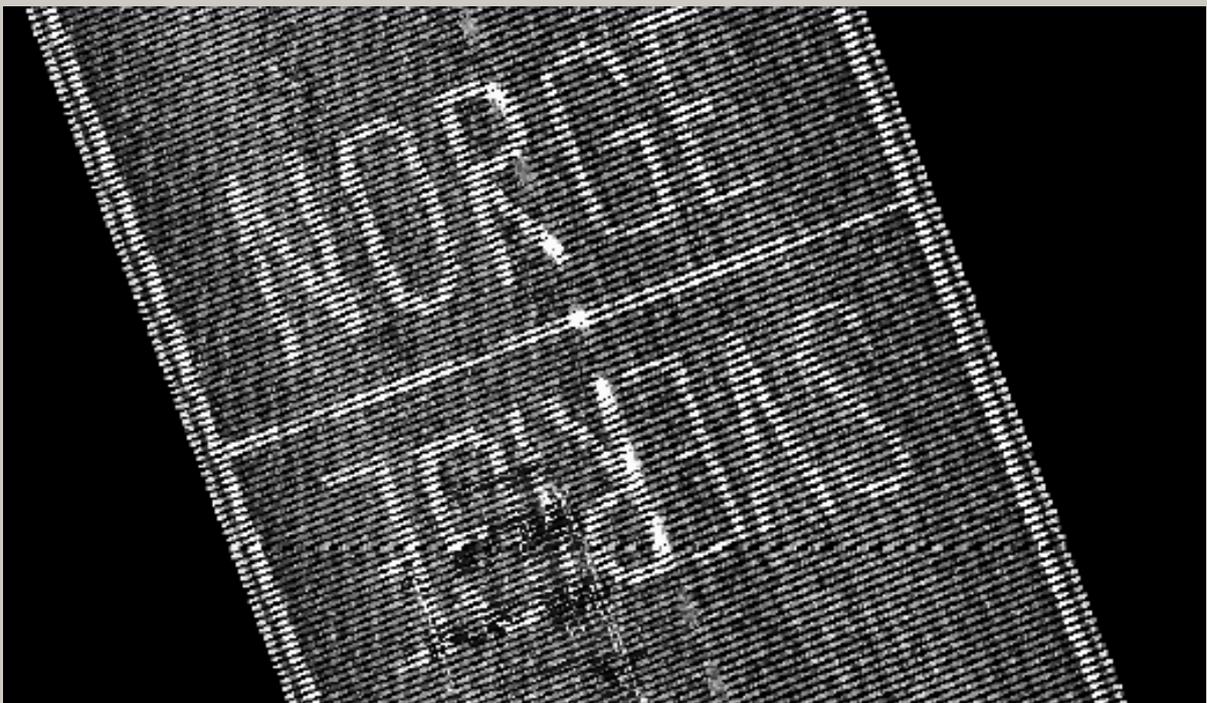


REPORT 1A

Analysis of needs and possibilities with the technology of the future

Part of R&D project "Infrastructure in 3D" in cooperation between Innovation Norge, Trafikverket and TerraTec



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Analysis of the present day, and the possibilities with the technology of the future

This project is a cooperation between Trafikverket, TerraTec and Innovation Norge. The background and motivation for this project are described in the following sections. A list of activities has been agreed between Trafikverket and TerraTec to fulfil the aims of this project. Reports will be written in languages in the following order of preference: Swedish, English, Norwegian. The reports, once delivered, will be publicly available for anyone who requests them. Data delivered will be stored by Trafikverket.

Introduction

Trafikverket note that they use billions SEK every year on new constructions, building, and maintenance of transportation networks in Sweden, and see the economic potential in having better cooperation between technologists and economists. Trafikverket note that they wish to invest in better coordination and utilisation of data internally, as part of Trafikverket's Research and Development program "Mer nytta för pengarna" ("More value for your money").

TerraTec has an aim to deliver ready-to-use tailor-made data to its customers, and is constantly expanding the potential market for its data and services. TerraTec has high technological and innovative competence, and was therefore a good partner for this project with Trafikverket.

Present-day situation

The present-day situation is that roads are partially documented, using length-coordinates. Objects underground are poorly documented or poorly positioned. Currently, there is no holistic maintenance plan for the roads. Road signs, road markings, damage, wear, and irregularities in the road surface are usually documented and repaired through separate supplier agreements, done partly manually and partly through contractors, and organised with different contact persons in Trafikverket. Development and rebuilding requires full data acquisition and measurement of the relevant section of road or railway under investigation, for substrate or engineering applications. Data are delivered but not necessarily used widely enough internally, and visualisation of the data require professional knowledge and specialist software.

Future vision

The future vision is that the road and surrounding objects will be fully documented in 3D as point clouds, vector data and complete National Road Database (NVDB) data in absolute (georeferenced) coordinates. In addition, structures below ground will be mapped and correctly positioned, to mitigate for unwanted surprises when digging, such as expensive power outages or water leaks.

Division of project

The project was started in January 2016, and finishes in December 2017, encompassing two full years of development and research on the part of TerraTec, with the aim to becoming a more holistic provider of services and to demonstrate how this can be useful for Trafikverket. This project then, gathers and presents all the innovations and developments that have been undertaken in TerraTec in relation to this project.

The project has been divided into ten activity areas, as defined below:

1. Analysis of the present day, and the possibilities with the technology of the future
2. Optimisation of Mobile Mapping production
3. Innovative data acquisition with phase scanner mounted on vehicle
4. How well can critical underground structures be mapped using Ground Penetrating Radar?
5. Towards high precision data from helicopter
6. Innovative methods for georeferencing
7. The future's processing and data handling
8. User-friendly and elegant management and visualisation of data
9. Input to the future's national road database (NVDB)
10. Cost analysis

This report comprises Activity 1, and describes an overview of all parts of the final delivery.

A list has been created to describe the products and contents of the reports that have been written for the different activity areas. This subdivided list is presented below the description of each activity. The full list is presented at the end of this report. Work will be carried out and data delivered to Trafikverket in local coordinate reference systems. Metadata will be included on the coordinate reference system used.

The ten activity areas are described in more detail below, to show the background behind the activity areas, and to summarise the developments that have been made on those specific points. The table below each section provides a summary of the report that has been produced to meet that particular activity's aims.

Activity 1: Analysis of the present day, and the possibilities with the technology of the future

Aim

In-depth understanding of Trafikverket’s requirement for road documentation in the future, and strategies for meeting these needs with concrete technical solutions.

Status

Several concrete possibilities for modernisation and new production lines have been developed and these will be presented in the following sections and activity areas.

Activity	Sub-activity	Description of report/s included
Analysis of the present day, and the possibilities with the technology of the future	1A	This document describes the outline of the reports that are provided for the different activity areas related to this project.

Activity 2: Optimisation of Mobile Mapping production

Aim

A very cost-effective production line where Mobile Mapping Systems data can be acquired at normal driving speeds along roads and railways, including in tunnels and urban environments without GNSS-coverage, while eliminating the need for either stopping the traffic or extensive fieldwork.

Status

There has been significant development of new and improved technology for both data acquisition and processing. A highly efficient production line has been developed for MMS data, including tunnel data, for producing a georeferenced point cloud for delivery soon after the end of data acquisition. The production line has been upgraded with state-of-the-art instruments and software to ensure high quality data and efficient processing, resulting in a product package available to meet the needs of Trafikverket.

Activity	Sub-activity	Description of report/s included
Optimisation of Mobile Mapping production	2A	Summary of what has been done in MMS to improve the workflow with respect to processing and hardware, and incorporation of GPR with MMS.

Activity 3: Innovative data acquisition with phase scanner mounted on vehicle

Aim

Usage of Viatech ViaPPS system (Zoller-Fröhlich phase scanner) for innovative data capture with high accuracy.

Status

From being in the experimental phase at the start of this project, this process has now become a well-established production line with data acquisition and related processing and georeferencing. This type of technology is originally offered by the system provider for road surface profiling applications only, with 2 m in width and with relative instead of absolute positioning. TerraTec now scans all structures to the sides and above roads (360 degrees) following an in-house modification of equipment with related testing and troubleshooting. TerraTec have developed production workflows with proprietary software to georeference each measured point to absolute x, y, and z coordinates instead of only relative positioning.

Activity	Sub-activity	Description of report/s included
Innovative data acquisition with phase scanner mounted on vehicle	3A	Summary of modification of the phase scanner system to scan in 360 deg, and TerraTecs utilization of this data.

Activity 4: How well can critical underground structures be mapped using Ground Penetrating Radar?

Aim

Map possibilities and limitations for detection of important structures in the subsurface.

Status

Technical and mechanical solutions have been developed that allow simultaneous data capture of Ground Penetrating Radar (GPR) data at the same time as MMS or phase scanner data capture, with common positioning data. Various data collection methods have been tested and underground objects and asphalt thickness have both been mapped. An efficient production line for GPR data processing and production is under preparation. TerraTec has used a 3D radar, and developed methods for georeferencing the data in the correct absolute positions.

Activity	Sub-activity	Description of report/s included
How well can critical underground structures be mapped using Ground Penetrating Radar?	4A	Summary of GPR surveying method and methods for positioning of GPR data. "Ground Penetrating Radar"
	4B	Summary of project with GPR to find voids underground.
	4C	Summary of project with GPR data acquisition at high speed
	4D	Report on acquisition, processing and interpretation of data from GPR data on railway.

Activity 5: Towards high precision data from helicopter

Aim

A typical point cloud of airborne data acquired by helicopter has a point density of 10-20 points/m² with an accuracy of 7-10 cm. The aim is to achieve a point density of 50-100 points/m² with an accuracy of 2-5 cm.

Status

TerraTec has developed a proprietary helicopter system with two RIEGL (VUX HA) laser scanners and (Phase One IXU 1000) vertical camera, as well as two mid-sized cameras (Nikon D810) for non-orthogonal/slanted images, that in many cases replace the need for direct measurement on road or rail. Typical point density is 70-100 points/m² with an accuracy of 2-3 cm in height. Vertical images provide GSD 2-5 cm and non-orthogonal/slanted pictures provide GSD 1-3 cm.

Activity	Sub-activity	Description of report/s included
Towards high precision data from helicopter	5A	Products and quality achievable by helicopterborne data capture using Terratecs custom built system L400
	5B	Comparison of terrain models from helicopterborne system (L400) and mobile mapping (Optech Lynx)
	5C	Comparison of road surface analysis and vectorization from helicopterborne system (L400) and mobile mapping (Optech Lynx)

Activity 6: Innovative methods for georeferencing

Aim

High precision positioning and rotation data to be calculated in real-time and with post-processing based on integrated measurement sensors, without the need for extensive field data. For instance, in a tunnel, to go from 10-20 cm accuracy of the acquired field data after significant field work and requirement for traffic stopping measures and a significant post-processing time, to an accuracy of 2-3 cm with minimal fieldwork and a fast, semi-automatic processing workflow.

Status

New components, based on SLAM algorithms, have been developed in TerraPos. These, and additional developed software, have the potential to give us increased precision in tunnels, urban environments and other challenging areas. Methods have been developed to use the point cloud itself as a correction factor in positioning the point cloud, thus reducing the need for additional surveying. Systematic measurements, analyses and post-processing methods have been employed, as well as competence from several different fields to implement the methods in practice.

Activity	Sub-activity	Description of report/s included
Innovative methods for georeferencing	6A	Terrapos for positioning of Mobile Mapping Systems
	6B	MSc thesis by Marianne Løvås on a developed SLAM-algorithm and its applications in mobile mapping.
	6C	Test of and further development of the SLAM-algorithm from subactivity 6B to correct for drift in tunnels.

Activity 7: The future's processing and data handling

Aim

High-performance automated processing workflows for all types of measurement data for infrastructure in 3D, including vectorisation and object recognition.

Status

High-precision processing of data to a georeferenced point cloud has become an efficient production line. In addition, a number of methods have been tested for detection of objects in point clouds, intelligent classification and automated vectorisation. There are also possibilities for automatic reading or recognition of signs.

Activity	Sub-activity	Description of report/s included
The future's processing and data handling	7A	Introduction: Extracting information from MMS data.
	7B	Automated mapping of road condition parameters. Use of TopoDOT for vertical object recognition in machine learning processes.
	7C	Automated mapping of road assets.
	7D	Automated recognition of objects (signs) in pictures - prototype

Activity 8: User-friendly and elegant management and visualisation of data

Aim

Finalised data should be able to be read directly into Trafikverket's National Road Database (NVDB). In addition, the basis data in 3D should be visualised and managed so that not only technologists but also economists and decision makers can clearly use and benefit from the data.

Status

Both Trafikverket and TerraTec have been working on solutions for visualisation and portals for data. Trafikverket has been using ORBIT software for their data management and visualisation. TerraTec has provided data in formats that are compatible with ORBIT, and will do so for this project. Data will be provided in local coordinate reference systems with meta-data, and will be converted to other coordinate reference systems by Trafikverket upon import into ORBIT.

Activity	Sub-activity	Description of report/s included
User-friendly and elegant management and visualisation of data	8A	Trafikverket are using ORBIT 3D for their visualisation and sharing. We will deliver example data from individual projects in formats that are compatible with ORBIT. Summary of deliveries with example data from individual sub-activities to be provided, in ORBIT-compatible formats.
	8B	Visualisation regarding merging of data from LIDAR+MMS+GPR, incl. Augmented Reality, combination above and below ground.

Activity 9: Input to the future's national road database (NVDB)

Aim

Develop a new standard or proposal for a new standard for Trafikverkets National Road Database that fully utilises modern technology and opportunities.

Status

The project is well-suited to showcase the possibilities of new technology. It is important to include enough foresight to show how 3D data can be used but keep a structure that is not too complex to manage. A report has been produced to show the uses of MMS and LIDAR data in NVDB.

Activity	Sub-activity	Description of report/s included
Input to the future's national road database (NVDB)	9A	Potential improvements/updates to NVDB using MMS or LIDAR data.

Activity 10: Cost analysis

Aim

TerraTec to undertake a thorough cost analysis for optimisation of the production line and identification of costly parts of the production line that need to be streamlined. Trafikverket to analyse the total costs in relation to operation/maintenance/documentation of roads, and the value of complete 3D-data, as well as the savings generated through use of new technology.

Status

Tests and analysis must be undertaken on a large scale to estimate the total costs and associated uncertainty or risk for a realistic future volume of orders. At the same time, information must be shared within Trafikverket so that not only technologists but also economists, see the benefit of using new technology.

Activity	Sub-activity	Description of report/s included
Cost analysis	10A	TerraTec will use ideal cases to visualize difference in executive hours, value of data from the different technological sensors versus traditional surveying.

Activity summary and descriptions

The full list of subdivided activities is presented below to provide an overview:

Activity	Sub-activity	Description of report/s included
Analysis of the present day, and the possibilities with the technology of the future	1A	This document describes the outline of the reports that are provided for the different activity areas related to this project.
Optimisation of Mobile Mapping production	2A	Summary of what has been done in MMS to improve the workflow with respect to processing and hardware, and incorporation of GPR with MMS.
Innovative data acquisition with phase scanner mounted on vehicle	3A	Summary of modification of the phase scanner system to scan in 360 deg, and TerraTecs utilization of this data.
How well can critical underground structures be mapped using Ground Penetrating Radar?	4A	Summary of GPR surveying method and methods for positioning of GPR data. "Ground Penetrating Radar"
	4B	Summary of project with GPR to find voids underground.
	4C	Summary of project with GPR data acquisition at high speed.
	4D	Report on acquisition, processing and interpretation of data from GPR data on railway.
Towards high precision data from helicopter	5A	Products and quality achievable by helicopterborne data capture using Terratecs custom built system L400
	5B	Comparison of terrain models from helicopterborne system (L400) and mobile mapping (Optech Lynx)
	5C	Comparison of road surface analysis and vectorization from helicopterborne system (L400) and mobile mapping (Optech Lynx)
Innovative methods for georeferencing	6A	Terrapos for positioning of Mobile Mapping Systems
	6B	MSc thesis by Marianne Løvås on the SLAM-algorithm and its applications.
	6C	SLAM-algorithm for using objects as reference to correct for drift in tunnels and urban areas.
	7A	Introduction: Extracting information from MMS data.

The future's processing and data handling	7B	Automated mapping of road condition parameters. Use of TopoDOT for vertical object recognition in machine learning processes.
	7C	Automated mapping of road assets.
	7D	Automated recognition of objects (signs) in pictures - prototype
User-friendly and elegant management and visualisation of data	8A	Trafikverket are using ORBIT 3D for their visualisation and sharing. We will deliver example data from individual projects in formats that are compatible with ORBIT. Summary of deliveries with example data from individual sub-activities to be provided, in ORBIT-compatible formats.
	8B	Visualisation regarding merging of data from LIDAR+MMS+GPR, incl. Augmented Reality, combination above and below ground.
Input to the future's national road database (NVDB)	9A	Potential improvements/updates to NVDB using MMS or LIDAR data.
Cost analysis	10A	TerraTec will use ideal cases to visualize difference in executive hours, value of data from the different technological sensors versus traditional surveying.



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