TOPCON

RESEARCH PROJECT

SMARTSITE and Utilisation

Documentation in the area of 3D road resurfacing with the support
of the European Commission
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Contents

Introduction

1 - Introduction

Digital Technologies are increasingly prevalent in all areas of the economy. While there is already a high degree of digitalisation and automation in other sectors, such as the retail trade or the stationary manufacturing industries, the construction industry is currently still lagging far behind in the use of new technologies *(Schober, Hoff & Nölling, 2016)*. This is reflected not least in very low productivity compared to other sectors and low growth rates in terms of productivity over the last few decades.

Although gross value added per hour worked rose by a factor of 1.7 between 1995 and 2014 in the world's 41 strongest industrial economies – and almost doubled in the manufacturing industry – in the construction industry it only rose by a factor of 1.2. This corresponds to an average annual growth rate of only 1% over the past two decades. In the USA, labour productivity in the construction sector is now even lower than it was in 1968. In Germany, productivity in the construction industry improved by only 4.1% between 2000 and 2011, while in the German economy as a whole there was an increase of 11%. The construction industry thus has a global productivity problem *(Barbosa et al., 2017)*.

For this reason, new digital technologies are seen in the construction industry as having great potential for raising productivity to a level comparable with that of manufacturing industry. Digitalisation affects all phases, from preparation to planning, construction and operation through to dismantling, as well as all the stakeholders involved in the construction – planners, construction company staff (both operational and supervisory), the client, suppliers of building materials, manufacturers and suppliers of construction machinery.

From a Technical Perspective, the focus is primarily on:
(1) end-to-end digital planning and unified data storage in digital Building Information Models (BIMs)
(2) the automated collection and processing of digital data (including the creation of digital twins and the establishment of an Internet of Things for the construction industry)
(3) the networking of process steps across entire value chains and company boundaries, and
(4) the automation of work steps, right up to autonomously working, self-organising systems in line with the principles of Industry 4.0. This report focuses on digitalisation in civil engineering and, in particular, the digitalisation of asphalt road construction.

Value Chains in asphalt road construction are characterised by the high dynamicity and complexity of the product, production process and environment. On the other hand, there is an extremely small fault tolerance with regard to the quality to be produced. Defects in the area of road construction – and in particular in the production of the surface layer – are always associated with significant costs in terms of time and money, since the previously constructed product needs to be laboriously dismantled and re-paved. Thus, in large infrastructure projects the remediation of avoidable defects results in losses equivalent to 5% of the total construction sum – but the macroeconomic costs (including traffic congestion costs) are substantially higher. For example, additional repair costs amounting to 2.2 billion euros are incurred in Germany each year as a result of deficient quality in road construction *(Ramsauer 2011)*.

The underlying reason for this is the division of labour between a large number of legally and economically independent stakeholders and the resulting significant amount of coordination required, a hitherto very low degree of automation and inflexible control systems. In particular, there is a lack of end-to-end automated data collection, logistical connections and user-related preparation of production process-related data, as well as the in-time reintroduction of this data into the manufacturing process.

An increase in the degree of automation with the aim of automating asphalt road construction and enhancing its process stability serves to substantially increase the quality of the road surfaces being produced. The result is a significant extension in the roads' service life and a major reduction in construction and renovation costs. This, in turn, improves operational efficiency and increases the macroeconomic benefits.

The Project

This Potential can, however, only be fully realised if individual systems are automated and networked based on standards and if they can exchange information bidirectionally with the digital building model. This enables quality-assured road construction through a quality assurance system integrated within the manufacturing process. In this way, existing approaches to quality control, which involve checks being carried out after the construction process – with correspondingly high costs and delays caused by the need to correct defects retrospectively – are now complemented by build-in quality procedures.

Over a three-year period, the SMARTSITE research project *(2013-2016, funded by the Federal Ministry for Economic Affairs and Energy, grant number 01MA13002)* addressed the challenges of digitalisation in road construction as part of a publicly funded collaboration between science and industry; from planning to execution through to documentation across the whole production and supply chain (asphalt plant, transport, paving, compaction and quality control).

This document evaluates the SMARTSITE research project based on the project documents and thus showcases the role of the project in Topcon's product development strategy, as well as the resulting work processes and products. SMARTSITE, its predecessor project AutoBauLog and the follow-up project Quality Road Construction Baden-Württemberg 4.0 (QSBW4.0) are integrated within Topcon's long-term research and development activities and reinforce the company's position as a leader in innovation and technology within the construction industry.

The first part of this document is an introduction to the SMARTSITE research project. It examines the visions, challenges and economic potential of digital and automated road construction.

Section 3 outlines the technical and organisational solutions which arose from the project and which have already led to products that are now established in the market.

2 - The SMARTSITE PROJECT

Duration	1 November 2013 to 31 October 2016 (36 months)
Project Volume	6.65 million euros
Funding	2.96 million euros
Grant Number	01MA13002
Funded by	Federal Ministry for Economic Affairs and Energy pursuant to a resolution of the German Bundestag. Technology programme "Autonomik für Industrie 4.0" (Autonomics for Industry 4.0)
Partners	• Ammann Verdichtung GmbH, Hennef (Ammann)
	• ceapoint aec technologies GmbH, Esse (Ceapoint)
	• Drees & Sommer Infra Consult und Entwicklungsmanagement GmbH, Stuttgart (Drees & Sommer / Dreso)
	• Topcon Deutschland GmbH (Topcon)
	• STRABAG AG / Ed. Züblin AG, Cologne / Stuttgart (STRABAG / Züblin)
	• University of Hohenheim, Stuttgart

SMARTSITE Project Profile

2.0 - **Summary**

The Central Project Results of SMARTSITE are open and flexible platforms for semi-automated, connected construction machinery and equipment, and for intelligent construction process control systems. To this end, innovative digital and mobile solutions based on Industry 4.0 technologies were developed and concepts associated with the Internet of Things and Services were transferred to road construction.

The Goal was fully autonomous, quality-assured, resource-efficient paving in asphalt road construction, explicitly taking into account the prevailing industry structure which consists predominantly of small and medium-sized construction enterprises.

For this purpose, SMARTSITE developed core innovations on the following three development trajectories and trialled them in simulations, experiments and on two real-life asphalt construction sites:

(3.2) Planning, Documentation, Visualisation and BIM
Project partners involved: Ceapoint & Topcon

Results:

- Procedures for terrain mapping *(Topcon)* using drone flights and surveying runs.
- Interface between digital terrain data and planning software *(Topcon & Ceapoint)*.
- Interface between BIM-based planning or visualisation and machine control *(Topcon & Ceapoint)*.
- Interface between planning and documentation and logistics control *(Ceapoint & University of Hohenheim)*.

(3.3) Logistics Control
Project partners involved: University of Hohenheim

Results:

- System for controlling material logistics by means of dynamic scheduling and predictive speed recommendations for the paver *(University of Hohenheim)*.
- Interfaces to routing services *(with Topcon)*, mixing plants *(with Ammann)* and BIM-based planning & documentation *(with Ceapoint)*, as well as integration of weather data via online weather services and local weather stations *(with Topcon)*.

(3.4) Machine Control, especially Roller and Paver Control
Project partners involved: Topcon & Ammann

Results:

- 3D machine control system for supporting machine operators with both manual systems and display systems, as well as with automated systems.
- Automated self-levelling lasers for terrain surveying, systems for GPS-based 3D machine control.
- Interface for linking digital terrain models to the machine control.
- Robotic total stations and an integrated satellite receiver chip (Paradigm G3) for all satellite transmission formats.
- Interface for using terrain models from the CAD & Building Information Modelling systems and directly implementing this data via machine electro-hydraulics.
- Complete 3D control of the road paver, including automatic steering and screed width control depending on the digital terrain model.
- Interfaces and sensors for the accurate detection of paving width and height, pre-compaction and temperature of the mix in the paver.
- CAN bus connection for rollers for the real-time collection of key quality-relevant data such as stiffness, vibration frequency, amplitude and asphalt temperature.
- Site communication infrastructure for transferring machine data to a central construction data cloud.
- Functional models for a self-propelled road roller *(Ammann, Topcon, University of Hohenheim)*.
- Rolling operator assistance system for the calculation and visualisation of compaction-optimised rolling patterns for all rollers involved in the process *(University of Hohenheim & Topcon)*.

2.1 - **Vision and Goals**

The Vision of the SMARTSITE project was to achieve end-to-end model-based planning, control and quality monitoring in asphalt road construction (see Figure 1). This includes mobile 3D terrain mapping (vehicle and drone flights), BIM-based modelling in the dimensions of space, time, cost and quality (6D), and machine and process control from milling to compaction and quality documentation of the completed road.

To realise this vision, intelligent processes were developed in an ad hoc association for the quality-driven control and coordination of **smart**, **autonomous, mobile construction machines**. This was achieved by combining Industry 4.0 technologies with decentralised, AI-based control of construction machines across the whole value chain. To this end, current technologies in the area of **sensors and networking** have been further developed to implement secure transmission and cloud-based evaluation, as well as incorporating site-external information sources such as weather and traffic reports, including the processing and intelligent predictive construction process control system that was implemented for the first time in the project. This included the development of procedures that analyse, monitor and, above all, autonomously provide real-time feedback to all stakeholders involved in the process. This was achieved by an autonomously controlled exchange of information between construction machines, between each construction machine and its environment and between site management and the construction machine. The monitoring of the building processes was implemented in the form of a (mobile) "cockpit".

These solutions were developed for the SMARTSITE project in conjunction with highly experienced partners at all the relevant value creation stages of the decentralised "civil engineering" production chain. This included the development of products (construction machines, construction site networking, construction robotics) and services (provision of service-oriented platforms for site control and quality management, including a mobile app-based cockpit). The consortium thus

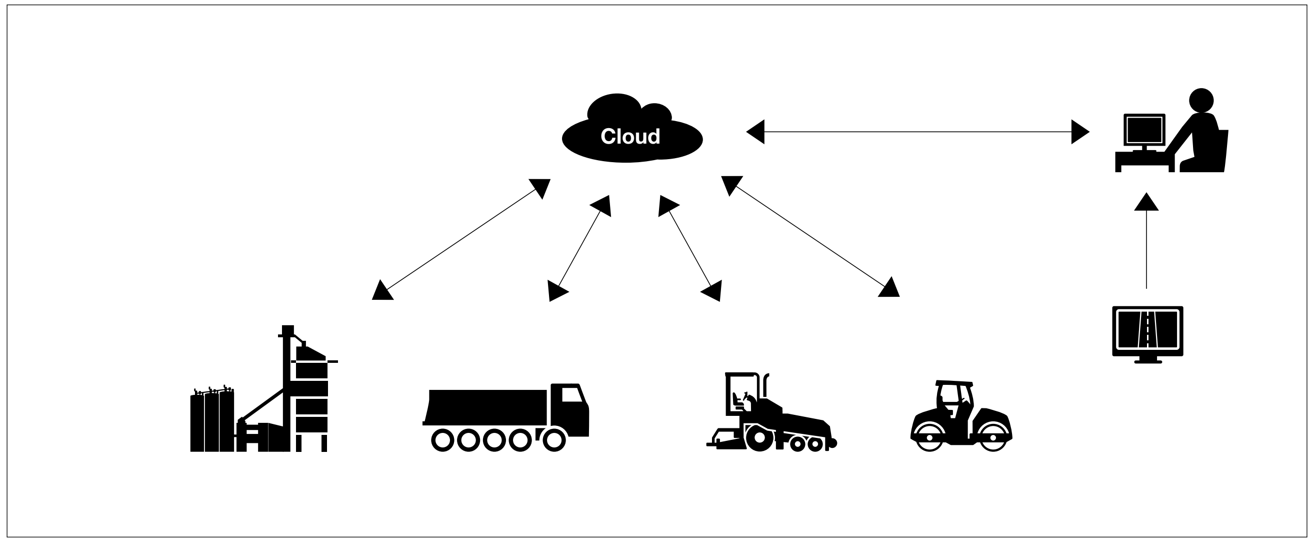


Fig.1 - End-to-end Model-based Control in Asphalt Road Construction

interpretation of structured and unstructured environmental data. Thus, for the first time, it was possible in SMARTSITE to establish a comprehensive cyber/physical system for road construction sites. This was the basic prerequisite for the covers all the relevant innovation chains for the high-level development, realisation and market-oriented testing of the targeted solutions.

2.2 - Project Consortium

The End-to-end Digitalisation of value chains in asphalt road construction can only be implemented successfully in a collaborative process, with the involvement of partners at all value creation stages. SMARTSITE therefore brought together Ammann and Topcon, two market leaders in construction equipment and construction equipment control, and Ceapoint, a software company specialising in BIM-based modelling solutions.

The construction company STRABAG/Züblin brought to the project the perspective of a user and operator of the solution. The interests of potential clients were represented by Drees & Sommer. The project results were developed in conjunction with the University of Hohenheim, an internationally renowned research institute in the design of information systems for multi-level supply chains for the individualised production of goods.

Fig. 2 - The SMARTSITE consortium

Client Perspective: Drees & Sommer		
	Planning (design and mass data acquisition), documentation, visualisation and BIM	Ceapoint, Topcon
	Logistics control	University of Hohenheim
	Machine control, especially roller and paver control	Topcon, Ammann
Testing on Construction Sites: STRABAG/Züblin		

SMARTSITE thus brought together interdependent, interacting and highly successful value chains in the areas of construction machinery, site environment, site networking and construction process monitoring and networked them in order to initiate or promote the next important steps in innovation in the road construction sector.

As a manufacturer of all types of machinery and equipment used in asphalt road construction, Ammann is in a position to provide sensor, process and quality data across the whole process chain. At the same time, Ammann is also able to provide direct access to sophisticated control systems for rollers and road pavers. Ammann's interfaces have already been adapted to some extent by market participants and thus form the ideal basis for a wide market penetration by the solutions developed in SMARTSITE.

In Cooperation with Topcon, it was possible to implement data transmission between machines, between a construction machine and its environment, and between construction machines and the construction process control system. To this end, the quality-relevant data collected by sensors was transmitted to Ceapoint's software solution for construction process control and evaluated there.

This Data is used by Drees & Sommer for construction project control and by STRABAG/Züblin to enable it to intervene in and direct the construction process at an early stage. At the same time, complete automation at machine level and at the higher logistics system level – which had never been achieved before – was supported by the coordination, evaluation and contextualisation processes developed by the University of Hohenheim.

STRABAG/Züblin and Drees & Sommer, the partners involved in using the solutions, cover the full range of applications in complex civil engineering sites. Right from the start, the research and development activities were oriented towards the utilisation planned by the industry partners. Requirement analyses and trials were carried out in real-life scenarios with the participation of experienced practitioners from the civil engineering sector.

The Results of the SMARTSITE project were evaluated and tested in two pilot road construction demonstrations under real-life conditions. For the industry partners in particular, the piloting of the solutions represented a highly relevant project goal from a marketing perspective. The aim was to test future applications of the developed solutions, especially with the involvement of small and medium-sized enterprises.

2.3 - Challenges

SMARTSITE addressed central technical and organisational challenges that until now were obstacles to the automation and networking of individual process steps.

On the technical side, there was initially an absence of a reliable high-availability communication infrastructure and of interface specifications, data formats and a common database for all stakeholders involved in construction planning and implementation.

In addition to technical innovations, this also encouraged organisational innovations, as process steps that had in the past been handled separately could now be networked more effectively than before.

It was possible to align 3D terrain mapping technologies with the planning processes, both technically and organisationally. The planning data in turn had to be of a suitable quality to enable it to be used for the control of machines and processes during construction. At an organisational level, this allows an even greater coordination of the planning and implementation process steps.

Interfaces and data models were created so that the actual data generated during construction could be fed back to the models directly and immediately. This made it possible to have model-based real-time quality monitoring of the whole construction process.

In order to Collect Data on the entire road construction value creation system, then store it and process it in a structured and targeted manner, the necessary technical conditions had to be created for data capture by sensors – or, in part, manually – and for data transmission. For this purpose, industry standards in communications networks and established cloud technologies were used.

Road construction is characterised by the interaction of a large number of stakeholders who are often legally and economically independent. The asphalt is delivered from a mixing plant to the construction site by haulage companies. In may cases, the operators of the mixing plants and multiple haulage companies are involved, in addition to the construction company. The machines and equipment used are produced by different manufacturers. As a result, the machines and equipment have specific characteristics in terms of built-in sensors and accessibility of machine parameters.

On the part of the construction company, the planning, milling and paving processes are handled by different teams using different software tools.

The Overall Picture is of a strong fragmentation of data and information resources and of the decision-making and implementation processes, leading – consciously or unconsciously; intentionally or unintentionally – to information deficits which result in a loss of efficiency and a reduction of the total value added.

In addition to the technical fundamentals, organisational steps must therefore be taken to ensure that all the stakeholders involved make the relevant information available in a timely manner. This includes, for example, loading information from the mixing plant and position information from the lorries, but also precise terrain and building models, as well as up-to-date operating data from the construction machines and vehicles being used.

In the course of the project it became apparent, among other things, that the organisational challenges in particular represent a barrier that should not be underestimated to the implementation of an integrated overall solution in asphalt road construction.

2.4 - **Economic Potential**

The competition-relevant economic potential of digitalisation relates to three different objectives *(cf. Callon 1996)*:

- Increased Efficiency: Digitalisation can be used for classical rationalisation, with the aim of reducing the required effort while maintaining the same result (quantity, quality, etc.) (minimum principle of economics).
- Increased Effectiveness: Digitalisation can also be used to maximise the result with any given effort (minimum principle of economics).
- Entirely New Products/Services for the Customer, which cannot be achieved in any other way, or only with a disproportionately large effort, and which extend the customer's competitiveness beyond its previous capabilities.

The SMARTSITE Project uses the potential of digitalisation for all three of these objectives. The systems for machine control and operator assistance resulted in an increase in economic efficiency and effectiveness.

The logistics control based on AI algorithms made it possible for the first time to automatically control the material flows without human intervention. Previously, this had only been possible with significant (manual) effort.

The new products and services resulting from the SMARTSITE innovations enable construction companies to adopt completely new approaches in asphalt road construction, to efficiently achieve the quality required by the client and to reliably demonstrate the results.

3 - Solutions

The SMARTSITE Solution collects and documents the evaluable data relating to environment, construction machine and construction process control across the whole road construction value chain – from the mixing plant to transport logistics through to the semi-automated paver and the assistance-controlled compactors.

The construction process control was supplied with data directly from the construction site. Process monitoring and visualisation took place in SMARTSITE via devices such as smartphones and smart tablets (mobile cockpit solutions) – the future working tools of the operators and site supervisors.

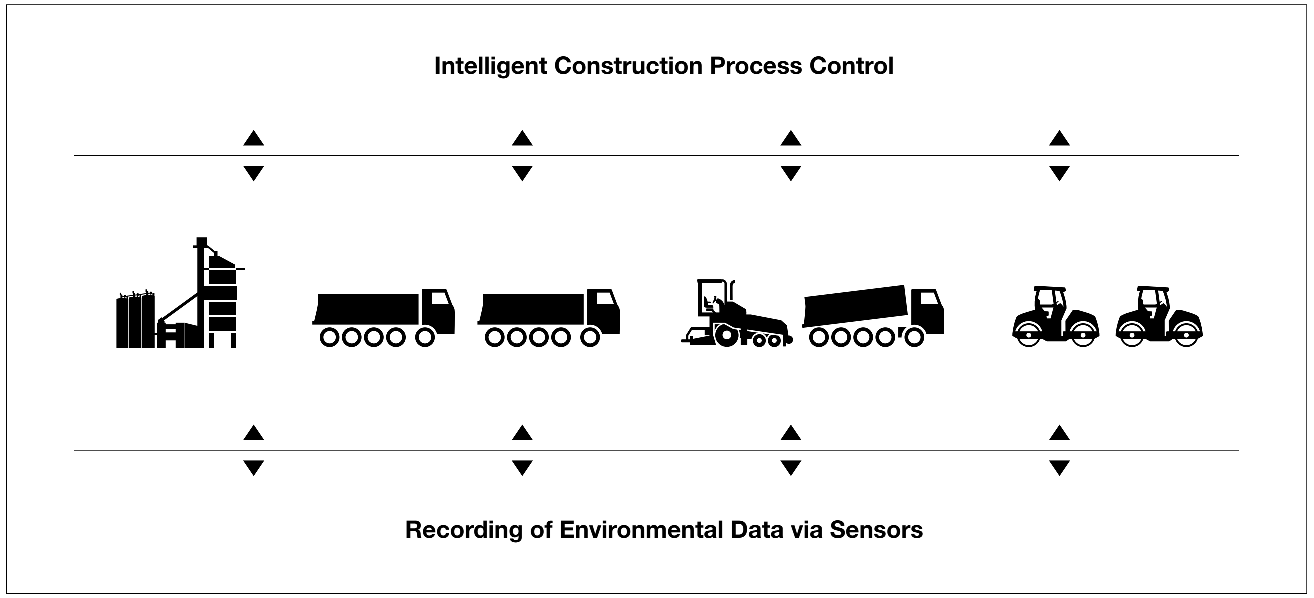


Fig. 3 - SMARTSITE Platform

To this end, SMARTSITE brought together the machine control with 6D planning data and the actual construction equipment data with the networked, digital, model-based construction process control. The result was a dynamic, bidirectional, IP-based end-to-end communication between machines and construction process control. For this purpose, the existing 6D models were structurally expanded and enhanced with the dimension of quality. Furthermore, new methods have been developed for integrating quality-relevant data into the machine control.

SMARTSITE thus supplies all industry partners with the basis for new products and services in the area of intelligent digital control, data transmission and data analysis across all plant and machinery.

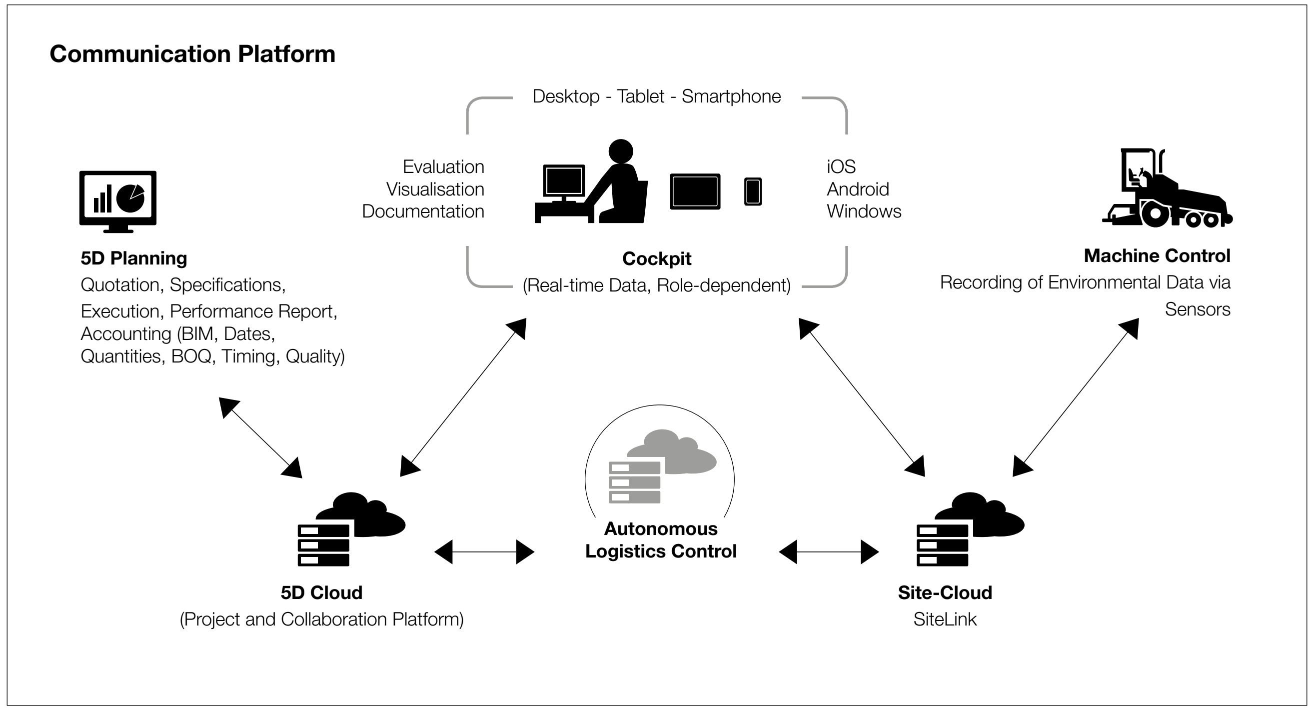


Fig. 4 - Overview of the whole Communication Platform

3.1 - **Planning, Documentation, Visualisation and BIM**

3.1.1 - **Terrain Mapping**

In order to survey the surrounding terrain and to take an up-to-date orthophoto, the area of the road to be resurfaced was overflown using Topcon UAS (unmanned aircraft system) Sirius Pro. A point cloud was derived from the photogrammetric images taken with a light aircraft, from which in turn a digital terrain model was created by meshing.

The image from the flight has a geometric accuracy of 2-3 cm, depending on local conditions, e.g. tall grass, objects, trees, shrubs and other plants. Using this recorded data, and the data derived from it, the 3D model can be enhanced with information such as crossing points, infrastructure, electricity pylons, usable areas and storage areas for construction site equipment, vegetation of the surrounding terrain etc. with a quality that is much more accurate and up-to-date than services such as Google Maps.

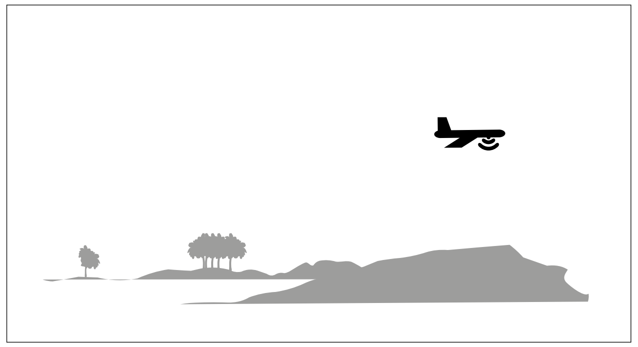


Fig. 5 - Topcon UAS for Terrain Mapping

3.1.2 - **BIM-based Modelling**

The 3D building model created with this high level of accuracy is already of assistance to the construction companies in the quotation phase. It makes it possible to draw up exact mass calculations which can be compared with the tender quantities.

At the same time, this model forms the basis for BIM-based construction, which although commonplace in structural engineering is not yet standard in earthworks and road construction. In particular, the continuous flow of digital data offers many advantages to companies working in this field:

– The construction site and the construction process can be planned and costed much more efficiently and economically thanks to the visualisation.

– Dynamic mass distribution plans can be created for earthmoving, and can then be updated automatically and in real time to reflect the loads that have actually been completed.

Lengthy planning sessions resulting in massive printouts that are rendered useless a week later by the actual conditions on the ground are now a thing of the past, as the BIM-based earthwork balance programme developed by Topcon is based on the real-life situation and is automatically updated and optimised. This has already been impressively demonstrated in the AutoBauLog research project.

– Thanks to construction site management systems such as Topcon's Sitelink3D, the current completion level is transmitted in real time to a central server and is even available via an app on a mobile phone. At the same time, Sitelink constantly calculates the current construction progress, so it can immediately tell you whether you are on schedule with your work, behind schedule or even in advance. This enables construction companies to plan their human and machine resources and the subsequent work steps much more efficiently.

3.1.3 - **Documentation and Visualisation**

More and more clients are demanding continuous digital documentation of the work being carried out. Rightly so, as construction companies can easily provide this if they are using BIM-based 3D site management systems. The advantages for the construction companies have already been demonstrated. This data can, however, also be used to demonstrate quality assurance to the client.

The current status of the work can be shown in real time not just for earthworks, but also for asphalt and concrete paving. CCC (continuous compaction control) is increasingly being required in asphalt paving. With documentation systems such as those from Topcon, you can equip all asphalt rollers with a manufacturer-independent CCC system – important in a mixed fleet, so that the machines can communicate with each other in real-time concerning passes completed, asphalt temperature and compaction dynamics used.

Visualisation of Construction Progress in Real Time offers construction companies considerable benefits for the organisation and logistics of the construction site and cost planning. Last but not least, you can give the client convincing proof of your performance.

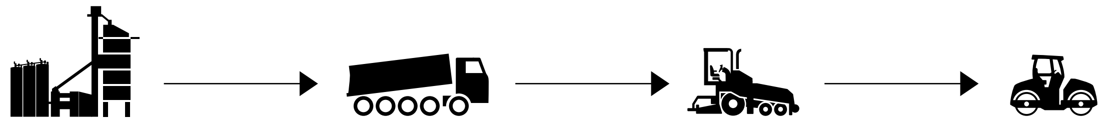
The billing process, including invoicing, is reduced to a minimum.

3.2 - **Logistics Control**

One of the central aspects of quality-assured asphalt road construction is efficient control of the logistical process. From the loading of the asphalt to the docking process on the paver, the flow of material must always be kept in balance in order to avoid standstills during paving – and the associated quality defects.

The process developed by the University of Hohenheim intervenes dynamically and in real time in the supply chain turnaround process. This was achieved firstly by dynamically assigning a new driving job to each lorry driver after the completion of a trip and then sending this job to a mobile device.

Planning	**Reality**	**Result**
Time sheets, route/time diagrams, materials planning, production planning in mixing plant	Disruptions in logistics chain caused by traffic congestion, mechanical defects, lorry breakdowns, weather conditions, etc.	No information on arrival times of lorries –> interruptions in production



Solution
– End-to-end transfer of control-relevant information from the mixing plant through to the roller.
– Use of intelligent, IT-supported processes for the end-to-end digitalisation, networking and autonomous control of construction site logistics.

Fig. 6 - Coordinated Planning across sub-processes – Execution – Logistics Control

In order to solve this problem, the University of Hohenheim developed and implemented coordination procedures that make it possible to control and optimise the entire process, from material production at the mixing plant through to compaction.

The Process Steps in road construction are highly time-dependent. As a result, in conventional paving without SMARTSITE, just-in-time supply chain procedures are already used. In road construction, this means a reduction in the queue of loaded lorries at the construction site and a smaller number of lorries required as a result of shorter turnaround times. The problem in practice, however, is that during construction the planning of a just-in-time supply chain is inadequately supplemented and updated with information concerning unexpected events, such as a lorry breaking down, and it is unable to react quickly enough to expected events, such as known traffic congestion on the lorry's route, so that a highly time-dependent supply chain leads to frequent interruptions in construction.

Secondly, a continuous review was carried out of the actual situation of the supply chain, which enabled early intervention in the event of any incidents. It was possible to achieve this by transferring data on the actual situation of the supply chain, e.g. position data from the lorries and expected arrival times at the destination, to the individual machine-based control components so that it was possible to react dynamically in both the upstream and downstream process steps.

If, for example, a lorry is stuck in a traffic jam, the expected delay can be determined using the available traffic information, then forwarded to the individual machine-based control of the asphalt paver, with the result being that the speed of the asphalt paver is reduced in order to close the gap that has arisen in the supply chain.

In Conventional Road Construction, these driving jobs are generated in advance in the planning stage, which often means that it is impossible to respond to deviations from this planning in the actual paving situation. SMARTSITE's intelligent construction process control, on the other hand, ensures that these deviations between planning and actual execution are taken into account immediately and continuously in the dynamic generation of driving jobs, ensuring a much more uniform construction process control across all the resources being deployed, even in the event of incidents such as lorry breakdowns or congestion on the approach route.

The interrelationships between optimum control of the asphalt paver and logistics control were evaluated in two scientific studies and the results subsequently published *(Müller et al. 2014)*, *(Müller et al. 2016)*. It was found that the speed control of the asphalt paver is of particular importance for the optimisation of the overall process, as this enables a flexible response to unexpected and expected events. Based on machine learning techniques, a process was developed in SMARTSITE that ensures the asphalt paver moves at the optimum speed at all times. This procedure was evaluated in a simulation study *(Meyl 2016)*.

With the development of a method for the real-time generation of time sheets, it has been possible to reduce the range of variation in delivery intervals by 99% compared to a method currently used in practice for creating time sheets. In the associated simulation study, Nill (2016) was able to show that average waiting times can be reduced by 26% and delivery intervals by 34% by means of combinatorial allocation. These methods were successfully tested in practice in the final demonstration of SMARTSITE.

The Dynamic Control of logistics in asphalt construction can only occur if the control algorithms have access to data on the actual situation in the logistics chain. For this reason, as part of the project, Ammann, together with Topcon and the University of Hohenheim, specified and implemented the SMARTSITE interface for asphalt mixing plants.

All process-relevant data of the load (delivery) in question is stored in the Topcon cloud via the "Shipment Confirmation". When the lorry arrives at the paver (unloading), the exact position and time are determined and stored. In addition, a "Delivery Confirmation" is sent back to the asphalt plant from the Topcon cloud. The whole data exchange is web-based and uses standardised REST interfaces in JSON format.

Over the course of the project, Topcon developed server-to-server communications, e.g. with TomTom, in order to include environmental parameters such as traffic congestion, delayed arrival time of lorries etc. SiteLink is based on GPRS communication from the machine to the server. To ensure the availability of faster ad hoc networks, Topcon developed and integrated new technologies, such as mesh networks.

Asphalt temperature is a key factor in determining quality in road construction. In SMARTSITE, Topcon developed a system for the seamless monitoring of this quality parameter. Firstly, the loading temperature at the mixing plant is recorded and transmitted to the cloud. During transportation to the lorry, the asphalt temperature in the trough is continuously measured via five sensors, read via a CAN interface and then transmitted to the SMARTSITE cloud.

Solutions

3.3 - **Machine Control**

3.3.1 - **Paver Control**

In the SMARTSITE project, complete 3D control of the road paver, including automatic steering, was implemented in accordance with the digital terrain model. In addition, further interfaces and sensors were developed in order to determine the paving width and height, the pre-compaction and the temperature of the mix in the paver, and to make this data available centrally. For the roller, it was necessary to create a CAN bus connection to transmit the key quality-relevant data, such as stiffness, vibration frequency, amplitude and asphalt temperature, to the construction site communication infrastructure in real time.

With SiteLink, Topcon has developed a construction site communication platform based on open standards. Machine data that can be recorded by sensors is available in a database and can be retrieved via a standardised REST interface and then analysed and processed further. However, for the collection and processing of quality-relevant data and for the integration of environmental sensors, further methodical and technical developments are fundamentally needed in order to meet the requirements in interdependent processes throughout the road construction value chain and in ad hoc networking. It is important that all the data from the individual machines can be adjusted and updated in the SiteLink platform and can then in turn be made available to all machines in real time.

Topcon supports machine operators with 3D machine control systems for the construction industry, as well as with manual systems, display systems and automated systems. Examples include automated, self-levelling lasers for terrain and interior surveying, systems for GPS-based 3D machine control (mmGPS), linking of digital terrain models to machine control, robotic total stations and an integrated satellite receiver chip (Paradigm G3) for all satellite transmission formats. Topcon systems make it possible for machines in earthmoving or road construction to use terrain models from CAD & Building Information Modelling systems and to implement this data automatically via the machine's electro-hydraulics. At present, the systems only serve to support machine operators. Further new developments in sensors and actuators would be required to make the construction equipment fully autonomous.

An automated directional and screed control system was developed for road pavers. For this purpose, paving height, longitudinal and lateral inclination and also the exact paving position were derived from the 3D model and then implemented fully automatically via the paver control system. This guarantees a precise installation of the asphalt layer in terms of height and position. In addition, this millimetre-precise control offers the possibility of accurately constructing tight curve radii and changing cross-sections. Extensive Topcon sensors on the paver ensure a continuous process of documentation and control. The data is available immediately and can be retrieved at any time from the Topcon SMARTSITE cloud. The installation process with the paver is closely linked to the downstream compaction phase.

In this area, the sensor/actuator platform on machines such as pavers and rollers was specified and implemented in close cooperation with Ammann. This extends the capabilities of existing CAN bus-compatible systems. Corresponding extensions to hardware (sensors/actuators) and software (sensor/actuator data interfaces) were specified, developed and tested for the defined road construction machine types.

The functionality of all interfaces, data flows and machine controls was confirmed emphatically and comprehensively during the final demonstration. One example of the Topcon developments in this area is Sitelink Enterprise with real-time visualisation of the actual machine data compared to the 3D model.

Fig. 7 - Operator View on the Paver with all Process-Relevant Information

Asphalt temperature is a key factor in determining quality in road construction. In SMARTSITE, Topcon developed a system for the seamless monitoring of this quality parameter. An important aspect in this connection is the paving temperature behind the screed. For this purpose, Topcon developed a temperature scanner (based on two thermal cameras) which records the temperature over the whole paving width. These measurements are then transmitted to the subsequent rollers via the cloud to ensure that cooler spots are compacted first. To complete the circle, each roller also records the surface temperature during the compaction process.

Fig. 8 - Temperature Scanner and Operator View

Topcon integrated a local weather station within the construction process control; the data from this station is continuously transmitted to the cloud and can thus be documented. In extreme conditions, the construction process control reacts accordingly and in extreme cases can recommend that paving should stop.

3.3.2 - **Comprehensive Compaction Control**

During the compaction process, the newly developed Topcon roller system records and documents the number of roller passes and uses satellite technology to precisely locate each passed and compacted surface. The number of passes can then be translated into a colour coding of the asphalt surface. The same applies to the asphalt temperature and the measured degree of stiffness, which is read in via the Ammann CAN interface and transmitted to the Topcon cloud. The colour coding is visible both in the documentation and on the user interface of the Topcon roller control unit.

Fig. 9 - Operator View of the Roller Control Unit

The data available on the Topcon servers was used by the University of Hohenheim to derive control commands for the rollers. The asphalt temperature, the compaction energy that has already been applied, the number of passes already made, the position of the paver and the positions of the other rollers are incorporated in the calculations. The resulting optimum rolling path is transmitted back to the roller control unit and displayed by means of a polyline.

Fig. 10 - Recording of Temperature Measurements from the Rollers

With regard to compaction machinery, the technical basis required for autonomous, ultimately operator-less machines already exists. The current control and networking technologies enable the practical implementation of such machines under narrowly defined conditions. The principal machine in the road construction process continues to be the road paver.

Solutions

This machine contains the highest density of preliminary information from the paving process, which may be important for the subsequent compaction rollers. With the smart exchange of information, it should be possible to calculate overall process information for the correct compaction procedures in order to execute these immediately in real time. The compaction machines are the last items of equipment on the construction site before the arrival of traffic and are thus responsible in their sub-process for ensuring an effective end result. The machine operator checks and monitors the paving and compaction process. He/she is supplied with so much information by the system that he/she can perform these tasks very easily and safely, avoiding both over-compaction and under-compaction.

Various approaches may be found in the literature for assistance systems for roller operators and for the automation of rollers. These approaches are based predominantly on static rolling paths that are planned in advance and do not contain any opportunities for responding to the variable environment by means of dynamic decisions and reactions. The real-time acquisition and processing of sensor data as well as the underlying environmental factors are often also not taken into account.

The use of machine learning processes has great potential for the development of autonomous systems in complex environments. Learning in software systems is divided into three sub-areas **(1)** representation of a knowledge base, **(2)** evaluation of plausible results, and **(3)** selection of the "best" result *(Domingos, 2012)*.

The goal in a Learning Software System is to learn a desired behaviour of the system in its environment in such a way that a set of target criteria are met in optimal fashion *(Bianchi, Celiberto, Santos, Matsuura, & Lopez De Mantaras, 2015)*. Ammann developed a machine-based interface in SMARTSITE to collect the relevant data for event-oriented process control. In addition, support tools were developed for the construction site guidance system or the process control in order to guide the networked machines (and machine operators).

With little effort, the defined work can be performed while at the same time optimally delivering the required result.

A corresponding assistance system was implemented and tested. The comprehensive documentation of the work that this makes possible can be used to confirm that the work has been carried out according to instructions and specifications.

The system controls the construction site process in real time and can therefore react comprehensively and at the earliest possible moment in all phases of construction. Based on the common use cases that were specified and implemented during the project, it was possible to simplify the information flows and increase the information content. Thanks to the rationalisation of work processes that was now possible, a significant increase in efficiency could be demonstrated. This is another result of the work that has been performed.

In the project, it was possible to show how the networked construction site process generates measurable added value for the overall result. To achieve this, two development goals were pursued:
(1) the prototypical implementation of a operator assistance system, which supports roller operators in their work with intelligent recommendations, and **(2)** the creation of a functional pattern for an autonomously moving roller, which converts the driving recommendations directly into machine kinematics.

Operator Assistance System: The operator assistant on the compaction roller guides the operator in performing the required compaction work efficiently and in a process-optimised manner. In simulations and on test construction sites it was possible to demonstrate that with consistent implementation unnecessary roller passes could be avoided and process efficiency could thus be significantly increased. In addition, the more homogeneous finishing of the surface simultaneously increases the quality of the end product.

"Autonomous Roller" Functional Pattern: The initial goal of developing a prototype of a self-propelled roller was achieved in full and functionally demonstrated during the final demonstration. The necessary preliminary work, including all machine assemblies, all interfaces and connections to the machines and all implemented decision models for specifying driving commands, was completed and forms an excellent basis for further product developments.

The sensor/actuator infrastructure required for both development goals, either as an extension or based on conventional road construction machines and machine controls, was implemented on several rollers. In addition, it was possible to create a manufacturer-independent specification by installing the system in a fully operational manner on a machine (paver) available on the market from a manufacturer that was not a member of the consortium.

The Autonomous Machine Control System was initially implemented on the paver in close cooperation with the consortium partner Topcon. The knowledge acquired was then transferred directly to the rollers' driving and steering automation systems. In addition to the kinematics, a further process has to be taken into account in automated roller control which a human operator can implement without any problems.

Trouble-free, fine rolling must always be guaranteed on hot asphalt. In particular, when braking or when rolling out, the machine control should also check and limit the changes in the driving and control commands received. The roller should perform the change in direction as smoothly as possible. Only events that would normally lead to an emergency stop or reaction should cause the same result in an autonomous state.

As Compaction by asphalt rollers is the final step in asphalt paving, it has a decisive influence on the quality of the road surface. The homogeneity of the compaction achieved, taking account of specifications such as the road profile, directly determines the durability of the pavement. For this reason, the coordination of the asphalt rollers in relation to the work progress of the upstream asphalt paver and the environmental conditions (asphalt temperature, weather) is of crucial importance.

The asphalt rollers' room for decision-making is restricted by the properties of the asphalt to be compacted. For example, abrupt changes in speed or steering movements should be avoided, as the resulting shear forces may damage the hot asphalt, which is still easily malleable.

To deploy the available asphalt rollers in the best possible manner, the following functions must be optimised:

- Highest possible homogeneity of the passes.
- Minimum number of passes or compaction at any point on the carriageway.
- Minimisation of speed changes and steering movements on hot asphalt.
- Constant distance between the asphalt rollers and the asphalt paver.
- Use of vibration *(only if this will not damage the asphalt).*

This Optimisation must be possible with either one roller or multiple rollers, where the rollers may be active in one or more rolling areas (compaction zones defined by the average distance between the active rollers and the asphalt paver). Since the temperature of the asphalt applied by the paver may change during the paving process – and there may also be differences along the width of the carriageway – and the cooling behaviour is influenced by the weather and by the passes that have already been made, a precise planning of roller behaviour in advance is not expedient. In addition, mechanical inaccuracies, changes in the behaviour of all the machines involved in the process and deviations by the human operator from the target behaviour may lead to discrepancies. For this reason, a control (planning) of the asphalt rollers in Real Time is indispensable, irrespective of whether this takes the form of an assistance system or a fully autonomous device.

Fundamental safety precautions had to be defined and implemented for the Fully Autonomous compaction roller. The system has been enhanced with LIDAR sensors that monitor the environment in front of and behind the machine. The safety system reacts adaptively to static and mobile objects located in the dynamically definable danger zone. The machine cannot be put into "autonomous drive" mode while a potentially dangerous or endangered object is in the defined reaction area. If the machine is in "release mode" and an object is detected, either the machine will be slowed down if the object is moving sufficiently fast through the danger zone that a collision can be avoided, or an emergency stop will be executed if the detected object is not moving and there will definitely be a collision.

The Path Guidance System for human operators may be described as a product that can be put into immediate use, having been developed as a working prototype during the SMARTSITE project and tested live on the roller during the "final demonstration".

This Assistance System supports individual operators in their work. If used correctly, it already leads to an optimisation of the processes and to increased efficiency and quality of the individual roller system.

This optimisation must also be possible with multiple asphalt rollers and must be able to take account of the change in the temperature of the asphalt applied by the paver during the paving process. In addition, mechanical inaccuracies, changes in the behaviour of the asphalt paver and deviations by the human operator from the target behaviour may lead to discrepancies that need to be detected and remedied. As a result, ongoing planning of the asphalt rollers in real time is essential.

In collaboration with Ammann, the University of Hohenheim developed in SMARTSITE a Novel System for the path planning of asphalt rollers in real time *(Künzel et al., 2015 & 2016)*. The overriding goal of the system is to maximise the quality of the asphalt surface. The developments were tested in simulation environments and in the field.

The path guidelines generated to guide the human roller operators are transmitted as an ordered list of GPS coordinates in WGS84 format with distances ranging from a few centimetres to a few metres *(depending on paver speed and course of the road)*. Figure 28 shows an example of a path guideline that was generated and submitted during the final demonstration, displayed on a road map. There is also a path as it appears to the human operator on the roller. In addition, as the human operator approaches the end of the target path, driving away from the paver, the next path is displayed to facilitate smooth transitions between the rolling paths.

The system is able to respond to changing environmental conditions, asphalt properties and process parameters, thus minimising the effects on road quality of any disruptions in upstream process steps. The system's potential and the ability of human operators to implement the instructions were demonstrated in simulations and in the final demonstration.

4 - SmoothRide – Road Resurfacing *(Utilisation)*

The traffic congestion caused by maintaining infrastructure means that innovative, efficient, high-quality road resurfacing is becoming ever more important. Against the background of construction in flowing traffic and the resulting traffic disruptions, special requirements are placed on the organisation and implementation of road resurfacing measures.

1. Recording the road surface using a scanner
2. Planning
3. 3D milling work with variable depths
4. Rescanning the carriageway, if necessary
5. 3D asphalt paving
6. Compacting the asphalt layer
7. Scanning the newly paved carriageway

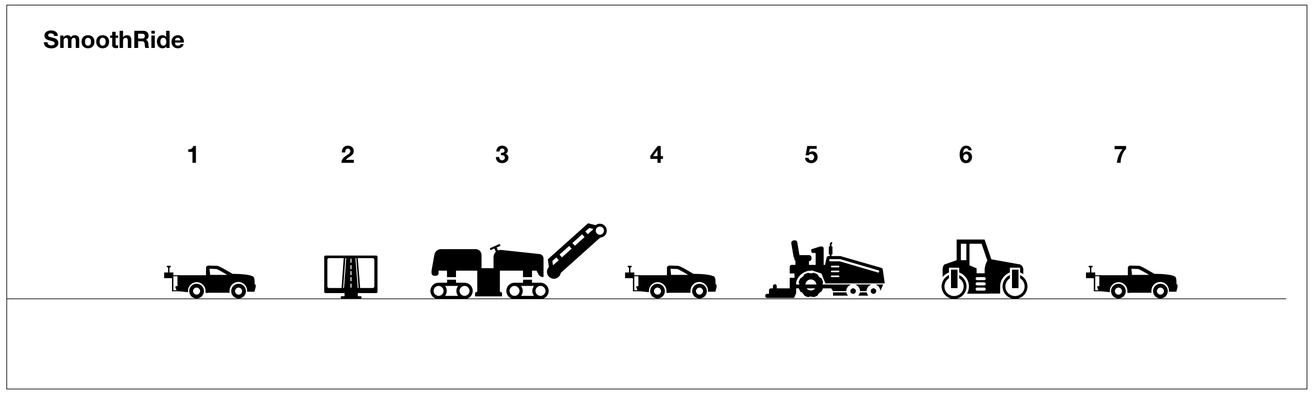


Fig. 1 - SmoothRide

To date, the greatest difficulties associated with construction on existing roads and in flowing traffic include:

- Data acquisition with very low point density.
- Inaccurate quantity surveying.
- Lane closures required for data acquisition long before the start of milling work and therefore additional traffic disruptions.
- Low level of occupational safety when surveying in flowing traffic.
- Achieving the required longitudinal and transverse smoothness.

The findings from the SmartSite research project enabled Topcon to implement a completely new approach to tackling these challenges: the fully integrated SmoothRide process for efficient, quality-assured road resurfacing. Aspects of safety and accuracy, as well as quality and cost, are taken into account in an overall working process. To this end, SmoothRide defines seven individual steps which have been coordinated and integrated for the first time in a comprehensive system *(Figure 1)*.

Although the integrated SmoothRide system developed by Topcon brings great benefits for road constructors, it cannot eliminate the efficiency or quality issues caused by incorrect practices. Before the system is installed and used, the technical principles of asphalt paving therefore not only need to be known and understood, but actually implemented in the construction process.

A smooth, level and safe road surface is the calling card of every asphalt construction company. Asphalt paving is teamwork. All employees involved in the planning and paving process must have received in-depth training to ensure correct results. With a well-trained paving team and the integrated SmoothRide system you can produce excellent asphalt pavements. This results in significant increases in efficiency, perfect surfaces and long road service lives.

4.1 - **Recording the Road Surface Using a Scanner**

The existing carriageway is scanned with the RD-M1 laser scanner. Scanning is possible with almost any standard vehicle. This means that the entire road surface and its lateral environment can be recorded in flowing traffic *(Figure 2)*.

The scanner allows travelling speeds of up to 80 km/h and also works under a wide variety of climatic and geographical conditions. Road closures for data acquisition are therefore in general not required, so that traffic hold-ups can virtually be ruled out.

Fig. 2 - Mapping the Road Surface Using an RD-M1 Scanner

The scan data is used to generate a 3D model, which contains horizontal and vertical projections, cross-sections and information on the condition of the road surface. This data forms the basis for the design planning of the asphalt surface to be renewed.

4.2 - **Planning**

In the next step, the high-precision mapping of the existing carriageway generated from the scan is used as the basis for planning the new road surface. Based on the available seamless information on the actual condition of the existing carriageway, the exact quantities of milled material and the actual requirement for asphalt can already be reliably calculated during the planning phase.

For design planning, the SmoothRide software offers open interfaces to practically all standard planning tools. It contains special, comprehensive tools for resurfacing planning and optimisation. SmoothRide does not require any special training. It is easy to operate and requires only a basic familiarly with road surfacing work and a knowledge of road construction.

The model (design) created in this way serves as a height reference for the ultrasonic sensors on the machines.

The program system offers the following options:

- Import of DWG/DXF, text and many other common file types.
- Various views for seeing detailed information on the condition of the carriageway.

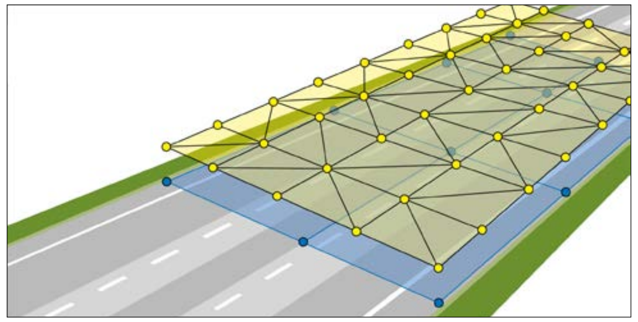


Fig. 3 - The 3D Model for the Milling Machine

- Road reconstruction with quantity calculation.
- Fast calculations for optimised longitudinal and transverse gradients, transitions, milling surfaces and compensation areas.
- Generation of machine control data for the Topcon systems.

These two models, the existing carriageway and the new road surface *(Figure 3)*, are then transmitted to the machine control.

4.3 - **3D Milling Work**

In road resurfacing projects, the process usually begins with the milling of the existing carriageway *(Figure 4)*. For automatic control of the milling depth, two GPS antennas are mounted on the milling machine. These serve exclusively to determine the position (x,y coordinates) of the machine on the carriageway.

The actual control of the milling depth takes place via a continuous relative calculation between the existing road surface model and the model of the milling surface to be produced.

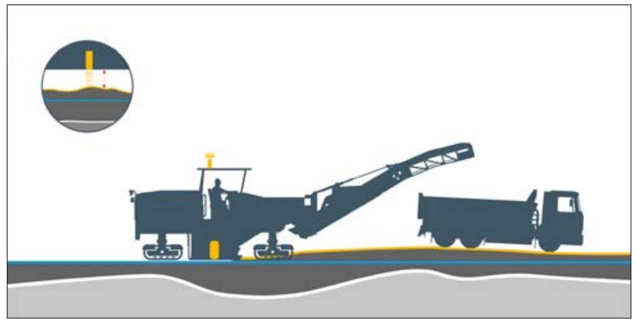


Fig. 4 - The Milling Process

The combination of precise position determination and continuous calculation of the milling depth required in relation to the current position enables the highly accurate generation of completely smooth milling surfaces thanks to a just-in-time continuous adjustment of the milling depths. This means that the minimum paving thicknesses can be guaranteed in all cases, while at the same time excessive or insufficient paving can be avoided. Each millimetre reduction in (unnecessary) layer thickness represents significant savings.

4.4 - **Rescanning the Carriageway**

After completion of the milling work, the newly created milled surface can now be scanned again with the RD-M1 laser scanner to create a highly accurate 3D model of the actual properties of the new surface. This step is optional, but relevant if existing irregular milled surfaces are to be asphalted or if the paving has to be carried out on surfaces that have not previously been milled, e.g. in overlay resurfacing.

4.5 - **3D Asphalt Paving**

For the paving work itself, both the existing model generated from the carriageway scan data and the new model of the road surface to be produced are required. In this case, the paver is also equipped with two GPS antennas for position determination. Ultrasonic sensors are used to control the paving thickness.

The yellow line in Figure 5 represents the existing carriageway, the blue line is the target design and the red dashed line is the surface after the paving screed.

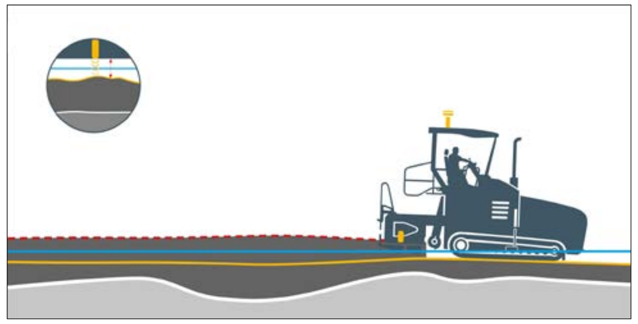


Fig. 5 - 3D Asphalt Paving

The red dashed line exhibits “waves”. The reason for this is that with all currently used paving methods and machine control systems any “waves” present, although attenuated after the paving process, will nonetheless still be found in the longitudinal direction. This results from the fact that the mix displays different compaction behaviour for different paving thicknesses during the subsequent rolling.

With high-precision information on every area of the existing carriageway and working with relative heights, SmoothRide enables construction companies for the first time to perfectly compensate for these waves during paving by precise fine-tuning of the paving thicknesses. This is made possible by the highly accurate 3D model of the surfaces to be asphalted, based on the laser scan, and the addition of a percentage compacting factor relative to the layer thickness. Once the compaction work has been completed, the result is an excellent, perfectly level asphalt surface course.

4.6 - Compacting the Asphalt Layer

After the paving, SmoothRide monitors the whole compaction process in combination with Topcon's intelligent compaction system. The number of passes required (determined, for example, from measurements with the Troxler probe) can be specified to the roller operator.

The compaction system then counts each pass and indicates when the optimum number of passes has been reached. The compacting work performed by the roller team is visualised in an easy-to-understand display and is available in the cloud for subsequent documentation.

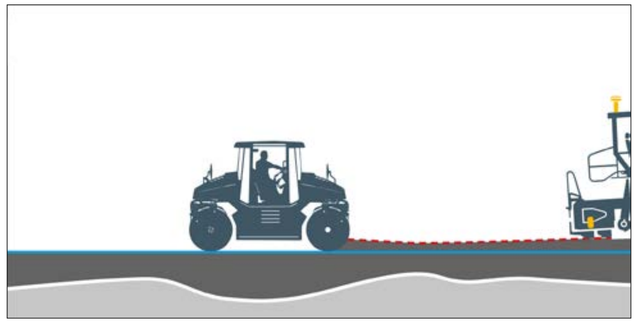


Fig. 6 - Compacting the Asphalt Layer

4.7 - Scanning the New Carriageway

On completion of the road resurfacing work, the new carriageway can be scanned again in the seventh and final SmoothRide process step for quality control.

This completes a comprehensive end-to-end digital workflow that is perfectly documented throughout with high-precision data, both on the implementation of the seven process steps and on the results achieved. This is of ever-increasing importance with regard to Construction 4.0 and BIM!

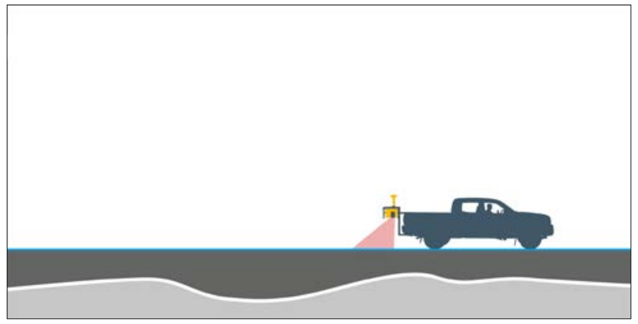


Fig. 7 - Scanning the New Carriageway

5 - Pavelink – *(Utilisation)*

Following the successful completion of the SMARTSITE research project, the next step for Topcon was to develop a new product, Pavelink, for self-learning networked control of the entire asphalt road construction process. This system monitors and controls the asphalt paving process, from mass data acquisition, planning, asphalt mixing plant, logistics chain, paving, compaction through to quality control – and all in real time:

Topcon decided to look at the overall work process. The aim was to make all the necessary information available in real time and at any time, to enable an immediate intervention in the process, if required.

It should, furthermore, be noted that a large number of stakeholders involved in the process need to be provided with a wide variety of information. For example, the mixing plant operator needs different information from the lorry driver or the paving site manager. All these stakeholders, their individual tasks and work processes, as well as the associated necessary coordinating activities, must be addressed by the process control.

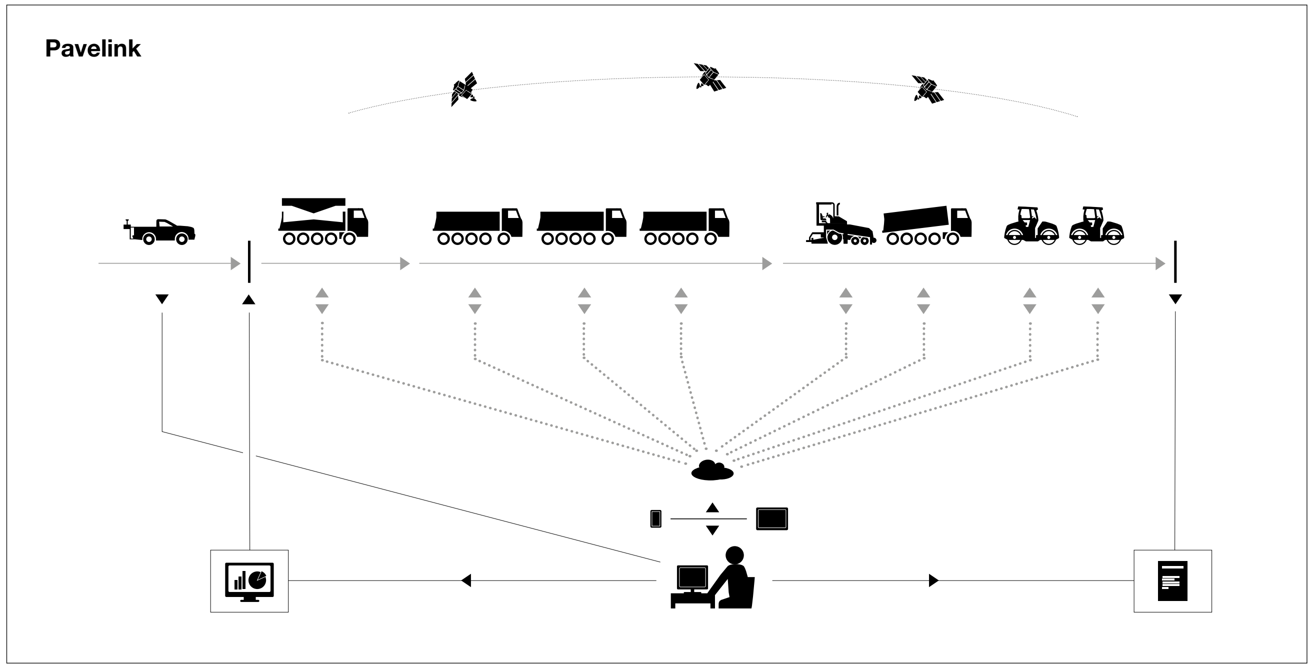


Fig. 8 - Pavelink

In the course of the SmartSite research project, investigations into existing monitoring systems available on the market in the area of asphalt road construction showed that they focused predominantly on the logistics process. From Topcon's perspective, however, the logistics process is only one part of the overall work process.

In addition, the daily analysis of the data reveals whether stoppages or interruptions have occurred in the asphalt paving. The data from logistics control arrive too late, however, to enable an active intervention in the process.

With the experience gained from the SmartSite research project and numerous asphalt paving projects carried out worldwide,

To achieve this, the Pavelink product comprises the following subcomponents:

- Mass data acquisition, quantity calculation
- Mixing plant
- Logistics
- Construction site, paver, rollers
- Evaluation, reports

5.1 - **Mass Data Acquisition, Quantity Calculation**

The overall process begins with the calculation of quantities for the asphalt paving. Every company has information on the required material quantities and the geometry of the carriageways to be produced. This information is either derived from the costings or there is a pavement design specification.

Pavelink uses the information that is already available for the planning of the asphalt paving. It does this without, as has been standard to date, a new quantity calculation, which is often performed manually to a greater or lesser degree.

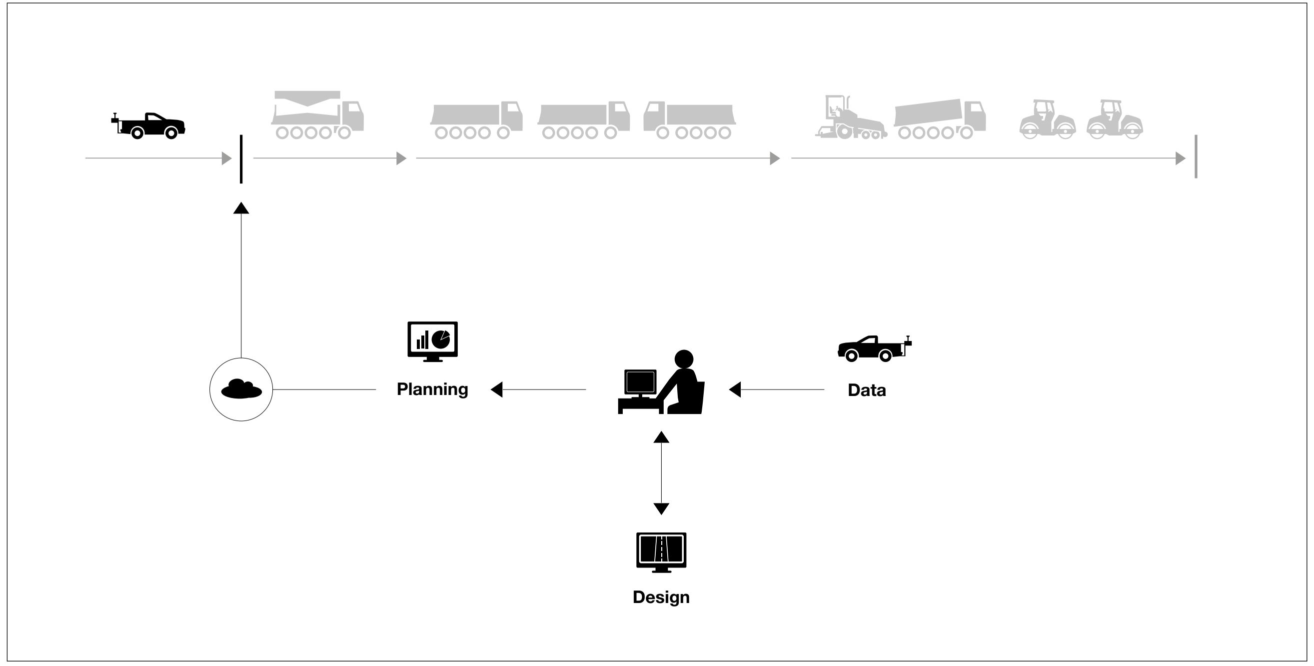


Fig. 9 - Quantity Calculation with Pavelink

5.2 - **Mixing Plant**

Pavelink obtains all the necessary information from the mixing plant via digital interfaces to the weighing systems. All weigh tickets are available digitally as PDFs and can easily be sent to customers and to internal archives. Furthermore, all the data on the delivery note is available digitally as a spreadsheet and via direct database connections.

Pavelink supplies the mixing plant, the logistics chain and the construction site with all the relevant information in real time. How much material has already been loaded and what still needs to be delivered, whether there are any disruptions in the logistics chain or in the paving operation, and much more. This ensures at all times that production can be reduced or stopped in the event of a disruption in the process.

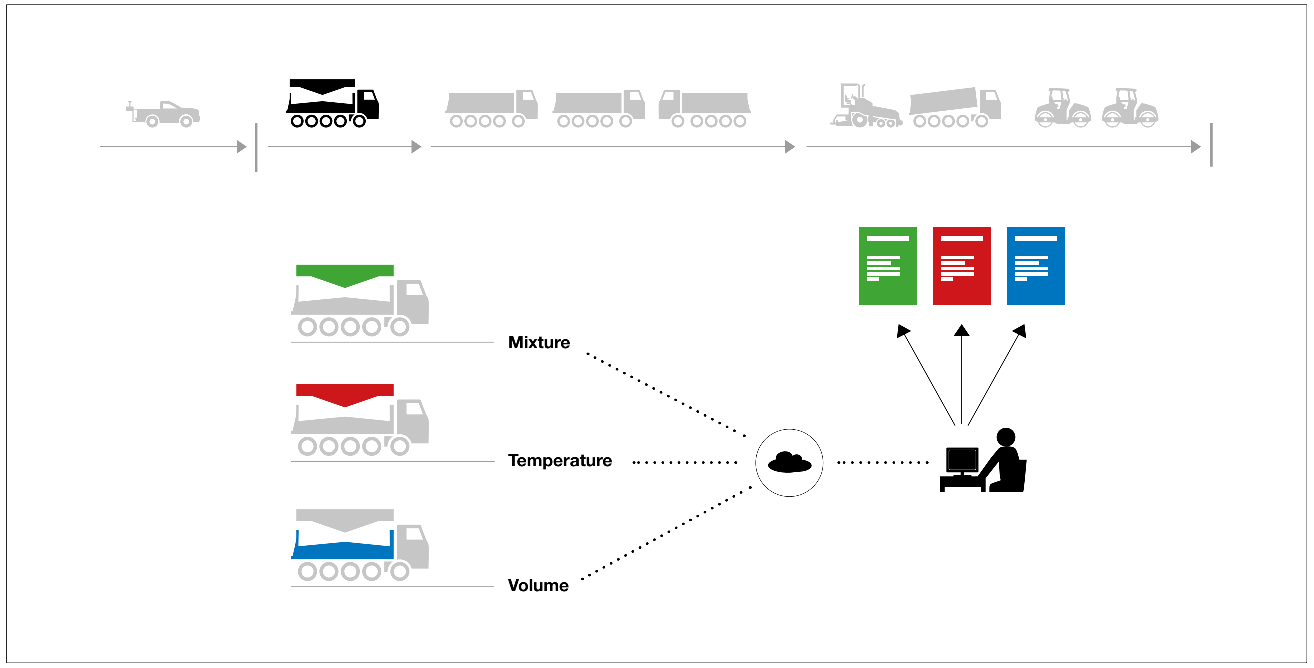


Fig. 10 - Connection of the Mixing Plants in Pavelink

Pavelink

5.3 - Logistics

The first step is to create a “timing plan”. Based on this plan, the required vehicles are then scheduled in connection with the planned turnaround times. When generating the plan with Pavelink, the user can immediately see, for example, what toll costs will be incurred and whether it might therefore make sense to choose an alternative route.

The logistics control works dynamically, i.e. any deviation from the original plan, traffic congestion, accidents, defective machines on the construction site etc. are recorded in real time and information sent to all stakeholders in the process via the system. Furthermore, the system is “self-learning”. This means, for example, that it recognises daily traffic

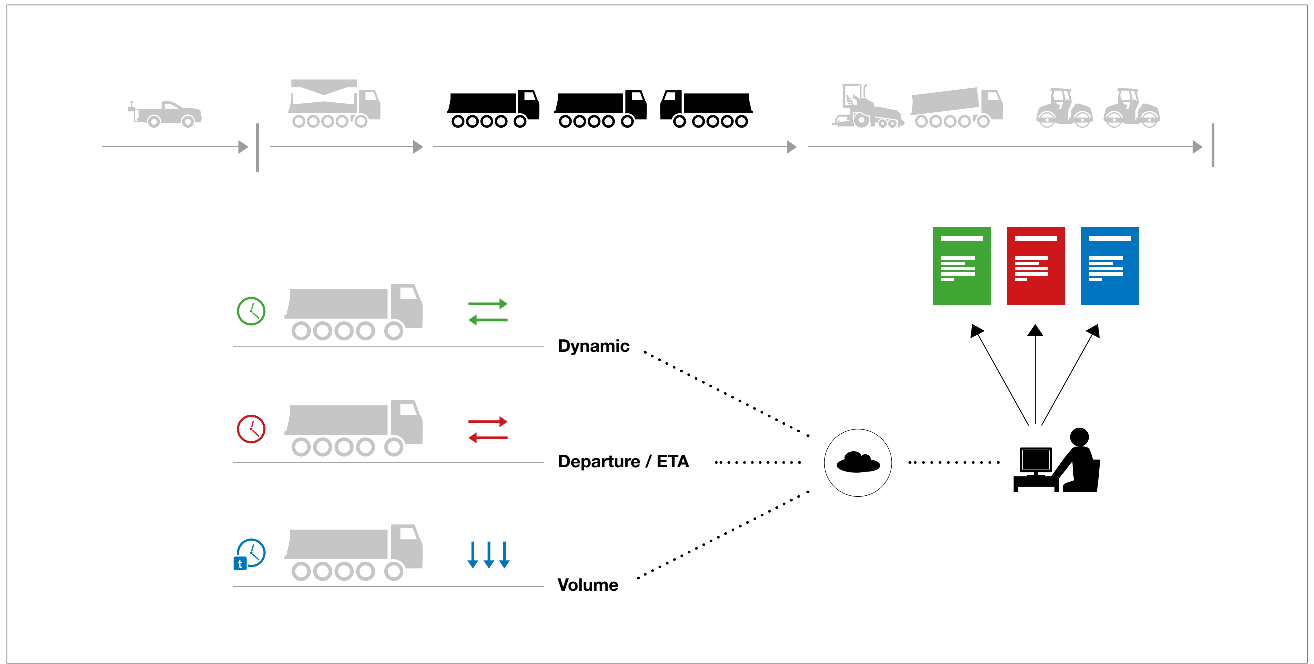


Fig. 11 - Logistics Control with Pavelink

All the “time stamps” are visible:

- Arrival at mixing plant
- Loading time and duration
- Departure to and arrival at the construction site
- Unloading at the paver
- Leaving the construction site

Naturally, data from other tracking systems, such as TomTom or FleetBoard, can also be used to determine the vehicles' positions.

With all this information, it is possible to generate a highly accurate analysis of downtimes, reasons for machine standstills, etc.

congestion times and proposes alternative routes or times for the subsequent paving days. The more information a user stores over a longer period of time, the greater will be the efficiency of the logistics process control. As with the digital weigh tickets, all the information is available digitally and can be used, for example, for daily invoicing or for accounting purposes with the logistics company.

The Pavelink logistics control makes it possible to optimise the number of vehicles used, provided that the paving can still be carried out without any logistics-related downtime and with a reduction in vehicle costs.

5.4 - Construction Site, Paver, Rollers

The Paver is equipped with a tablet computer, which in the base version also supplies the paver's GPS position. If the loaded lorry docks on the paver, it is detected by a sensor mounted on the paver. All information, such as vehicle, mix quantity, loading temperature, unloading position and paving position, is thus recorded in real time.

- Asphalted surface
- Material consumption/m²
- Built m² per lorry

If the paver is equipped with a Topcon 3D machine control system, not only are the exact paving thicknesses available,

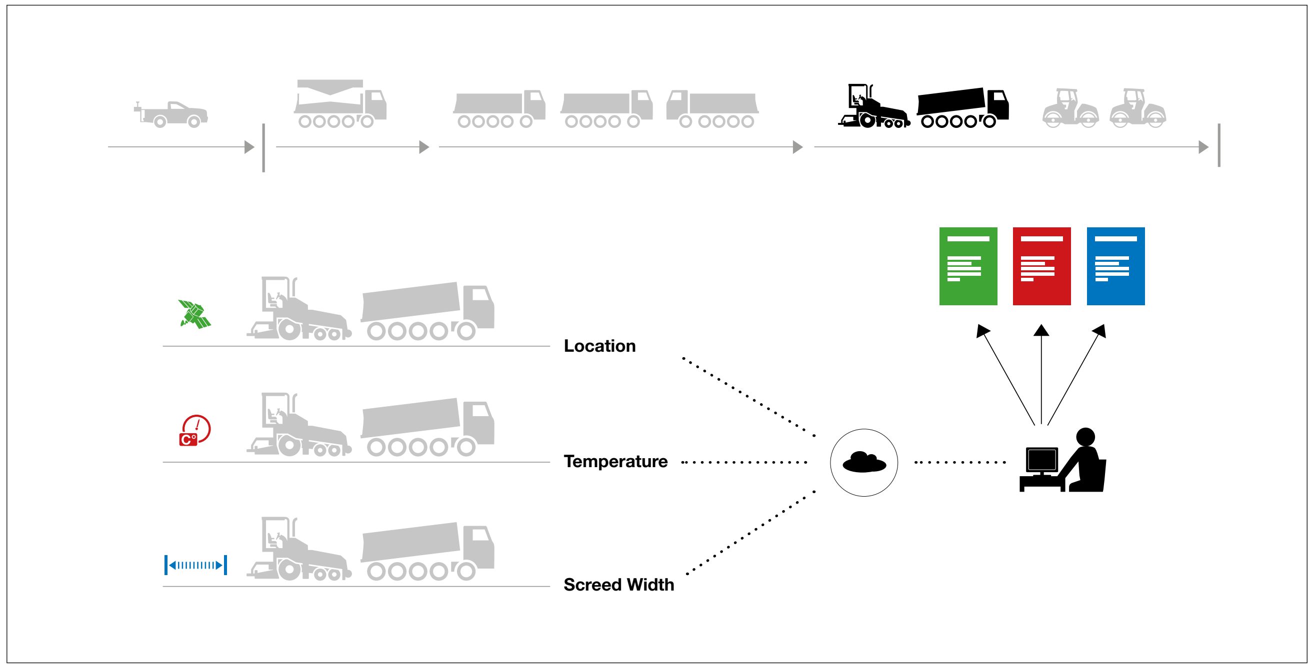


Fig. 12 - The Pavelink Paving System

If, however, the paver is equipped with the Pavelink sensor kit or if there are interfaces to the machine control, all paving-relevant data will be recorded automatically:

- GPS position
- Paving speed
- Surface temperature of the substratum
- Mix temperature, i.e. the core temperature before the paving screed
- Screed width, and therefore paving width, at every position on the construction site

but in the event of over- or under-paving it is known in real time whether this deviation results from the width or the thickness. This can be immediately remedied in a targeted manner.

If the Topcon Thermoscanner is also mounted on the paver, the temperature will be recorded directly behind the screed. Cooler areas can be recognised immediately. This information is transmitted in real time, i.e. immediately to the rollers equipped with the Topcon intelligent compaction system, so that they can compact these areas as a matter of priority.

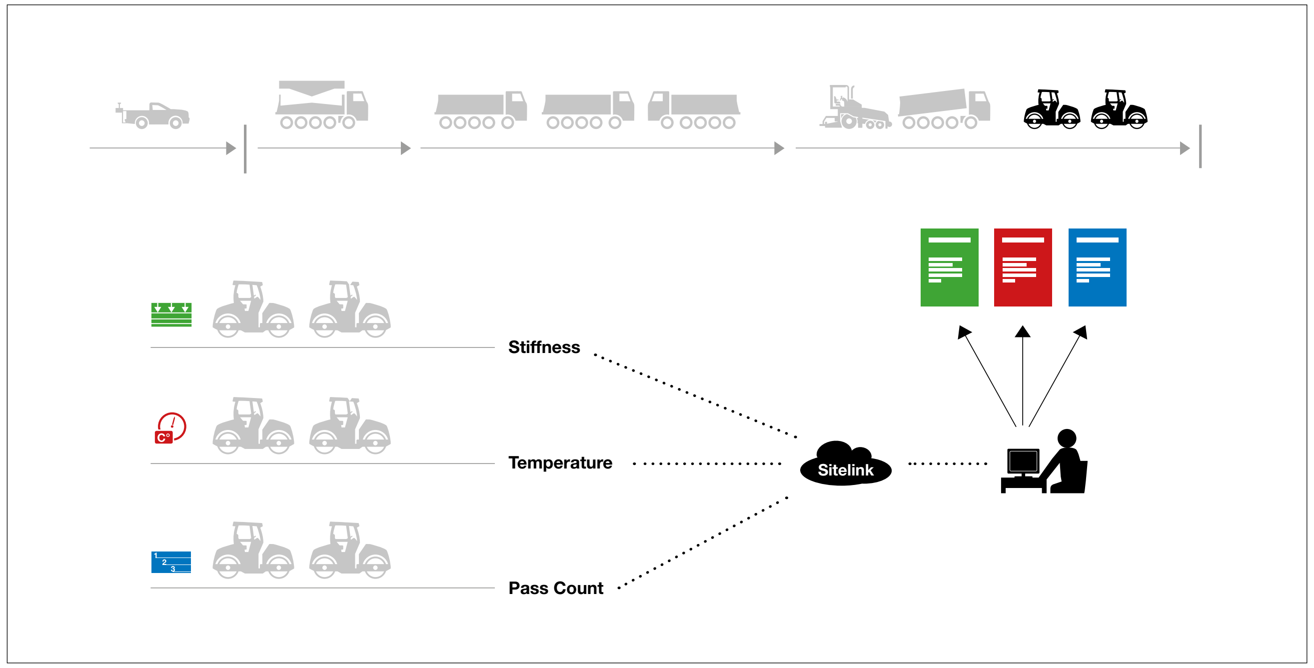


Fig. 13 - The Pavelink Compaction System

The compaction system also records the number of passes, the stiffness of the asphalt and the surface temperature.

All rollers involved in the process are connected to each other via Sitelink. This means that over- or under-compaction is almost impossible.

5.5 - Evaluation, Reports

With Pavelink, all the information on the whole process is available digitally and centrally. This gives rise to many new possibilities for detecting and eliminating areas of weakness, for reducing costs and for increasing productivity. Delivery notes no longer need to be collected and sorted in order to then generate an invoice manually, after a significant time delay. Dynamic self-learning logistics control increases efficiency from project to project. Pavelink provides accurate evidence of quality control, both internally and for your clients.

(Construction Site)

- Arrival time, unloading time and departure time
- What material has been laid at what position and at what temperature
- Material consumption, target/actual comparison
- Productive and unproductive times on the paver

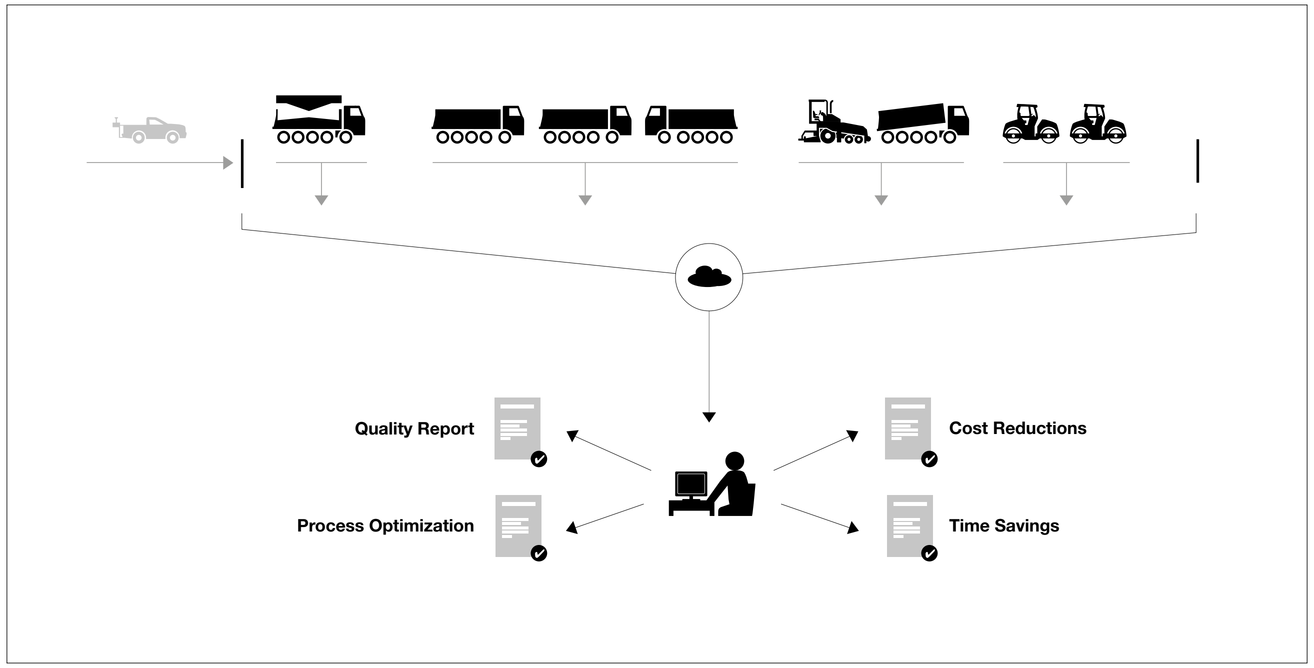


Fig. 14 - The Pavelink Reporting System

Some examples of reporting:

(Mixing Plant)

- Arriving and departing lorries - including standby and waiting times

(Logistics)

- Proof of each individual trip
- All trips to a construction site
- All trips by a particular company
- Standby, waiting and break times
- Toll costs

These are just a few examples of the possibilities that Pavelink offers for optimising your processes. In the past, each stakeholder involved in the process had their own priorities, documents and databases for reporting and evaluation.

With Pavelink, this information is brought together for the first time in a separate knowledge base and, unlike previously, the individual items of information and their interrelationships can be evaluated in detail. This opens up almost infinite possibilities for making the overall process and the numerous sub-processes better, more efficient and faster in the future.

6 - Appendix

6.1 - **List of Figures**

SMARTSITE *(Project)*

SmoothRide / Pavelink *(Utilisation)*

6.2 - **Literature**

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6.4 - Comments in the Press

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6.5 - Websites

http://smartsite-project.de
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SMARTSITE and Utilisation

Gefördert durch:

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