](image)

**Figure 6-5: Handheld Reader option**

#### 6.3.1.1 Log identification before being transported

Once the logs have been tagged, they will be read with a handheld RFID reader. Manually reading and counting the trees will assure that all trees have been identified and traced.

The information read by the RFID reader could be communicated via Wi-Fi to an external system, or by GPRS to a destined server. Some RFID handheld devices are shown next.

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP30 Handheld RFID Reader(^{11})</td>
<td>EPCglobal UHF Gen 2, ISO 18000-6b, ISO 18000-6c RFID Frequency Ranges: 865, 915, and 950 MHz bands, supporting multiple regional configurations Bluetooth and USB configurations (model dependent)</td>
</tr>
<tr>
<td>ATID AT870(^{12})</td>
<td>13.56 MHz HF and 868 MHz UHF RFID</td>
</tr>
</tbody>
</table>


The transport truck will also have integrated an RFID UHF tag, which will be read with the handheld device. At this point the identified logs become linked to the transport truck.

6.3.1.2 Truck on route

Once the truck starts moving, its location will be detected with a GPS tracking device with GPRS functionality. The device has a GPS antenna, which is able to locate the vehicle with longitude and latitude measurements. The device also includes a SIM connection, which allow for 3G communication between the device and a central server. The position is sent to the server periodically, and can be used to know real time location and followed routes.

The device used to trace the truck is a Teltonika, model FMS4200. Next Figure shows how the SIM card is integrated into the Teltonika.

![Teltonika SIM card](image)

Next some images regarding Teltonika integration into vehicles are shown.
**Table 6-4: Teltonika FMS4200**

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teltonika FM4200&lt;sup&gt;13&lt;/sup&gt;</td>
<td>GPS and I/O, 1-Wire, CAN data acquisition</td>
</tr>
<tr>
<td></td>
<td>External sensors connection capability</td>
</tr>
<tr>
<td></td>
<td>Real Time tracking</td>
</tr>
<tr>
<td></td>
<td>Smart algorithm of data acquisition (time and distance based)</td>
</tr>
<tr>
<td></td>
<td>Sending acquired data via GPRS</td>
</tr>
<tr>
<td></td>
<td>Flexible configuration of data sending in roaming networks (depending on GSM providers list)</td>
</tr>
<tr>
<td></td>
<td>Events on I/O detection and sending via GPRS or SMS</td>
</tr>
<tr>
<td></td>
<td>Scheduled 24 coordinates SMS sending</td>
</tr>
<tr>
<td></td>
<td>Multi geofence zones (rectangular or circle)</td>
</tr>
<tr>
<td></td>
<td>Sleep mode and deep sleep mode (saving vehicle’s accumulators)</td>
</tr>
<tr>
<td></td>
<td>Acceleration detection (harsh breaking and accelerate measuring)</td>
</tr>
<tr>
<td></td>
<td>OTA (firmware updating via GPRS)</td>
</tr>
<tr>
<td></td>
<td>Real time internal processes monitoring</td>
</tr>
<tr>
<td></td>
<td>Authorized numbers list for commanding</td>
</tr>
</tbody>
</table>

6.3.1.3 Log identification after being transported

Finally, all tags are read again when they arrive to destination. This step can be omitted if desired, although it is useful to assure that all logs have been received correctly at destination.

The tags would be read at destination with a handheld device, with readers like presented on Table 6-3: Handheld readers.

6.3.2 Option 2. Reader in truck

This option includes the reading device into the truck, placing the antennas and the reader in a place of the truck with good visibility of the logs. The main benefit is to automatize the reading of the logs, and that they will be read during the whole transport.

However, placement of the logs in the truck become critic as some tags could become hidden or out of reading range. Also, it is an expensive option, since there is a need to include a reader and antennas in each truck of the transport fleet. The antennas and readers will need to be protected against physical blows from the logs and trees.

![Figure 6-8 Reader in truck option](image)

6.3.2.1 Log tagging

Tags need to be are placed in the logs, similarly to option 1. Some examples of RFID tags are presented on Table 6-1.

6.3.2.2 Truck on route

A reader and a minimum of 4 antennas need to be integrated into the truck. The antennas should be protected against hits, but also they should have good visibility of all tags. Each antennas has a reading range of 4-6 meters, so multiples antennas could be needed depending on the truck.
Figure 6-9 Some logs could become hidden if only 4 antennas are placed in the truck.

Once the truck starts moving, its location will be detected similarly to option 1, with a Teltonika device and a GPS antenna. The Teltonika allows for communication via RS232 with an RFID reader, gathering log identification information. The information is sent via GPRS (3G) capabilities of the Teltonika device.

Table 6-5: Reader and antennas to be integrated into the truck.

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFID reader IV7 for vehicles</td>
<td>EPCglobal UHF Gen 2, ISO 18000-6b, ISO 18000-6c, Philips Version 1.19, Fairchild G1</td>
</tr>
<tr>
<td></td>
<td>RS232</td>
</tr>
<tr>
<td></td>
<td>865, 869 and 915 MHz</td>
</tr>
<tr>
<td></td>
<td>Supply: Vehicle DC power 12 to 60V, 4.5 A maximum</td>
</tr>
<tr>
<td></td>
<td>Vehicle mount DC power cable kit</td>
</tr>
<tr>
<td>Antenna IA33D / IA33E</td>
<td>IA33D: 865 – 870 MHz</td>
</tr>
<tr>
<td></td>
<td>IA33E: 902 – 928 MHz</td>
</tr>
<tr>
<td></td>
<td>Gain: 6.0 dBi</td>
</tr>
</tbody>
</table>


Max Input Power: 10 Watts
Impedance: 50 Ohms

Once the logs are unloaded from the truck, they disappear from the detected devices.

6.3.3 Option 3. RFID portal

Option 3 presents the use of an RFID portal to use instead a reader integrated in each tag. A portal with a RFID reader and a minimum of 4 antennas will be placed in each landing. When the truck goes into the portal, all tags inside the truck are read.

The main issues related to the option are (i) the need of landing space, to place the portal and allow for the truck movements; (ii) the possibility that some tags became hidden and therefore not read; and (iii) it is an expensive solution, as a portal with 1 reader and 4 antennas is needed in each landing and each destination.

Nevertheless, is a very interesting option, as it will allow using unmodified trucks while maintaining automated identification.

6.3.3.1 Log tagging

Tags need to be are placed in the logs, similarly to option 1. Some example of RFID tags are presented on Error! Reference source not found..
6.3.3.2 Log identification before being transported
A RFID portal will be created in each landing. An RFID portal is basically a structure with 4 antennas and a RFID reader. When the truck goes through it, all RFID tags in the load are read. Since some tags could become hidden or out of the antennas range, testing would need to be done to detect reading percentage.

The reader and antennas that will for the portal are common RFID components, like those presented in Error! Reference source not found..

![Figure 6-11: RFID truck portal](image)

6.3.3.3 Truck on route
Once the truck starts moving, its location will be detected similarly to option 1, with a Teltonika device and a GPS antenna. The information is sent via GPRS (3G) thanks to the Teltonika device. The Teltonika device is presented in Error! Reference source not found..

Once the logs are unloaded from the truck, they disappear from the detected devices.

6.3.3.4 Log identification after being transported
Finally, all tags are read again when they arrive to destination with another RFID portal. This step can be omitted if desired, although it is useful to assure that all logs have been received correctly at destination.

6.3.4 Option 4. Microwaves
Finally, option 4 introduces the microwave RF technology. This technology has a long reading distance, (100-150m), and will assure log detection even without direct reading. A node device which includes battery and RF communication is
placed in each log, to identify it. A truck node is placed in the truck, which detects all near tags within 100-150m. Finally the nodes are removed at destination to be reused.

The main inconvenient for this approach is the price of each device (70-80€), the need to recharge the batteries periodically, and the need to protect the devices so that they are not damaged when loading / transporting / unloading the trucks.

This option would use specific hardware, which would be developed by ITENE.

6.3.4.1 Log tagging
In this case the devices could be screwed into the logs. The encapsulation and integration methodology will be defined in the project.

6.3.4.2 Truck on route
Once the truck starts moving, the truck node will detect all near “log” nodes. On the road, the traceability of the logs could be followed and received. The “truck” node will be connected to the teltonika device via RS232, and the information will be send via GPRS.

6.3.4.3 Log identification after being transported
Once the logs are unloaded from the truck, they disappear from the detected devices.

6.3.5 Smart Truck system selected
Due to easiness of use and low cost, option 1 and option 2 are selected as the main solutions to be analysed and tested within task 3.5. Option 1 included manual RFID reader and tracking device in trucks, and option 2 included fixed RFID reader with tracking device integrated in the truck.

Portal option is a priori dismissed because of (i) overall price and (ii) the difficulty to power and give connectivity to a portal in middle of the forest. Microwaves are dismissed mainly due to tag cost.
6.4 Fleet management and tracking systems

Cost efficiency and flexibility of wood transport can be improved by reducing trip times, increasing the capacity of the vehicles, reducing delay and waiting times and optimizing routes. For analysing and optimizing wood transport, the knowledge of every process and its attributes within the supply chain is an important factor. Fleet management systems (FMS) provide an opportunity to record data of transport activities automatically over a long-term period and with minimal input by the driver.

The most important benefits from a FMS are:

- Optimization of utilization and use of resources by order representation and processing with variable disposition,
- Tour and delivery times monitoring,
- Loading and unloading control,
- On-time delivery with real time proof of delivery and a tour analysis (Figure 6-13).

Figure 6-13: Standard functions and equipment of a fleet management system (www.eurotelematik.de)
Vehicle tracking and the automated data recording is a good opportunity for analysing time consumption of the supply chain processes. Vehicle tracking systems combine the use of automatic vehicle location in individual vehicles with software that collects these fleet data for a comprehensive picture of vehicle locations. Vehicle tracking provides a detailed dataset on productivity and costs, which helps identifying bottlenecks and critical elements. This data can be also used for Task 6.3 (Second Integration-Forest management) within the SLOPE project.

### 6.4.1 Hardware and software

The following components are usually part of a fleet management system:

- **An On-board Unit (OBU)** retrieves vehicle data from fleet management system interface. A touch screen is used for (a) the exchange of information about orders & tours, (b) drivers input, and for (c) the navigation system.

- **A desktop client** (a) manages orders & tours, (b) gives information about location & vehicle data and (c) communicates with the driver.

- The telematics **server** manages data flows and controls all features and services that are necessary for data transfer, processing & storing. The server communicates via GPRS between headquarters and drivers. If necessary, the devices can receive or send their data from the server via wireless or satellite communication.
6.4.2 Data management

6.4.2.1 Data collection
FMS support the technical part of data collection by the equipment built-in in the driver’s cabin and the attached GPS antenna. The pre-defined software routines for reporting routes and interpretation of engine data should have been modified prior to data collection to include all important transport processes. Standard processes for wood transport are represented in Figure 6-17. For the SLOPE project, the process flow diagram will be defined in Task 7.1.

To initiate automatic data recording for the different transport processes, driver input is needed. If the driver’s input is missing, some data can also be generated from activities of the machine. Therefore, semi-automated assignment routines for the working steps have to be developed based on the recorded engine signals. Data for vehicle speed and fuel consumption can be explored from the internal CAN-bus of the truck engine. The data is sent via GSM-module to the database running on a PC at the entrepreneur, saw mill or biomass plant. Each row of the database represents one time stamp with associated data. For analysing the transport volume, all trips to the customers can be combined with the load volume according to the delivery note or with information gathered from the traceability system using RFID tags (See also chapter 6.3).
Figure 6-16: Process flowchart for data collection during the transport of round wood from the forest site to the mill and interim storage (Holzleitner et al. 2011)

Digital data for road networks should be used to consider information for different road categories and their attributes. The roads should be divided into different classes. Each class should contain some basic information about its condition and congestion such as average speed or vehicle weight or height limits.

In mountainous regions there might be limitations for data transmission because of a weak signal via GPRS. This drawback can be resolved with an adapted intermediate storage system. GPS-data in an integrated GIS can be used for an event orientated analysis for improving data handling and reducing errors associated with incorrect inputs. The data itself can be used further for several tasks with the objective to improve the efficiency of transport activities. Cost analysis and decision support tools of round wood transport are two examples. A similar approach will be used for Task 2.5 (Road and logistic planning) to allocate harvesting sites to saw mills and biomass plants and to calculate transportation costs and traffic load on forest roads.

6.4.2.1.1 Data analysis
The working elements can be analysed twofold: (a) activity based (vehicle data, location) (Figure 6-17) and by (b) drivers input.
The progress of each processing site should be monitored by the entrepreneur and supported by reports. Reports should be generated automatically and usually contain basic information regarding time consumption, distances and additional driver input. If the system costs of the vehicle are known, also the transportation costs can be calculated. To reference the transport productivity, load data from the digital delivery notes should be combined with the transportation data.

### 6.4.3 Fields of application and benefits for SLOPE

Fleet management systems can support many activities which are related to timber transport. The following table shows activities that are related to several SLOPE tasks.

<table>
<thead>
<tr>
<th>Activity</th>
<th>SLOPE task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navigation of trucks and other vehicles on the forest road network</td>
<td>Task 3.5 – Intelligent transport truck</td>
</tr>
</tbody>
</table>
| Vehicle positioning and vehicle disposition (optional) | Task 3.5 – Intelligent transport truck  
Task 5.4 – Short-term optimization |
| Order management and checking the order status | Task 5.2 – Near real time control of operations  
Task 5.4 – Short-term optimization |
| Order change request directly to the          | Task 5.2 – Near real time control of operations     |
Supply chain processes identification, documentation and analysis

Task 5.2 – Near real time control of operations
Task 6.4 – System validation
Task 7.1 – Definition of evaluation methodology

Interface with the SLOPE forest information system (optional)

Task 5.4 – Short-term optimization

Electronic logbook

Task 5.2 – Near real time control of operations

Recording and evaluation of technical vehicle data

Task 5.2 – Near real time control of operations
Task 6.4 – System validation

The use of FMS in SLOPE provides the opportunity to reduce costs by controlling orders in real time, optimizing wood supply chain processes, minimization of waiting times and reduced disposition costs per order. An increased efficiency, an optimized structure of operational processes and an early detection of delays in the daily schedule increase the quality of the whole supply chain. As a side effect, all processes are documented with time and location stamp, which gives the possibility of a comprehensive analysis of the data and to identify bottlenecks in the supply chain.

6.4.4 Practical experiences with fleet management and tracking systems

Fleet management systems provide solid and precise data (e.g. time and fuel consumption) for analysing transport activities. A digital on-board data recording system monitors automatically supply processes for a saw mill or biomass plant. Different processes can be identified by a machine activity based assignment. Developed routines allow the execution of semi-automated time studies with relatively no additional input from the drivers themselves. The creation of daily efficiency reports for the entrepreneur is another important aspect which is covered by a FMS.

The results can be used for implementing and improving cost estimates and for using least cost surfaces for wood transport (Möller and Nielsen 2007) but also as an input for the development of simulation models for wood supply based on discrete-event simulation or static simulation approaches (Asikainen 1995, Asikainen 2007). The data is also needed to develop vehicle routing algorithm or verify respectively improve already existing models in the timber transport sector especially for minimizing driving times and reducing greenhouse gas emissions (Oberscheider et al. 2013).
Technical limitations for data transmission via GPRS due to weak signal in mountainous regions can be resolved with an adapted intermediate storage system. The semi-automated data recording during transport is normally accomplished with minimal additional input from the driver (Holzleitner et al. 2013).

In the future, FMS-protocols will become easier to handle in different truck models. In addition, new machinery enables the availability of digital data for monitoring machine activity based on logistic process analysis (e.g., digital tachographs). Furthermore, the use of software applications must become easier to use. Interfaces between already existing systems, such as book-keeping or enterprise resource planning systems, are necessary to support the implementation of FMS. Nevertheless, detailed process analysis requires more detailed data collection with additional effort by the drivers. Replacing an on-site time study with skilled scientists by using a fleet management system with automated analysis will be still difficult to conduct (Holzleitner et al. 2013).

### 6.4.5 Resource and Work Management

Resource management and work management are based on MHG Biomass Manager Service. MHG Biomass Manager Service usage requires internet connection and modern Web Browser. MHG Systems services are built with modern technologies. Services are provided from enterprise class cloud platform which insures good stability and scalability. All connections to the cloud are secured with SSL technology.

Web user interface is designed to use with modern browsers to insure the best user experience. Minimum recommended screen resolution is **1280*800 for web user interface**. Supported browsers are Microsoft Internet Explorer (8.0+) and Mozilla Firefox (all newer versions). Service works also with another browsers but user interface is tested only with these browsers. MHG Systems recommends Mozilla Firefox.

If MHG Biomass Manager is installed as a dedicated instance, it will need about four GB memory for the database and application server. MHG ERP is designed to use hardware resources economically. When simultaneous user load is rising and database is growing, the hardware requirements are rising, too, and more memory and processing power is needed.

The best platform to these kind of changing needs is the newest cloud technology that MHG provides to customers. With this technology MHG can easily add memory, storage, and processing power of virtual server instance. Cloud
technology provides to our customers the most reliable platform and there is no need to care about hardware. In the cloud there are automatic system recoveries and monitoring so if the one physical server crashes, users won’t even notice that.

The Cloud is built top of VMware vSphere and all data is stored to the enterprise class Hitachi storage system. In the datacenter there are fast internet-connections to the Russia and Europe. Data is backed up every day to another datacenter. MHG Systems uses Telecity Group as hosting service provider. Cloud service platform is located in Helsinki, Finland.

<table>
<thead>
<tr>
<th>Processor</th>
<th>2pcs Intel Xeon cores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory</td>
<td>4GB</td>
</tr>
<tr>
<td>Hard drive</td>
<td>100GB (On enterprise class storage system)</td>
</tr>
<tr>
<td>Operating system</td>
<td>Linux CentOS 64bit</td>
</tr>
<tr>
<td>Location</td>
<td>Helsinki, Finland</td>
</tr>
</tbody>
</table>

The system is very scalable, supporting many different kind of setups and hardware. It is designed to fulfill scale needs from a small company ERP to a large enterprise serving as a secure front-end ERP system for them. The system can be installed from small virtual servers to clusters of a multiple servers, so the scalability of the system is ensured.

**MHG Mobile** is a field workers mobile application which can be used on Android devices. Mobile application supports offline usage. MHG Systems recommends Android version 4.04+ usage for the best and smooth user experience. MHG Systems uses Samsung Galaxy XCover 2 as reference platform
Table 6-8: Hardware specifications for the applications

<table>
<thead>
<tr>
<th>Application</th>
<th>Hardware requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>MHG Mobile Application</td>
<td>Android 4.04 or newer device. Can be a tablet or phone. HTML5 version is coming on autumn 2014 which can run on Windows Phone 8+.</td>
</tr>
<tr>
<td>MHG Biomass Manager Web Client</td>
<td>Modern browser and device that can run modern web browsers.</td>
</tr>
<tr>
<td>MHG Biomass Manager Server</td>
<td>Virtual server instance with minimum 2 CPU cores, Public IP, 4GB RAM and minimum 50GB HDD.</td>
</tr>
</tbody>
</table>
7 Conclusion

This document contains the main specifications in terms of HW and SW for the SLOPE framework. Many of the aspects related to the software system will be reported on the deliverable D1.05 system architecture.

For what to concern the hardware several components are not completely defined due to the fact that these will require a more deep investigation during the Work Packages 3, 4 and 5. In particular the description of the sensors to be installed on the processor head should be considered as a general concept. The system configuration is continuously improving and is evolving along the SLOPE project progress. The new information (such as details of the processor head, measurement conditions, etc.) expected to be available soon will allow more precise definition of the requirements. Moreover, the ongoing research activities within WP4 provide additional selection criteria and know-how assuring proper selection of optimal sensory solutions. The detailed definition of sensor characteristics will be provided in the following releases of this Deliverable as well as will be included in the reports related to WP4 activities.

To these reason it may be needed a new release of this document when the abovementioned specification will be more defined.
8 References


