Project no. 34732

INDISPUTABLE KEY

Intelligent distributed process utilization and blazing environmental key

Instrument: IST

Thematic Priority: 2

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Final report

Indisputable key

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Final report

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This report presents results from the EU Integrated Project of the Sixth Framework Programme, Priority 2, Information Society Technologies, n° 34732: INDISPUTABLE KEY – Intelligent distributed process utilisation and blazing environmental key.

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Did you know?

Key facts about the forestry and wood industries in Europe.

- Forests in the EU account for only 5% of the world's total, but the forest-based sector in Europe produces 25–30% of the world's forest based products.
- The sector accounts for 8% of the manufacturing added value in the EU.
- The wood working and pulp and paper industry provide millions of jobs with a production value exceeding €500 billion.
- 171 million ha of forest in Europe accounts for 41% of its land area.
- Most of the forests in the EU are privately owned and there are at least 16 million private forest owners in Europe.
- The amount of wood and biomass in Europe's forests is on the increase.
- Europe's woodworking and furniture industry is highly diversified, producing products ranging from sawn wood, wood-based panels, joinery and wooden packaging.
- The wood products industry in Europe comprises over 340 000 companies employing close to 3 million people.
- The European pulp and paper industry is a global market leader, producing 27% of the world's paper and board.
- The pulp and paper industry in EU contributes €21 billion to the gross domestic product.
- There are around 1200 paper and pulp mills in the EU that directly employ about 260 000 people.

1 Project execution

1.1 Background

Deep in the forest, cutting through the singing of birds and the gentle burbling of a nearby stream, comes the unmistakable sound of heavy vehicles. Foresters are at work using powerful machines to clear large areas of trees and hauling freshly harvested logs to waiting trucks. Out here in the open we witness the first step in a complex and highly distributed processing chain (see Figure 1).

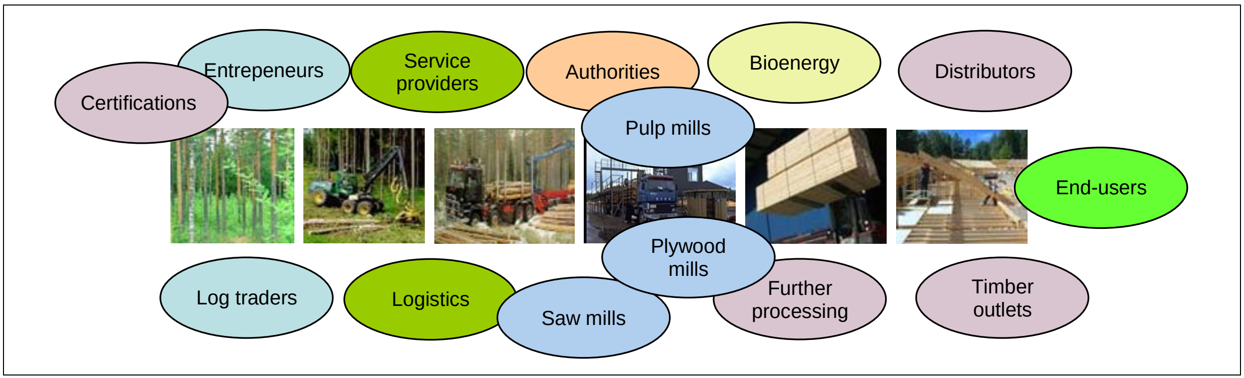


Figure 1 The forestry-wood production chain

Some of the logs could end up as telegraph poles, others may be sent to a pulping plant and eventually be turned into paper or card. Some logs will go to a sawmill for cutting into boards, which are then further processed into planks, batons, veneer and other timber components for the building trade, furniture makers and specialist manufacturing firms.

But in the forest today, when each tree topples to the ground and is cut to length it becomes an anonymous log.

Yet every tree is unique. Each has experienced unique growing conditions, so two trees that grew just a few hundred metres apart in the forest may have remarkably different characteristics. Some trees may have more knots, more moisture or a thicker trunk. Some may be better suited than others for particular end uses. But today the supply of the most appropriate wood down the processing chain remains more a matter of chance. There is no way to find out about the original log from which your timber board was cut. There is no system to link individual logs to information about their natural properties or how they have been stored and handled.

Regulation has encouraged the European food industry to develop a strict 'farm to fork' traceability system. It is possible to trace your beef steak through the supply chain and right back to the farm where the cattle were reared. It is even possible to find out about the individual animal your steak came from. The benefits of a similar system for the forestry-wood production chain are now being recognised. Traceability could help firms improve yields, reduce waste and lower their environmental impact.

Environmental and business benefits of traceability

The Indisputable Key (IK) EU integrated project was established to develop tools, knowledge and practical technological solutions that would enable operators in this supply chain to significantly increase yields of raw material and optimise the use of resources through smarter harvesting and processing. Currently approximately 25 million m^3 of ‘raw’ wood material goes to waste each year (equivalent to €5 billion) because the material is not allocated to suppliers in an efficient and optimal fashion.

A major reason for this wastage is that important information regarding the raw material is not passed through the processing chain. IK aimed to change the supply strategy from one based on volume (overproduction to compensate for high wastage) to one based on knowledge (smarter use of resources based on shared data). The economic and environmental benefits to the optimisation that an automated traceability system could bring are evident. Moreover, the results from this project will also be applicable to other biological raw materials, thus opening up opportunities for much wider use beyond the forestry-wood sector.

The full project title is *Intelligent distributed process utilisation and blazing environmental key*. The processing chain is certainly distributed, and includes the cutting and hauling of logs within the forest, the transportation of logs to users and processing in sawmills, pole and veneer production plants and the pulp industries. The idea is to make this processing chain *intelligent* by making it possible to identify individual items in the chain and access a wealth of data on their properties and provenance. The concept of a *blazing environmental key* makes it clear that the environmental benefits of a traceability system are not merely taken into consideration, but are a critical driver for smarter processing.

The shortening of the project title to *Indisputable Key* reflects the objectivity of the results: the traceability system provides all the evidence should an end product be found unfit for purpose. In practice the acronym IK has become the working name of the project; this acronym is used throughout this report.

Project heritage

IK builds on an earlier FP5 project called LINESET (2000–2003) which delivered a proof of concept that wood traceability was practical. LINESET demonstrated that traceability could be achieved for a full forestry-wood production chain, from when the trees are cut to the final processing step in a secondary manufacturer. LINESET also demonstrated the substantial financial benefits that users of a wood traceability system could obtain.

However, LINESET encountered some obstacles that would need to be overcome before the industry would widely accept and adopt wood traceability. The project's final report also suggested some more cost effective code marking techniques for logs as well as boards. Follow-up activities to introduce traceability systems focused on economic, ecological and environmental issues.

The work of IK

IK's objectives and research activities are largely based on the final recommendations for further research made by the LINESET project. IK was arranged into nine different Work Packages (WPs) that together aimed to remove the remaining obstacles and drive a swift adoption of wood traceability within the industry, see Figure 2.

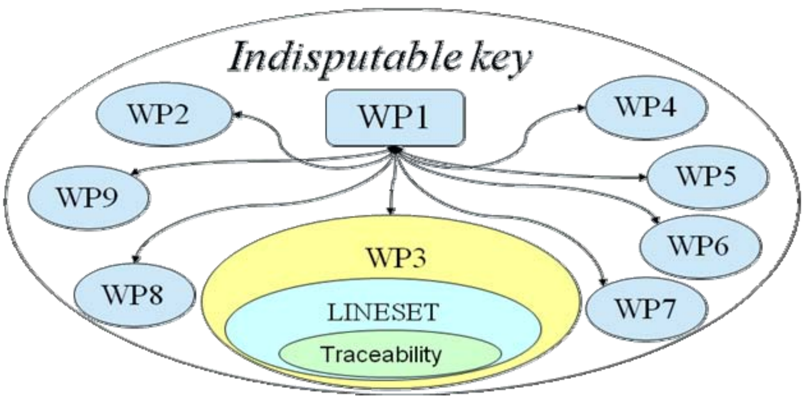


Figure 2 The 'morphology' of Indisputable Key

WP1 covered all the management activity of the project and coordinated all the project's efforts to fulfil the main objective: **"to initiate and stimulate an industrial breakthrough in traceability systems for biological raw materials, specifically wood, leading to**

substantial economic and environmental improvements in the wood processing chain."

WP2 developed an open digitial data communiation standard to facilitate data exchange between operators in the supply chain and foster the wide implementation of interoperable traceability solutions. WP3 explored the possible benefits that wood traceability systems might offer to individual operators and the supply chain as a whole. WP4 and WP5 developed efficient code marking and reading technologies for identifying individual logs and boards. WP6 developed the nescessary software solutions to make the traceability usable for business and turn the wealth of data into exploitable business knowledge. WP7 focused on the efficient dissemination and exploitation of the project's results. WP8 encompassed several real-world, full-scale demonstrations of the developed technologies and solutions while WP9 developed and carried out the training required by users wishing to use the system or its components.

1.2 Summary description of project objectives

IK addresses the strategic objective of IST (Information Society Technologies) Call 5, specifically Strategic Objective 2.5.8 'ICT for Networked Businesses', Research Focus 2 'Extended products and services'. IK meets the outlined vision for intelligent networked products and services capable of delivering business transformation.

The project's achievements, collectively known as IK Solutions, pave the way for a powerful, distributed and networked system which can be deployed in the field to generate knowledge and business intelligence. This knowledge helps to improve the use of wood materials and optimise production.

The traceability system establishes a new business model in the industry which is based on collaboration and coordinated planning and material management between businesses at all points along the value chain. The wealth of data and business intelligence created by the IK Solutions encourage greater agility, innovation thereby adding value to this sector.

The overall project objectives were to:

- improve competitiveness for sustainable raw materials;
- improve European and SME competitiveness;
- generate valuable new environmental data for use in waste and energy minimisation initiatives;
- enable materials at any point in the value chain to be tracked back to the raw material of origin.

These objectives could not possibly be achieved by a single company or country alone, but by an international effort involving representatives from the entire industry value chain, including forestry firms, primary and secondary transformers, manufacturers, distributors and end users.

The consortium of 27 partners, including 13 SMEs, worked together to develop technologies and ICT solutions that contribute to the realisation of these ambitious objectives.

The project developed prototype technologies and techniques for marking wood to enable tracking through the processing chain. It also developed and tested a traceability system that was deployed and testing among partners at different stages of the value chain. The demonstrations have revealed previously unknown relationships between raw materials and final products. For example, by selecting raw material (logs) with specific properties, a manufacturing partner was able to increase its yield by some 20%.

Another IK demonstration has shown how traceability can transform business models and permit both suppliers and manufacturers to return higher profits. IK developed an award/penalty system between a veneer log supplier and a veneer producer. The system helped to lower the proportion of logs that had to be downgraded (i.e. producing a lower quality veneer) or rejected because they did not meet log specifications (for example logs of the wrong dimensions or those that were too oval in shape). In this scheme the returns from the system were shared between the veneer manufacturer and its supplier. The manufacture reported gains of 6% and the supplier had gains of 1.5% (expressed as a percentage of the annual cost of raw material for the veneer manufacturer).

The project partners believe that the IK traceability system is an indisputable key to unlock business and environmental improvements in this sector: it increases in the yield of raw material, maximises processing resources and minimises environmental impact!

User-focused solutions

SMEs constitute a substantial proportion of the firms involved in the forestry-wood value chain in Europe; these companies play an important socio-economic role and are major employers in rural areas. It was therefore important that IK tailored its solutions to the needs of rural SMEs. The project therefore developed an SME support programme which included training, organisational networking and support for process integration. IK also ensured that its solutions were flexible and could improve the adaptability and responsiveness of SMEs to rapidly changing market demands and customer requirements.

The specific technology development objectives in the project were to:

- develop user-friendly tracing technology, based on the individual associated data (IAD) approach, for wood supply chain management and wood production operations, covering the complete supply chain and with a potential for reducing total supply chain costs by up to 20%;
- achieve flexible and cost-effective exchange and use of the data collected by the tracking systems by defining an open standard for communication and creating an open source environment for data exchange;
- develop reliable and cost-efficient systems and components for code marking and reading wood materials, with read errors below 1% and at a cost below €1 per cubic metre of raw wood material
- develop robust and affordable radio frequency identity (RFID) transponders for forest use which could be applied automatically to logs (target price range of 0.1–0.2€ per transponder within the next five years);
- develop a novel RFID reader that is tolerant to disturbance (e.g. strong vibrations and shocks, and the movement of large metallic vehicles), to be integrated into forestry machinery and with a read accuracy of at least 99.5% after preliminary testing;
- develop an code marking device, capable of integration into a sawmill's saw blade using micro-machined systems, with operating costs of no more than 0.01€ per coding;
- integrate real-time, item (e.g. log, board, product) specific, environmental and economic key performance indicators (KPIs) to permit a holistic view of forestry operations and responsible eco-management of forest and wood resources.

The scientific objectives of the project were to:

- improve on existing models that have been developed to predict the properties of wood materials;
- test and improve existing models that relate the quality of wood products to the properties of the raw wood material and the processing conditions along the supply chain;
- advance knowledge within the forestry industry about the possibilities and capabilities of RFID technology in automatic tracking applications, and to quantify the financial return on investment that such technology could realise by reducing logistic costs, reducing wastage and improving service along the supply chain;
- advance knowledge in RFID antenna design and optimisation;
- advance knowledge and develop new concepts in adaptive radio frequency solutions and schemes;

- investigate the manufacturing of ‘synthetic wood’, a novel environmentally sound material produced from isolated and modified wood components using technologies typically employed by producers of plastics;
- develop a methodology to quantify the environmental performance of the supply chain in real time by integrating life cycle analysis (LCA) indicators with supply chain management methodology;
- develop a multi-objective methodology for holistic supply chain management, including environmental, economic and product quality objectives with the aim to reduce total supply chain costs by more than 20%.

The work performed to meet these technological and scientific objectives – and the results of the work – are described within this report, beginning at Section 1.4.

1.3 Contractors involved

1.3.1 Participants and consortium

Forestry and wood processing firms and wood-based manufacturing companies are in great need of modernisation, and they have great scope for transformation through the application of information and communication technology (ICT). IK’s vision was to pave the way for entirely new operational and processing procedures that would instigate novel business models.

The IK consortium required partners with knowledge of processes and business models at each stage in the value chain. It also needed a critical mass of companies and organsiations with sufficient ‘muscle’ to help the project reach its goals and drive adoption within the industry.

The IK consortium therefore consists of two main groups: technology developers and technology users.

The technology developers had experience in basic and applied research within this industry sector.

A total of 27 project partners (see Figure 3) effectively came together to integrate fragmented solutions and to solve the problem of value chain traceability.

The core partners came from Estonia, Finland, France, Norway and Sweden and had all been previously involved in the predecessor FP5 project LINESET, thus ensuring that the results of LINESET would be further exploited.

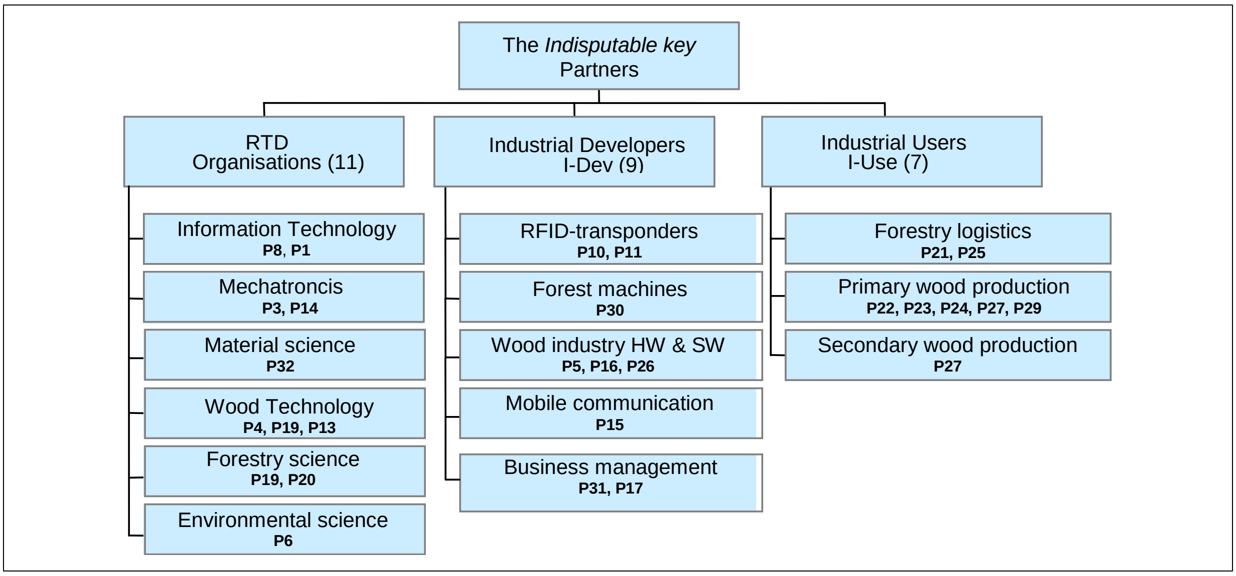


Figure 3 Indisputable Key partners’ areas of expertise

All the IK participants are listed below:

P1: **Technical Research Institute of Sweden (SP), www.sp.se.**
The Swedish national institute responsible for technical evaluation, testing, metrology, and research and development.

P3: **Royal Institute of Technology, Department of Machine Design (KTH), www.kth.se.**
Sweden's largest technical university, in classical mechanical engineering, mechatronics and embedded control systems.

P4: **FCBA, www.fcba.fr.**
This organisation was founded from the merger in 2007 of the wood and furniture technical centre CTBA and the forest and cellulose research center AFOCEL.

P5: **CIRIS Engineering, www.ciris.com.**
Specialist in scanning systems and optimisation of logs to improve processes in southern sawmills.

P6: **Swedish Environmental Research Institute (IVL), www.ivl.se.**
Sweden's leading organisation for environmental research and one of the most respected institutes of its kind in Europe.

P8: **Technical Research Centre of Finland (VTT), www.vtt.fi.**
Expert organisation for research, development, testing & information broker to public sector, companies & international organisations.

P10: **Confidex Ltd, www.confidex.fi.**
Offers RFID solutions and services for the packaging and printing industries, and integrators of RFID physical layer systems.

P11: **Idesco Oy (Idesco), www.idesco.fi.**
Develops, manufactures and markets readers, reader modules, tags and cards based on RFID technology.

P13: **Lappeenranta University of Technology (LappUniT), www.lut.fi.**
LappUniT's Sawing Technology Laboratory investigates and educates enterprises about productivity and quality control of sawmill processes and technologies for online measurement in sawmills.

P14: **Tallinn University of Technology, Department of Mechatronics (TallUniT), www.ttu.ee.**
Specialises in mechanics, electronics and mechatronics.

P15: **Oskando OÜ, www.oskando.ee.**
Develops GSM based telemetric controllers and has more than six years of experience in the development and integration of telemetric controllers.

P16: **AS Hekotek, www.hekotek.ee.**
Situated near Tallinn, Hekotek is the largest company in the Baltics producing machinery and installations for the woodworking industry.

P17: **Skog-Data AS, www.skogdata.no.** ,
For more than 30 years Skog-Data has delivered ICT services to companies spanning the entire forestry industry value chain, from forestry businesses to manufacturers of wooden consumer goods.

P18: **The Norwegian Forest and Landscape Institute, www.skogoglandskap.no.**
The leading research institute in Norway in areas related to forestry and the use of forest resources.

P19: Norsk Treteknisk Institutt (NTI), www.treteknisk.no.
Research association for sawmills and the wood industry in Norway.

P20: **Skogforsk, www.skogforsk.se.**
The Forestry Research Institute of Sweden is the central research body for the Swedish forestry sector.

P21: **Sveaskog, www.sveaskog.se.**
Sweden's largest forest owner, with 15% of the country's productive forest. Sveaskog is the country's leading supplier of saw logs, pulpwood and bio fuel.

P22: **Ducerf Scierie, www.ducerf.com.**
One of the first oak sawmills in France. Its main activities are harvesting, transportation and sawing, with an annual consumption of 40,000 m^3 of round wood (80% of which is oak).

P23: Raunion Saha Oy (Raunion), www.raunio.fi.
One of the leading medium-sized sawmills in Finland, producing 155,000 m^3 per annum, of which three-quarters is exported.

P24: **Eidskog Stangeskovene AS, www.esas.no.**
This Norwegian sawmill is well known in the market for superior quality, especially for external and internal panel in various profiles.

P25: **Scanpole AS, www.scanpole.com.**
Producer of impregnated wood poles. The company has plants in Norway and Sweden and a sales operation in the UK. It can produce up to 350,000 poles each year.

P26: **MAUCHAMP, www.pierremauchamp.com.**
Developer of software solutions for the forestry and wood sectors, including management systems and computer-integrated manufacturing suites.

P27: **SETRA Group, www.setragroup.se.**
Part of the SETRA Group, the Malå sawmill produces data from three-dimensional log scanners and the FinScan green sorting system. It uses fibre direction, heart wood and moisture in-line sensing as part of its final product grading methodology.

P29: **Rolpin, www.smurfit-rolpin.com.**
Produces plywood directly from logs incorporating traceability technologies adapted for its own proprietary production management systems.

P30: **Rottne Industri AB, www.rottne.com.**
A leading manufacturer of logging equipment for modern forestry, including advanced harvesters and forwarders for cut-to-length (CTL) logging.

P31: **Tieto Finland Oy, www.tieto.com,.**
Develops, integrates and hosts frontrunner information systems for clients in the pulp, paper, paperboard and mechanical forestry sectors.

P32: **Tampere University of Technology, TTY-säätiö, Institute of Biomaterials (TUT), www.tut.fi.** Education and research in biodegradable synthetic and natural polymers, their processing and applications.

1.4 Work performed and end results

This report presents the research, investigations and demonstrations of the IK project, and the main outcomes and results of these efforts. The objectives, activities and results of each Work Package are described in the numerical order of the Work Packages (WP2 to WP9). The results from WP7 are presented in Chapter 2 'Dissemination and use of knowledge'

1.4.1 Work Package 2 – Standards and architectures

Key results

- A data collection, storage and exchange architecture for the efficient storage, retrieval and sharing of information associated with individual objects (e.g. logs, boards etc.) and processes (transportation, sorting, cutting, drying etc.) within the wood supply chain.
- An XML-based eDocument as a standardised method for exchanging traceability information within this supply chain.

Find out more

The IK architecture and standard for communication is described in technical detail in the public deliverable report D2.12 'Indisputable Key Architecture and Communication Standard' available for download from the IK website (www.indisputablekey.com).

A traceability system is based on three key concepts: identification of individual items using code marking and detection technologies; the association of each item with item-specific data (for example the physical properties of a log, or the date and time it was harvested); and the exchange of this data between buyers and suppliers in the value chain.

WP2 sought to develop standards and architectures to facilitate the deployment of a traceability system throughout the value chain and ensure that data could be exchanged efficiently and simply between different actors. The adoption of standards and open architectures provides the foundation upon which functional systems and applications may be built. Moreover, as the ICT sector has demonstrated time and again, the use of standards and open architectures encourages healthy competition between vendors, leading to more choice, innovation and cost effective solutions in the marketplace.

IK recognises this requirement for an open architecture in traceability solutions. WP2 explored various options. The goal was to develop an architecture that remained simple so that it could be implemented by small businesses, yet have the flexibility and scalability to handle the more complex operations of larger businesses and multinational corporations.

WP2 also aimed to develop a communication standard for the exchange of data along the value chain.

The final architecture and communication standard was reached through testing and discussion; a full description is available in the public deliverable report D2.12 'Indisputable Key Architecture and Communication Standard'. The communication standard is based on XML and has now been made public. In 2009 it was incorporated into the papiNet standard, (see www.papinet.org).

The eDocument (XML message) developed by IK for data exchane between different actors in the supply chain, is called the *IadEvent message*. This message can be used for business-to-business (B2B) information exchange and for the collection of IAD information generated and collected from wood supply chain processes (events).

1.4.1.1 Communication standard

The communication standard is designed to support the forestry sector supply chain schematised in Figure 4.

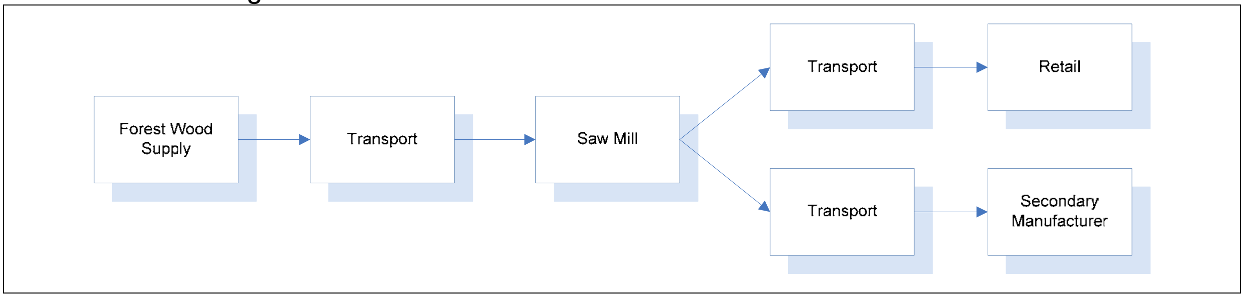


Figure 4 Basis for the communication standard – the forestry sector value chain

Each of the steps in the supply chain outlined in Figure 4 can be broken down into a set of more complex, interdependent activies and processes. Figure 5 illustrates the process model for the supply and transportation of raw material from the forestry firm to the sawmill.

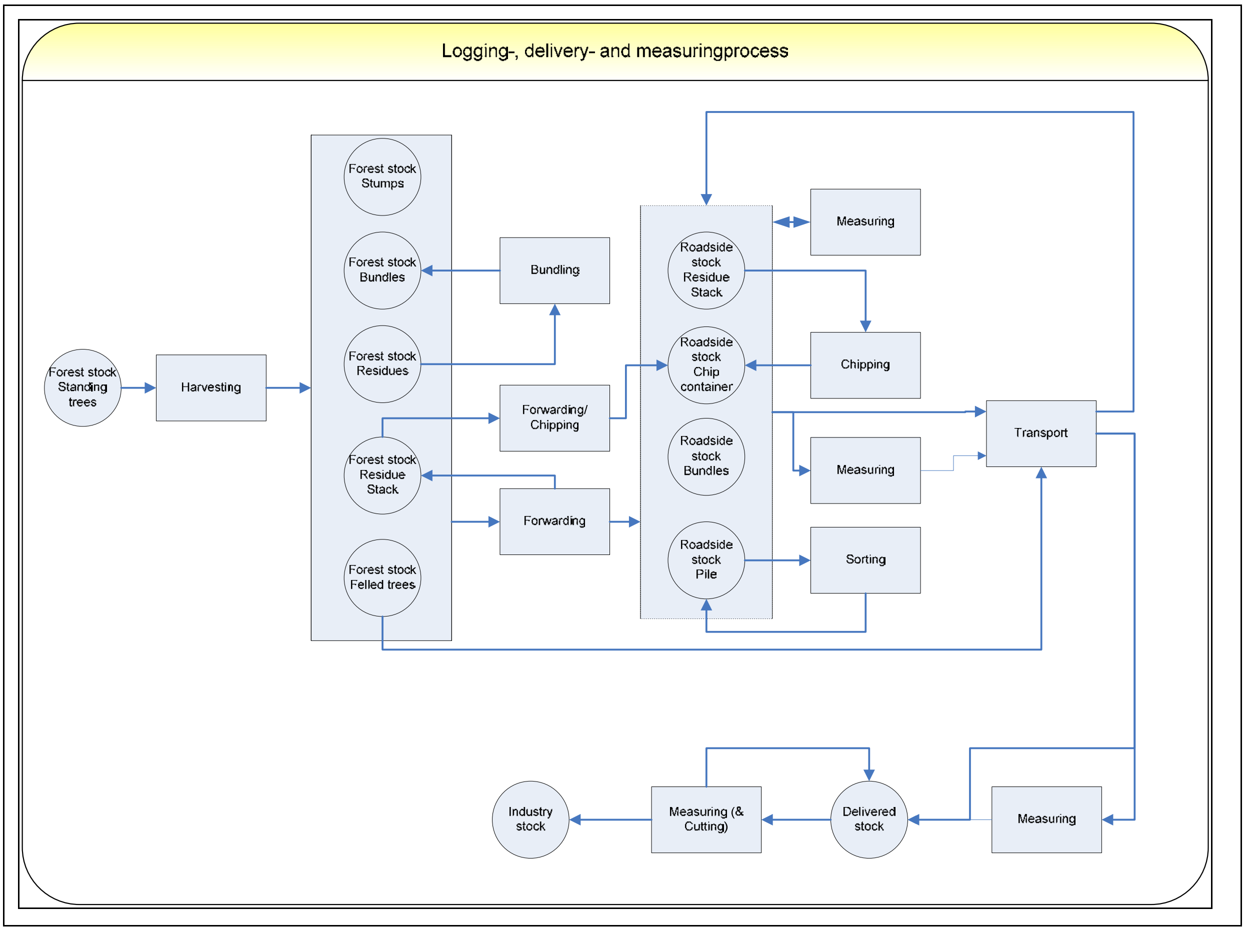


Figure 5 Detailed process model for the supply of wood to a sawmill

The communication standard developed by this project supports data collection at different points in the value chain, for example at the point of harvest and through different steps during the processing of wood within the sawmill (see Figure 6). The standard defines how this data can be shared and exchanged with other components of the architecture.

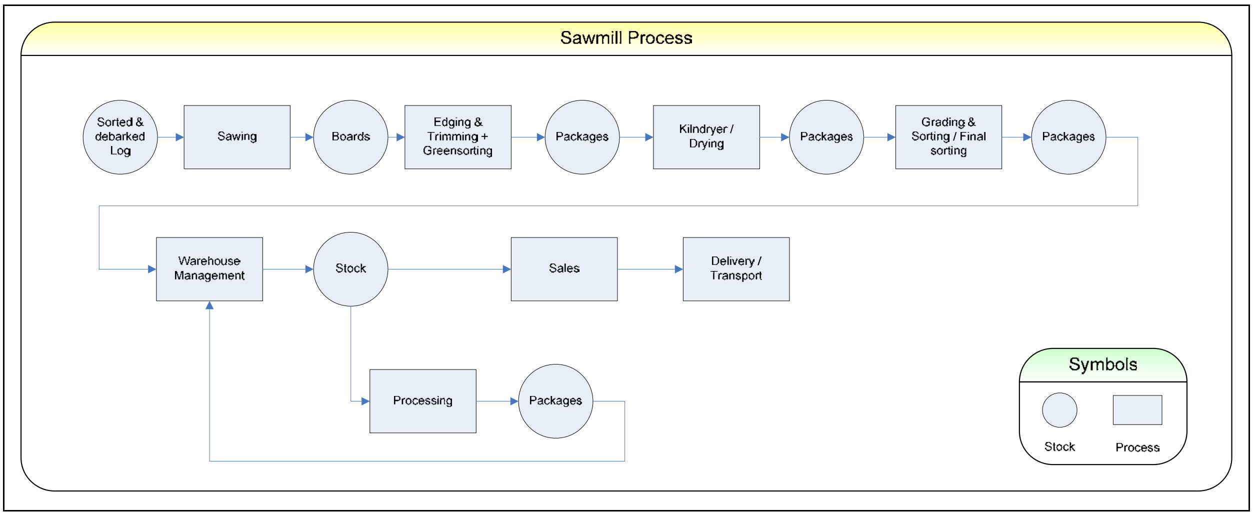


Figure 6 The different processes inside the sawmill

The information of every object (e.g. log, board etc.) is referred to as individual associated data (IAD). IAD is defined as the entire set of accumulated information, current and historical, which can be associated with an object. A log, for example, has a certain length and diameter, it has a specific age, it was planted on a particular date and harvested on a specific date (under certain weather conditions). All these attributes and properties could be measured, recorded and associated with the object. All you have to do is ensure that every object is identifiable by marking them with a unique identity (ID) code; this code is associated with all the other data about the object and its processing. The scope of information will vary from one type of object to another.

The IAD information is stored in a database. Where the IK architecture specifies the use of "a database" or "the database", this could in effect be any database. There is no requirement for specific software developed by the project.

The IAD approach references every object (using their unique ID code) back to its parent object(s) and even to the initial object of origin (i.e. the log). The referencing to the originating object makes it possible to restore traceability where chains are broken. Objects with no parent (or origin) reference are assumed to be "root objects" or "original objects" (although there are a few production processes that lead to the traceability chain 'snapping')..

To exchange the IAD information between modules of the architecture, the IK project has defined a standard for data exchange using an eDocument, based on the common XML markup convention.

1.4.1.2 Architecture

In the proposed IK traceability architecture, information exchange is either internal (internal to the company or organisation) or external (i.e. business-to-business, B2B).

Most sawmills already collect a broad range of internal data on their proceses and operations. Typical monitoring looks at the consumption of logs (the number of logs use, their dimensions and other attributes) and the output of the sawing processes (the number of boards, their dimensions etc.). This monitoring data is stored in databases.

IK simply builds on this existing practice: now each log is identified and each board uniquely coded, thereby transforming the movement of wood through a sawmill into a fully traceable process.

The architecture for internal message handling ensures that the applications developed as part of this project will be able to exchange information with existing applications and legacy ICT solutions. This project defines a set of messages for internal information flow to facilitate the implementation of the architecture for companies that currently do not collect process information.

In the forestry and wood processing industry there is a limited use of B2B or external electronic information exchange. IK recognised that the lack of B2B data integration could severely limit the adoption of traceability measures and cooperation along a supply chain. It project therefore decided to define a standard for external data exchange. The architecture is expected to handle both “push” and “pull” mechanisms of information exchange. “Pull” refers to the provision of data when requested (data on demand); “push” occurs when data is ‘broadcast’ or sent to other parties who have subscribed to receive the information whenever it becomes available.

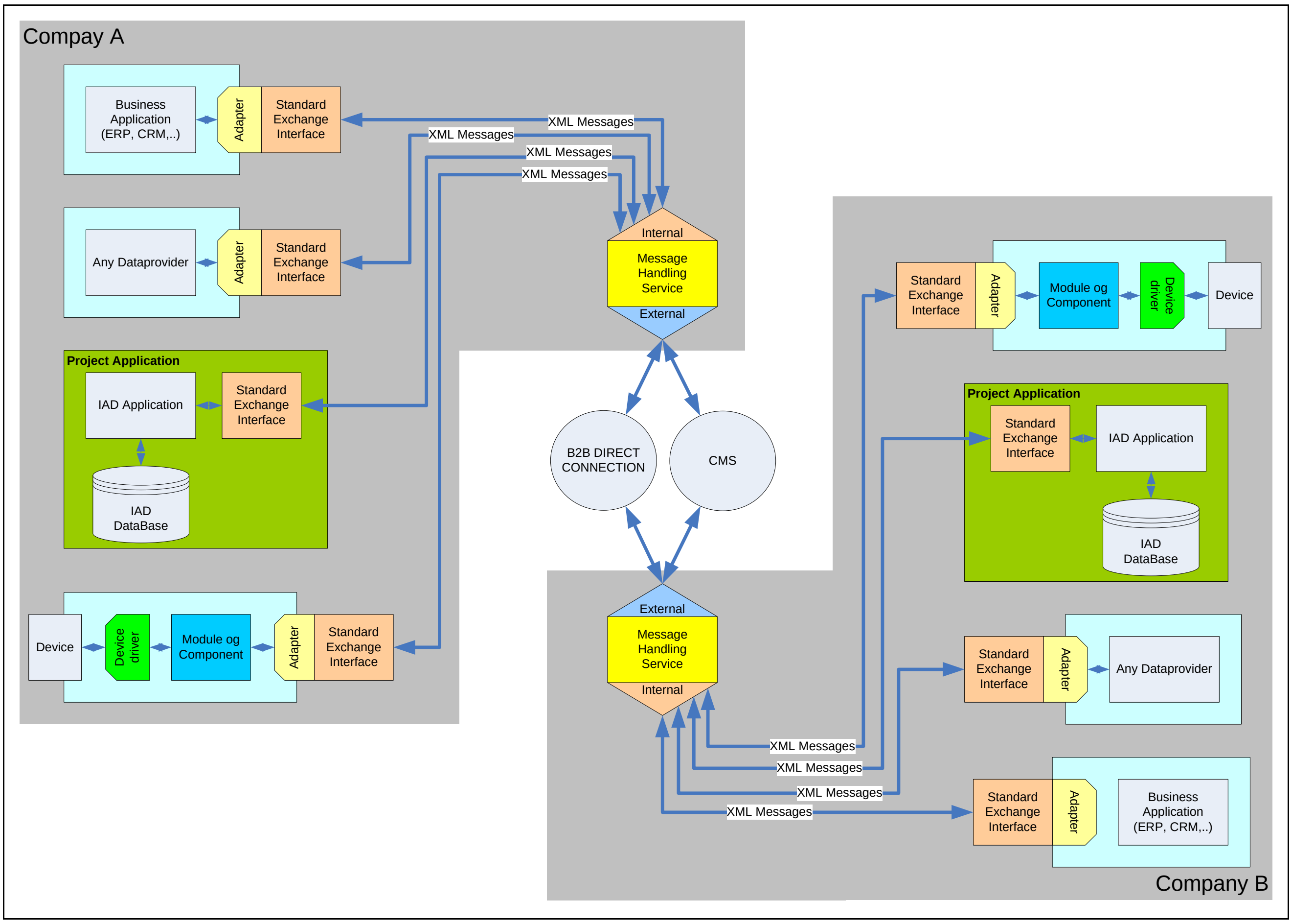


Figure 7 Model for information transfer between companies

The architecture uses XML messages as carriers of information. Basic modules in the architecture are the Message Handling Service (MHS) and the Standard Exchange Interface (see Figure 7).

All applications, software, equipment or devices developed or installed as part of this project conform to the communication standard for information exchange within the architecture defined in architecture specification document.

For existing applications, software, equipment or devices, an adapter may be needed to parse or convert data so that it conforms to the specifications of the Standard Exchange Interface (SEI).

The MHS controls the flow of messages containing data within the architecture and to external parties. It provides different functions such as subscribing to particular messages, conversion to/from different interfaces or protocols, or converting to/from defined XML message formats.

1.4.2 Work Package 3 – Assessment of supply chain performance

Key results

- A deeper understanding of the key barriers and drivers for traceability in the wood supply chain which will help to inform R&D priorities, marketing and commercialisation plans.
- The selection of several key performance indicators (KPIs) which can be used to aggregate data and analyse the environmental and economic performance of actors and processes in the wood supply chain.
- Several models that can be used to predict the quality and behaviour of wood products during production, based on a selection of measured parameters or properties of the raw material.
- Use of traceability data to provide insights on the influence of wood properties (e.g. moisture content) and processing conditions (e.g. drying time) on the yield and efficiency of sawmill operations.
- Development of tools to analyse traceability data, including harvester data files and sawmill information, and simulate supply chain operations for insights into operational improvements.
- Calculations for the return on investment and payback times for different scenarios involving investment in traceability systems.
- Analysis of the environmental and economic impact of a traceability system in European wood supply chains.

Find out more

Several reports on the results of this Work Package are available to the public (see Section 2.3 'Publishable results') and can be downloaded from the IK website (www.indisputablekey.com).

In many respects WP3 formed the core of IK; the other Work Packages functioned as satellites to develop specific components of the traceability system whereas WP3 brought it all together and assessed its performance. WP3 provide the necessary enhancements, applications, demonstrations and background research for the core traceability premise.

WP3 builds on the success of the predecessor FP5 project LINESET. It progresses the work of LINESET and ensures that the results of this previous project continue to be exploited (see Figure 2).

The work of WP3 in IK has involved the development of models and metrics to ensure that the collection of object-level data (i.e. information about the attributes, properties and history of individual logs, boards etc.) through the forestry and wood processing value chain can be used to realise the anticipated business and environmental advantages (see Section 1.1 ‘Background’).

The upper part of Figure 8 describes several strategic uses of data by a forestry company, a sawmill and a secondary manufacture to help them increase their yields, reduce wastage and improve the quality of their output. These strategies were investigated in WP3, although the diagram takes account of some of the findings in the earlier stages of the project.

The arrows in the lower part of Figure 8 highlight the tools that were developed under WP3 to improve supply chain management and evaluation.

The extent to which the different strategies have been investigated and refined, and development and impact of the tools have varied, depending on their progress at key milestones and delivery deadlines.

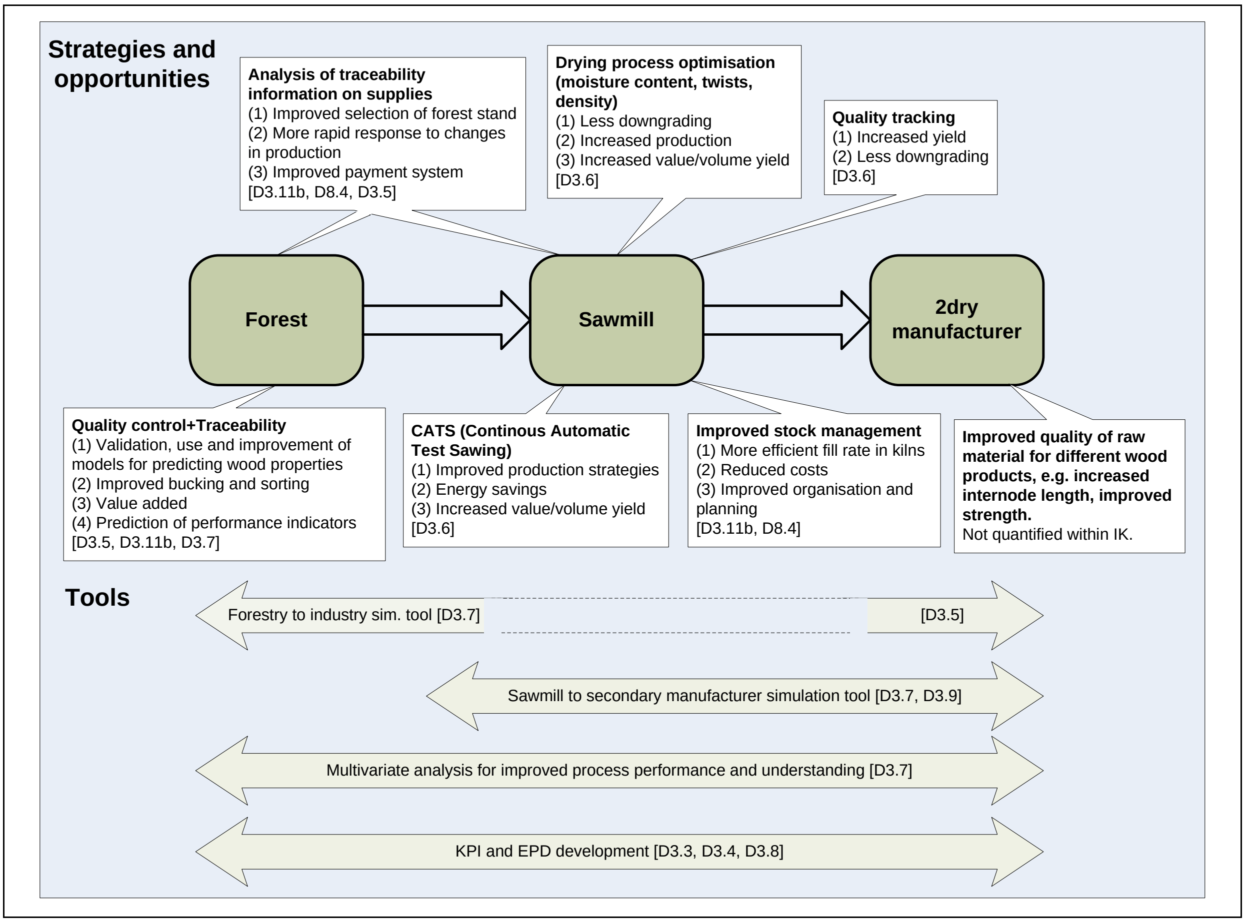


Figure 8 Tools developed and strategies/opportunities studied in WP3 - Assessment of supply chain performance

1.4.2.1 The influence of economics and the environment in the supply chain

Drivers and barriers

The WP3 team analysed the drivers and barriers for deployment of a traceability system in the wood supply chain. The analysis covered general factors as well the specific characteristics and circumstances of this industry sector and the application technologies in this area. The full report D3.1 'Report on initial analysis of drivers and barriers' can be downloaded from the project website (www.indisputablekey.com).

KPIs

The overriding premise of IK is that the collection of data on the quality and processing of wood across the forestry supply chain should enable companies to derive environmental and economic benefits. However, these benefits have to be measured. Appropriate monitoring data must be selected and key performance indicators (KPIs) defined.

For the environmental KPIs the WP3 work team decided to comply with the forthcoming European standard for environmental product declaration (EPD). The environmental KPIs selected for this project were:

- climate change;
- acidification;
- eutrophication;
- stratospheric ozone depletion;
- ground level photochemical ozone;
- depletion of non-renewable resources;
- human and ecological toxicity.

Some site-specific KPIs were also added to assess the environmental performance of individual companies. It was also recognised that supplementary information about a company's inventory could also be treated as KPIs. The material composition of all output products in a process is also regarded as a KPI; this information is also reported in product declarations and will form part of an EPD.

Economic KPIs were selected that would make it possible to analyse the end-to-end economic impact of traceability on the full supply chain, but also the return on investmnent for individual companies. Improvements across the supply chain are important for the competitivess and financial strength of this industry, but no business would be willing to invest in such a system simply for the 'greater good'; each business needs to see a return on its investment.

A total of 11 economic KPIs were selected, namely: reliability;

- responsiveness (velocity);
- flexibility (agility);
- wood material related quality;
- management of uncertainties;
- sawmill costs;
- efficiency of sawmill;
- value creation;
- transport;
- IK system diffusion and adoption;
- financial performance (of the IK system).

The full report D3.3 'Selection and definition of environmental and economic key performance indicators' can be downloaded from the project website (www.indisputablekey.com).

1.4.2.2 Baseline performance for manufacturing sites

With the KPIs selected, WP3 then used them to establish the baseline performance of the key manufacturing sites which would later be implementing the IK traceability system. This baseline measure gives a picture of how the companies were performing environmentally and financially before the deployment of traceability. By comparing the "before" and "after" KPIs, it is then possible to determine the effect of traceability for each site.

The work team analysed all the processes of the participants in the demonstrators, plus some extra analyses at Scanpole and Raunio.

The results of the analysis and the calculated baseline KPIs have been reported for each manufacturing site (confidential data) and is the foundation for future comparisons.

The inventory work to establish economic KPIs encountered three main difficulties: data availability, data confidentiality and data quality. Nevertheless, the project has trailblazed in this respect and companies in the wood and forestry sector have for the first time openly shared KPIs.

1.4.2.3 Models relating wood properties to processing and quality

1.4.2.3.1 Existing models

An inventory of different models for assessing and describing the quality of wood was completed by WP3 at the end of 2007. The report documents several existing models. It discusses their applicability within IK, analyses the availability of input data and possible refinements that could be performed by the project.

The full report D3.2 'Existing models and model gap analysis for wood properties' can be downloaded from the project website (www.indisputablekey.com).

1.4.2.3.2 *Relating wood properties and storage conditions to process efficiency and product quality*

Several methods and models were investiagted to relate the properties and storage conditions of wood to the efficiency of its processing and the quality of products made from the wood. The purpose of the work was to see how traceability and digital information exchange through the supply chain could provide valuable data regarding these relationships. This information could then be used to make better business decisions and inform prediction models.

WP3 conducted some extensive simulation and modelling studies, working closely with SWSC. The analyses showed that models and simulations were good representation of real production processes. There was a good correspondence between the log properties predicted by our software and the measured (by harvesters and a 3D frame at the sawmill) and predicted properties of sample logs found in production files supplied by SWSC.

These simulations were able to provide more information on the direct and indirect impact of some of the properties, but only those properties explicitly included in the model. These results still have to be validated by studies that compare the simulation outcomes with real-world production, preferably by using a traceability system.

The WP3 simulation studies and development are presented in two confidential reports that are not available to the public.

1.4.2.3.3 *The influence of processing conditions and wood properties on sawmill operations*

The work team looked at how combinations of wood properties, processing conditions and operating practices in the sawmill affected the properties of the output products. The work also explored how traceability could be used to optimise a sawmill's processes.

The investigations conceded that a sawmill could achieve these outcomes without full supply chain traceability. A sawmill could install an internal IAD system even if the origin of the log batch must be known. However, in some cases optimisation might be strengthened by integrating with data generated further upstream (i.e. to include information from the supplying forestry company), and/or downstream (i.e. to include information from customers).

This WP3 task explored several possible scenarios of what could be achieved using a functional IAD-based traceability system within a sawmill. The main findings are outlined in the following sections.

1.4.2.3.4 *Final moisture content supervision at Malå sawmill.*

It is important for a sawmill to ensure that its stocks of wood have the correct levels of moisture and possess other properties that meet customer specifications so the wood is fit for purpose. Certain processes must be matched with wood of certain properties, for example to avoid cut boards becoming under- or over-dried. If the input or output material does not have the correct moisture content, the sawmill could suffer from productivity losses, energy losses and the downgrading of its products because they have the wrong moisture content, the wrong dimensions or become deformed or cracked.

The WP3 team looked at the output properties of products after they has been dried and correlated these properties to both the properties on the input material and the parameters for processes taking place both inside and outside the drying kiln.

Boards were marked at the green sorter and traced through the full drying process. At the final sorter the boards were identified and evaluated according to their grade and length.

Automated data collection was not possible, so sufficient data was unavailable to produce any meaningful results. However, data that had been collected manually from test sawings (primariliy to validate the installed traceability system) was available. An initial analysis suggests that there is great potential to measure moisture content before and after drying and correlate this with shrinkage measurements. This kind of data would then help to develop predictive models so that drying processes could be optimised and yields and/or the quality of dried boards increased.

1.4.2.3.5 Homogenisation of density in Norway spruce boards in drying batches at ESAS – potential benefits and application

The density of wood and the time it takes to dry are directly correlated. But in any batch of wood in a kiln there is a natural spread of densities; unsurprisingly there is also a spread in the moisture content within the batch of wood that comes out of a kiln. It is highly profitable to dry wood in batches with the same density because it is then possible to reduce drying times.

A study by the WP3 work team looked at the benefits of drying wood in batches of 'homogenised' density.

In one trial the wood was classified as either 'low' or 'high' density. By drying either low or high density wood it was possible for IK partner ESAS to reduce timber drying times by 4%.

1.4.2.3.6 Handling of twist prone logs/boards.

Sometimes output production from a sawmill has to be downgraded due to a phenomenon called twist, where the wood warps in three dimensions (see Figure 9). A study at Malå sawmill measured the grain angle of green boards. These were then sorted so that the boards with the largest angle were placed at the bottom of the stack entering the drying kiln. This places a heavy load on the boards most likely to twist and reduces the warp.

Figure 9 Two packages with twist-prone boards. Package (Paket) 1 was placed on top and package (Paket) 4 at the bottom. It is seen that in package 1 more boards are twisted than in package 4.

The objective of the study was to correlate parameters such as downgrading, cut, board quality, grain angle and their position in the kiln. This allowed the team to analyse and define different actions for different groups of boards. Boards were manually marked and traced. Preliminary analysis suggests that stacking strategies hold a lot of promise and that IAD can help to refine these stacking strategies.

1.4.2.3.7 Quality tracking – logs to green centre boards at Raunio sawmill.

It is widely accepted that the quality and other properties of sawn timber depend in part on the location from which the source logs were harvested. However, the lack of traceability data has made is all but impossible to correlate these characteristics.

Supply chain traceability made it possible to record the harvesting location, trace the passage of logs to the sawmill and their processing into board. The data on the harvesting location was linked to processing parameters (e.g. drying properties) and the measured properties and quality of the output board.

The correlations can be used as a tool to help companies reduce downgrading and maximise value yield. For example, a sawmill could request a delivery of logs from a certain forest location to the supplier. Alternatively, when it processes logs, the sawmill could channel them through different processes or adjust process parameters depending, at least in part, on where the log was harvested (seeTable 1) and see a reasonable return on investment from this smarter working method.

Table 1 Estimated yearly benefit from traceability at Raunio sawmill

Advantage	Calculation	Yearly benefit (€)
Increased yield	0.5% better yield improves gross margin by 0.8€/m^3	144 000
Increased production	900 m^3 because of increased yield	
Less quality downgrade	5% of pine product to the higher quality class	80 000

1.4.2.3.8 Continuous Automatic Test Sawing – CATS.

Continuous automatic test sawing (CATS) is a technique based on automatic gathering of a small amount of IAD during full production. A small amount of IAD could be generated with existing IK solutions by marking logs from the forest – as control trees – and passing them through different steps in the sawmilling manufacturing process. After one year, the IAD from just 10 control logs adds up to 2000 logs and 4000 boards.

This WP3 study found that the use of CATS allows companies to evaluate strategies for how to handle twist-prone logs, find the correct tolerance for shrinkage and predict which logs in the log yard will produce boards with a large board cut at the green sorting stage. With this information, the sawmill can optimise its processing operations and increase its value yield.

CATS does not need every log to be marked for traceability; the approach works well with sub-sampling where maybe just 0.5–1% of the logs are marked and traced. The use of sub-sampling is important because it means that the cost of using CATS could be lower than traditional methods. If it costs €2 to trace a log, the cost for a sawmill processing 10,000 logs per day would be €100 per day (0.5% or 50 logs traced per day). This can be compared to a cost of €27 per log using traditional test sawing.

1.4.2.4 Holistic supply chain management and statistical analysis of supply chain data

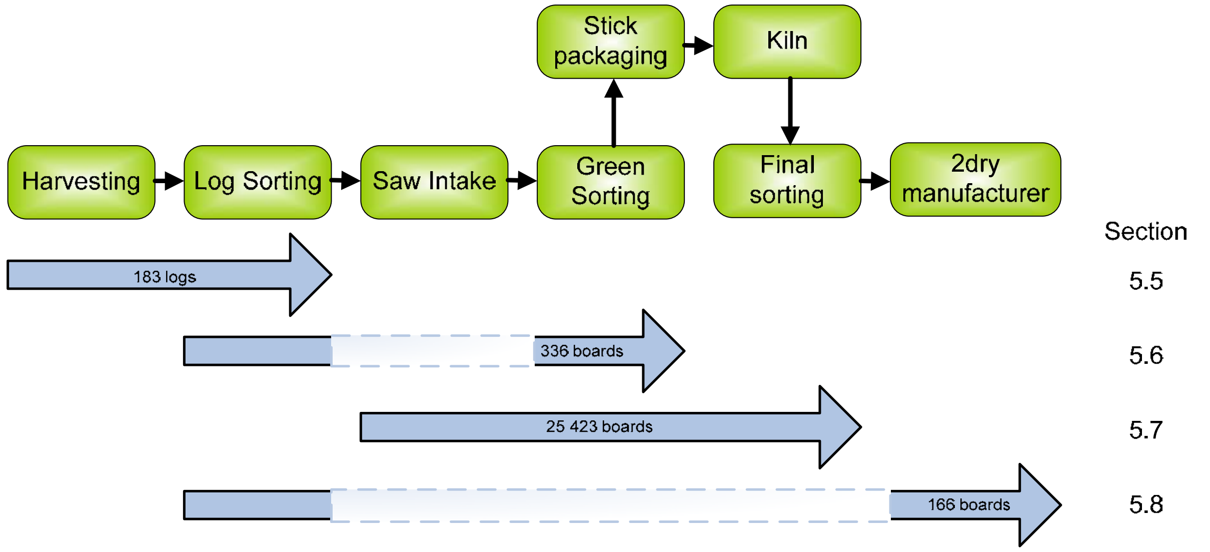
Two important WP3 studies looked at tools that could be used for:

- trade-off visualisation and analysis of the wood supply chain;
- multivariate statistical analysis of supply chain data.

The first part of the work involved statistical multivariate analysis of data collected from the SWSC (see Figure 10). Unfortunately, traceability data for the full length of the supply chain under investigation (forest to secondary manufacturer) was still not available at the end of the project. However, subsets of traceable information were available for limited sections of the supply chain.

Multivariate analysis was also performed on non-traceable data taken from individual production steps. Two of the multivariate models developed using this non-traceable data have been incorporated into the project's *sawmill to secondary manufacturer simulation tool* which was built as part of this work.

The WP3 team also constructed and tested a *forestry to industry simulation tool*. This software consists of three different sub-tools that simulate then extend PRI data (a PRI file is normally produced by a harvesting machine; it contains data on a harvested stand of trees and the cut logs).



Note: Black connectors represent the physical flow between production units (green boxes). The stick packaging and kiln is by-passed in all traceability chains due to non-availability of data and/or possibility to link with other steps. To the right there is reference to the section in the report (D3.7) that covers the respective data chain.

Figure 10 Overview of the data traceability chains used for multivariate analysis (blue arrows).

The work team has begun to build a model which can incorporate parameters on the properties of wood (available in the extended PRI files) within the planning of wood sorting and transportation. This model would function as an extension to the existing Skogforsk FlowOpt tool.

The third part of this modelling and statistical analysis task produced a tool to simulate the supply chain from a sawmill to a secondary manufacturer. The tool uses extended PRI files as input data and simulates the processes of the complete SWSC. The simulation results are expressed as KPIs. The user of the tool can modify various parameters and starting conditions to how these variables change the performance of the supply chain (i.e. how they affect the KPIs). Several analysis functions have been built into the tool; a simplified web version is also available on the project website (www.indisputablekey.com).

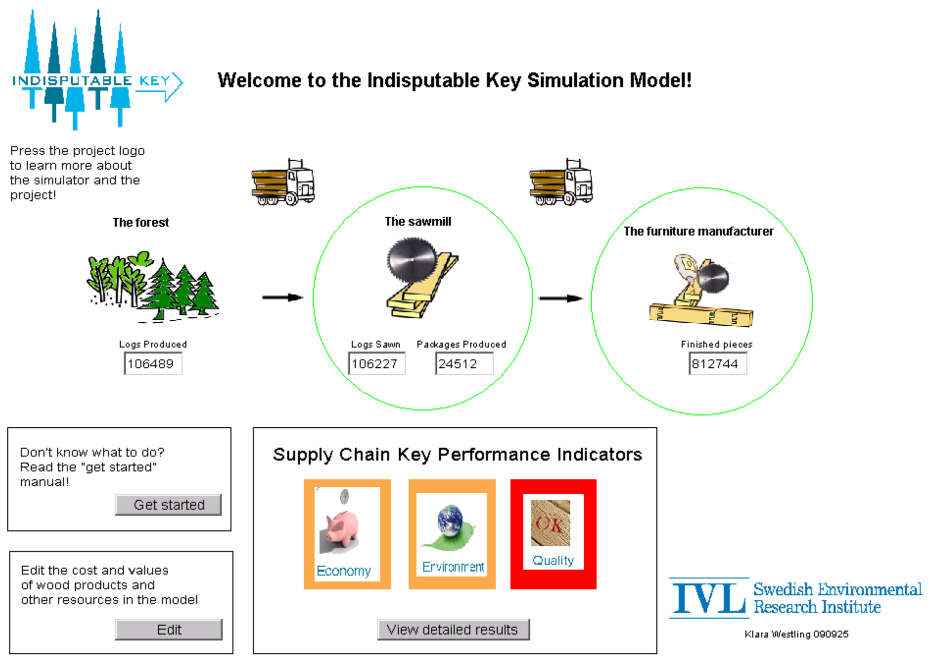


Figure 11 Main graphical user interface of the simplified web version

Actual use of the tools for analytical purposes formed part of a separate WP3 task, reported in D3.9 'Report on optimal wood allocation' (see Section 1.4.2.6).

The modelling and simulation methods developed by IK could help operators make their production more efficient, thanks to a proper evaluation and clear visualisation of what happens in their supply chain. By simulating different production strategies (without having to test them in real life) it should be cheaper and easier for businesses to optimize their production and improve their environmental performance.

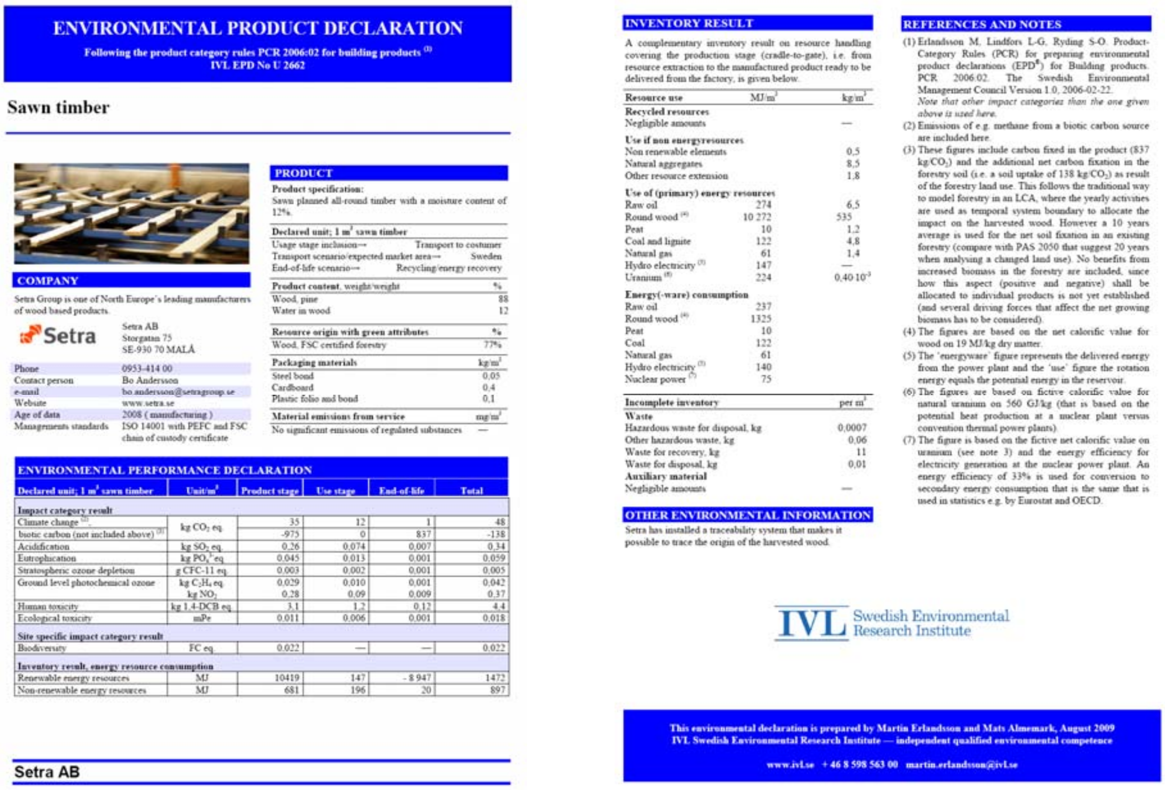
1.4.2.5 Environmental product declarations (EPD) for selected products

The first step towards environmental responsibility is for a company to assess the environmental performance of their products or services. An environmental product declaration (EPDs) is one way to describe the environmental characteristics of a product or service from a life cycle perspective.

The IK project developed a generic IK EPD format to report on the environmental performance of wood products coming from the supply chain under scrutiny.

A traditional EDP typically takes a 'cradle-to-gate' perspective (i.e. it covers everything from the extraction of raw material to the delivery of the final product to the customer). But IK extends this basic information and incorporates data on the usage and end-of-life disposal and recycling into the IK EPD.

This particular work stream produced EPDs for selected products from five IK industrial case studies: SWSC, Rolpin, Ducerf, Raunio and ScanPole.



ENVIRONMENTAL PRODUCT DECLARATION

Following the product category rules PCR 2006:02 for building products (1)
IVL EPD No U 2662

Sawn timber

COMPANY

Setra Group is one of North Europe's leading manufacturers of wood based products.

Setra AB
Storgatan 75
SE-930 70 MALÅ

Phone	0953-414 00
Contact person	Bo Andersson
e-mail	bo.andersson@setragroup.se
Website	www.setra.se
Age of data	2008 (manufacturing)
Managements standards	ISO 14001 with PEFC and FSC chain of custody certificate

PRODUCT

Product specification:
Sawn planned all-round timber with a moisture content of 12%.

Declared unit; 1 m^3 sawn timber	
Usage stage inclusion→	Transport to costumer
Transport scenario/expected market area→	Sweden
End-of-life scenario→	Recycling/energy recovery

Product content, weight/weight	%
Wood, pine	88
Water in wood	12

Resource origin with green attributes	%
Wood, FSC certified forestry	77%

Packaging materials	kg/m^3
Steel bond	0,05
Cardboard	0,4
Plastic folio and bond	0,1

Material emissions from service	mg/m^3
No significant emissions of regulated substances	—

ENVIRONMENTAL PERFORMANCE DECLARATION

Declared unit; 1 m^3 sawn timber	Unit/m^3	Product stage	Use stage	End-of-life	Total
Impact category result					
Climate change (2)	kg CO_2 eq	35	12	1	48
biotic carbon (not included above) (3)	kg CO_2 eq	-975	0	837	-138
Acidification	kg SO_2 eq	0,26	0,074	0,007	0,34
Eutrophication	kg PO_4^{3-}eq	0,045	0,013	0,001	0,059
Stratospheric ozone depletion	g CFC-11 eq	0,003	0,002	0,001	0,005
Ground level photochemical ozone	kg C_2H_4 eq	0,029	0,010	0,001	0,042
	kg NO_2	0,28	0,09	0,009	0,37
Human toxicity	kg 1,4-DCB eq	3,1	1,2	0,12	4,4
Ecological toxicity	mPe	0,011	0,006	0,001	0,018
Site specific impact category result					
Biodiversity	FC eq	0,022	—	—	0,022
Inventory result, energy resource consumption					
Renewable energy resources	MJ	10419	147	- 8 947	1472
Non-renewable energy resources	MJ	681	196	20	897

Setra AB

INVENTORY RESULT

A complementary inventory result on resource handling covering the production stage (cradle-to-gate), i.e. from resource extraction to the manufactured product ready to be delivered from the factory, is given below.

Resource use	MJ/m^3	kg/m^3
Recycled resources		
Negligible amounts		—
Use if non energyresources		
Non renewable elements		0,5
Natural aggregates		8,5
Other resource extension		1,8
Use of (primary) energy resources		
Raw oil	274	6,5
Round wood (4)	10 272	535
Peat	10	1,2
Coal and lignite	122	4,8
Natural gas	61	1,4
Hydro electricity (5)	147	—
Uranium (6)	224	$0,40 \cdot 10^{-3}$
Energy(-ware) consumption		
Raw oil	237	
Round wood (4)	1325	
Peat	10	
Coal	122	
Natural gas	61	
Hydro electricity (5)	140	
Nuclear power (7)	75	

Incomplete inventory	per m^3
Waste	
Hazardous waste for disposal, kg	0,0007
Other hazardous waste, kg	0,06
Waste for recovery, kg	11
Waste for disposal, kg	0,01
Auxiliary material	
Negligible amounts	—

OTHER ENVIRONMENTAL INFORMATION

Setra has installed a traceability system that makes it possible to trace the origin of the harvested wood.

REFERENCES AND NOTES

(1) Erlandsson M, Lindfors L-G, Ryding S-O. Product-Category Rules (PCR) for preparing environmental product declarations (EPD®) for Building products. PCR 2006:02. The Swedish Environmental Management Council Version 1.0, 2006-02-22.
Note that other impact categories than the one given above is used here.

(2) Emissions of e.g. methane from a biotic carbon source are included here.

(3) These figures include carbon fixed in the product (837 kg CO_2) and the additional net carbon fixation in the forestry soil (i.e. a soil uptake of 138 kg CO_2) as result of the forestry land use. This follows the traditional way to model forestry in an LCA, where the yearly activities are used as temporal system boundary to allocate the impact on the harvested wood. However a 10 years average is used for the net soil fixation in an existing forestry (compare with PAS 2050 that suggest 20 years when analysing a changed land use). No benefits from increased biomass in the forestry are included, since how this aspect (positive and negative) shall be allocated to individual products is not yet established (and several driving forces that affect the net growing biomass has to be considered).

(4) The figures are based on the net calorific value for wood on 19 MJ/kg dry matter.

(5) The 'energyware' figure represents the delivered energy from the power plant and the 'use' figure the rotation energy equals the potential energy in the reservoir.

(6) The figures are based on fictive calorific value for natural uranium on 560 GJ/kg (that is based on the potential heat production at a nuclear plant versus convention thermal power plants).

(7) The figure is based on the fictive net calorific value on uranium (see note 3) and the energy efficiency for electricity generation at the nuclear power plant. An energy efficiency of 33% is used for conversion to secondary energy consumption that is the same that is used in statistics e.g. by Eurostat and OECD.

IVL Swedish Environmental Research Institute

This environmental declaration is prepared by Martin Erlandsson and Mats Almemark, August 2009
IVL Swedish Environmental Research Institute — independent qualified environmental competence

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A complete two page EPD for the Setra product of sawn, planed all-round timber with a moisture content of 12%.

Figure 12 Example of the IK EPD reporting format

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In the future it should be possible to replace the manually gathered EPD data with information obtained from the information system developed within IK. This should make it possible to analyse the environmental impact for individual products using high resolution data that is not available today in any form.

1.4.2.6 Optimal wood allocation

Building on previous work the IK partners ran the data generated from their simulations on the influence of processing conditions and wood properties on sawmill operation (see Section 1.4.2.3.3) through the simulation tools developed during the work on methods and algorithms for holistic supply chain management (see Section 1.4.2.4).

The analysis focused on a specific business scenario, that of a Swedish furniture manufacturer with specific demands for timber of particular dimensions, conforming to various qualitative parameters such as internode length or the tendency to warp or crack.

Investigations on the influence of internode interval length on the recovery rate revealed that it was worthwhile for the furniture manufacturer to pay a premium for high quality wood (i.e. with a high internode length, see Figure 13).

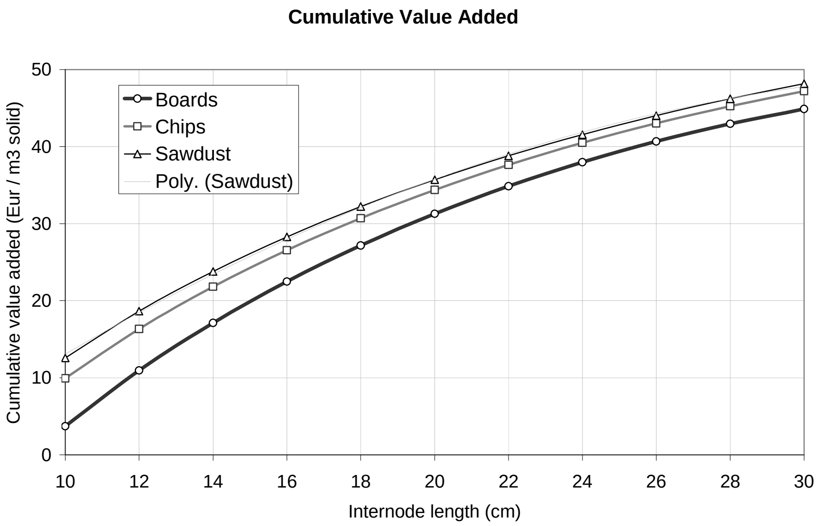


Figure 13 The potential for the final customer to add value to a cubic metre of frame boards, at varying internode length

This work task revealed that the internode length of logs coming into the sawmill is the most important parameter that influences the financial return for the secondary manufacturer. A high internode length helps to decrease volume recovery while shorter internode distances tend to increase processing costs.

But could improved traceability help to increase the internode distance of logs in incoming supplies? For the supply chain studied here, it is possible to screen for internode length at the final sorting procedure at the sawmill – the sawmill supplies a variety of customers and only a proportion of sawn boards are sent to the furniture manufacturer. Therefore, provided that other customers of the sawmill do not set similarly stringent thresholds on internode length, it would be possible direct boards of high internodal length to the furniture manufacturer out of the existing product mix. Greater knowledge about the origin of the incoming logs would not be necessary.

However, if the sawmill was vertically integrated into the secondary manufacturer (i.e. the furniture manufacturer was its only customer), or if multiple customers required higher proportions of clear timber (i.e. boards with a high internodal distance), it would then become extremely important for the sawmill to source logs that met these quality criteria. In this case, it would be highly beneficial to associate this data with individual logs and ensure that it could be traced from the forest to the sawmill. In either case it is clear that traceability data is important for the financial success of different operators in the chain.

1.4.2.7 Economic, strategic and political perspective of supply chain performance

WP3 also incorporated a study of the socio-economic impact of the performance of this supply chain. The purpose of this study was to analyse the micro- and macro-economic effects that the deployment of traceability tools and systems in the wood supply chain might bring about.

This WP3 task tackled a number of questions that various IK activities had highlighted but not answered. For example, at the point of proceeding with the implementation of a traceability system, would it be more efficient for actors in the wood supply chain to share the costs and benefits of traceability or would it be better for every operator to make their own separate investments?

1.4.2.7.1 Survey of project participants

The socio-economic study was divided into two steps. First, an internal project survey pulled together all the existing knowledge generated by the project on the economic impacts and benefits of traceability. Second, the work team developed a number of scenarios to highlight the economic and strategic benefits of adopting traceability in the wood supply chain.

Although the number of respondents to the internal survey was relatively low, it still revealed some important potential economic impacts and benefits of traceability implementation in the supply chain. The survey also highlighted just how hard it is to quantify the benefits of traceability.

Quantitative estimates of benefits reported by respondents are listed below:

- Reduction in costs – associated with sourcing, production, delivery and shipping, inventory holding and other supply chain related costs – between €1 per m^3 and €4 per m^3 of wood material.
- Improvement in reliability, responsiveness and flexibility between 7% and 17%.
- Reduction in uncertainties related to production, to suppliers and to customers between 8% and 10%.
- Improvement in the quality of wood (for both materials and products) between 7% and 15%.
- Reduction in overconsumtion by 8–10%.
- Creation of additional value estimated at around 5%.

The survey revealed that the upstream players (i.e. the forestry firms and the primary manufacturers) and collaborative behaviour were the main generators of benefit. The survey also showed that the choice of technological solution for traceability (RFID vs luminescent nanoparticles vs bar/matrix codes) did affect the economic outcomes, although the difference was small.

Most companies said that their biggest concern was the overall cost associated with traceability and the lack of apparent benefits or quantifiable outcomes. They remarked that the benefits were hard to quantify while the costs were clear.

The survey showed that actors would be more likely to adopt traceability if it could be shown that the technology could reduce uncertainties (related to raw materials, production, deliveries etc.), lower costs that occur due to an inadequate supply of raw material, or improve yield. Companies also said that they would adopt traceability if at least half of their supply came from companies using such solutions.

1.4.2.7.2 Business scenarios

Following the internal IK survey, the second part of this task developed a number of scenarios to explore the socio-economic impact of traceability in two representations of the wood supply chain. These scenarios would make it easier to tease out how traceability could have an impact on the performance of companines.

The first scenario involved a forestry firm and a sawmill, the second involve a forestry firm and a plywood manufacturer.

The scenarios outlined in this work task revealed that the deployment of **traceability is always beneficial to the downstream partner** (i.e. the sawmill or the plywood manufacturer). However, the economic advantages of traceabililty depend significantly on the volume and value of the raw wood material supplied by the forestry firm. For example, 10 years after deploying a traceability solution using luminescent nanoparticles (LNPs), the plywood manufacturer registers a return on ivestment (ROI) of 399%, with a payback time of just one year. With an RFID-based system the 10-year ROI is 245%, but payback is still within one year. However, the results from this same scenario reveal that the forestry firm sees no financial benefit from either LNP marking or RFID if it invests in traceability alone.

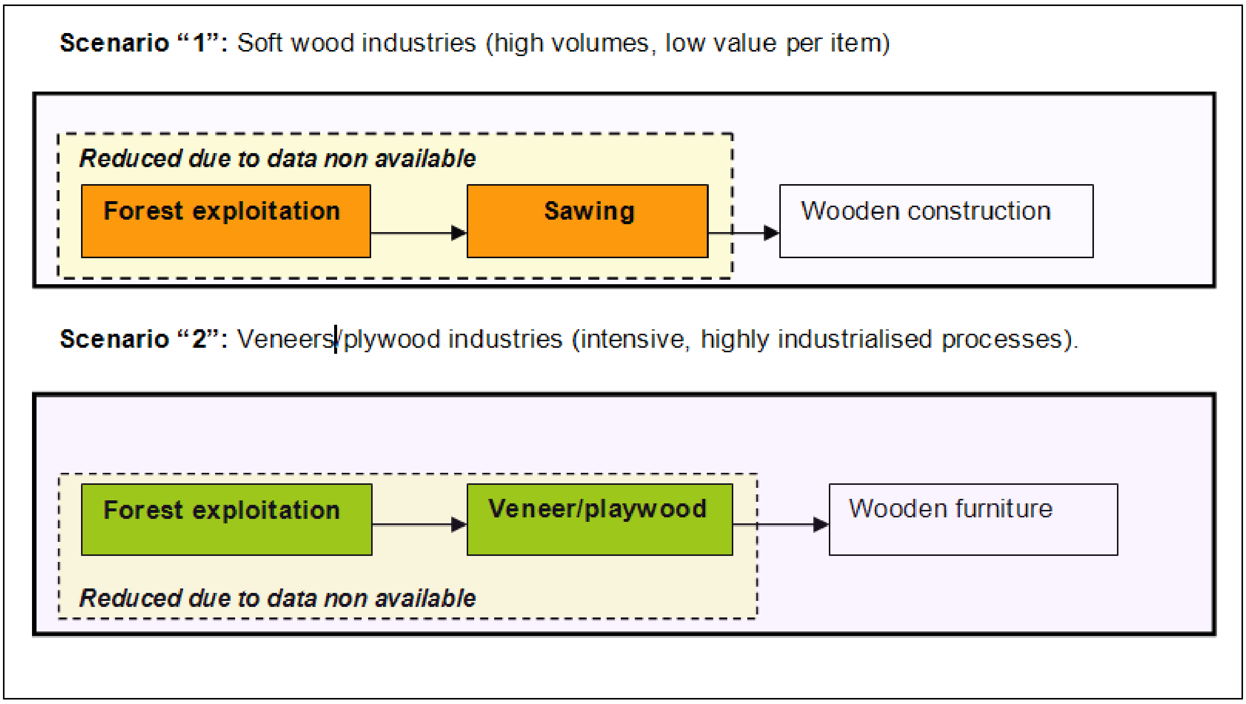


Figure 14 Selected scenarios

When actors in the supply chain collaborate on a traceability solution, however, they see an improvement in the efficiency of their investment, particularly when partners share the costs. On this basis, it is more efficient for the actors to share the costs of investment with business partners. An upward investment (in forest exploitation) can generate downward benefits (in the sawmill).

There are still many questions that need to be answered, with little hard fact on which to quantify the impact and benefit of traceability. For instance, can the deployment of partial traceability in the supply chain have a network effect and a knock-on benefit to other actors, even without their direct participation?

A number of policy issues must also be taken into account which could affect the uptake of traceability solutions (for example, the presence and availability of affordable broadband internet access, trust and security of the system).

1.4.2.8 The environmental and economic impact of traceability implementation

At the end of the project, following the completion of the three industrial demonstrators (SWSC, Ducerf and Rolpin), it was possible to assess the impact of traceability at these three sites. The results from the demonstrations were evaluated where possible against the baseline KPIs calculated earlier in the project (see Section 1.4.2.2).

The results from the installations at Ducerf and Rolpin were analysed. It was clearly shown that the deployment of a traceability system can realise long and short term environmental and economic benefits for individual companies.

The assessment of the demonstrators also looked at the costs of components in the traceability systems, both the fixed costs of stand-alone equipment/components and the overall cost to deploy installations similar to those of the three project demonstration sites. The costs are limited to best estimates for post-project installations made in the near future (the price of transponders depends significantly on sale volumes). The cost for model development is not included in the calculation of fixed and variable costs since it is not needed to achieve traceability.

From these figures it was possible to estimate the payback time for each of the companies (see Table 2).

Full details of the analysis are available in the public deliverable report D3.11b 'Environmental and economic impact of implementation od developed approach and on further possibilities and challenges in wood traceability' (available for download from the project's website).

Table 2 Calculations of payback time for different scenarios comparable to SWSC, Ducerf and Rolpin installations

	Level of marking (%)	Marked items/logs (/year)	Total fixed costs (k€)	Total variable costs (k€/year)	Est. benefit (k€/year)	Payback (years)
SWSC 1	80	2 500 000	277	975	360	-
SWSC 2	80	2 500 000	277	1035	360	-
SWSC 3	80	2 500 000	293	116	360	<2
SWSC 4	80	2 500 000	293	176	360	<3
Ducerf	100	32 000	169	22	40	<10
Rolpin1	100	672 000	248	42	190	<2
Rolpin2	100	672 000	248	42	135	<3

Note: The level of marking refers to the level of marking at the sawmill.

1.4.3 Work Package 4 – Forest RFID system

Key results

- A specially designed wedge-shaped RFID transponder made from biodegradable artifical wood material that is compatible with pulping.
- A device that can be integrated into the harvester's head and which can automatically embed transponders into the base of logs.
- An RFID reader with good readability rates and tolerant to vibrations that can be integrated into the harvester's control and data recording systems.
- The correct association of a log's read ID and its measurement data for approximately 95% of logs.

Find out more

The evaluation of the RFID system's performance during harvesting and in the sawmill is presented in the public deliverable report D4.11 'Forest RFID System Operation'.

Radio frequency identity (RFID) tags or transponders are small electrical devices which transmit low power, high frequency radio signals. These signals can be detected by receivers in the near vicinity of the tag. The signal transmitted by a tag is effectively an identity code. The identity code of a tag can be linked in a database to other information about the tagged item.

RFID tagging is being increasingly used in industrial and consumer applications, from the tracking of packaging pallets by logistics operators to keyless domestic security systems.

RFID-based tracing of logs was identified as a suitable approach for tracking the movement and fate of logs in the wood supply chain, from the point of harvesting to their eventual destruction at the sawmill when the logs are cut into boards.

RFID-based tagging systems have several advantages over visual coding systems, for instance:

- in-line code reading with no time cost as items pass through an RFID reader gateway;
- the potential to integrate RFID readers into existing machinery;
- the code cannot be tampered with or changed in a way that makes it impossible to read.

The concept for the IK RFID solution required each log to be 'marked' or embedded with an RFID transponder during harvesting when a felled tree is cut into logs. The ID code signal of the transponder is read by a reader on the harvester. The code is associated with all the other data recorded by the harvester for the log and stored in the harvester's PRI file.

Following transportation, the logs are received at the sawmill, where they are measured and sorted. Here the RFID tag is read again so that all the measurement data can be associated with individual logs. Before being cut, each individual log (now debarked) is again identified via the RFID tag and measured. This data is again added to each log's data set.

WP4 of the IK project developed a novel RFID system that is suitable for tracing logs from the forest to the sawmill. The system consists of passive ultra high frequency (UHF) transponders used to mark the logs, a specially designed transponder applicator for automatic and manual marking, the harvester and sawmill RFID readers, and the control software to handle communication between the IK adapter (the system which managed the collection of data from the physical devices) and the database.

The system was tested within the Swedish Wood Supply Chain (SWSC) demonstrator.

1.4.3.1 The RFID transponder

The RFID transponders had a number of design requirements so that they would function well when they were embedded in logs. The transponders would have to provide:

- good readability, with long reading distances;
- high survivability and readability in wet logs (water absorbs radio signals and can cause problems for RFID systems in damp environments);
- compatibility with pulping operations (the transponders has to be made from harmless materials that could be incorporated into the paper production stream);
- the potential for automated application, with a size and shape that is suitable for mechanised and automated insertion into logs;
- the potential for cheap manufacturing (i.e. using mass production methods).

The tags would have to be read accurately and reliably at some distance and in all weather conditions. It was essential that the tags could survive and continue to function within the logs, despite the logs being subjected to quite 'rough handling'.

The prototype transponder designed and tested by the WP4 team is an 80 mm long wedge made of an artificial wood material that is compatible with pulping (see Figure 15). Inside the wedge-shaped casing is a planar dipole antenna optimised to operate inside moist wood. The transponder is EPC Class 1 Generation 2 compatible.

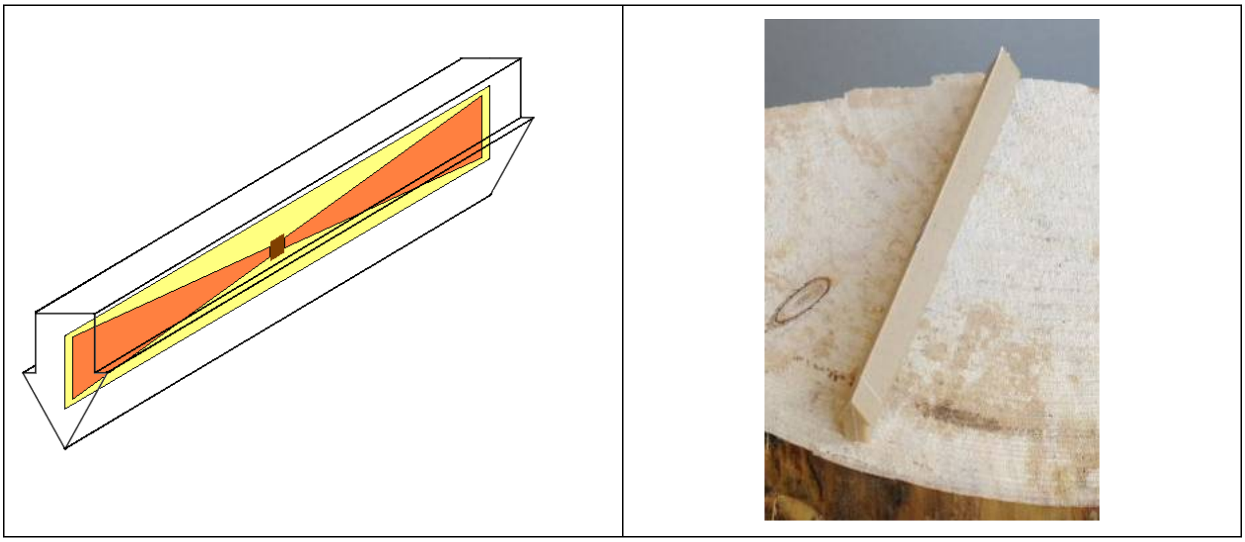


Figure 15 The wedge-shaped UHF IK RFID transponder, developed for inserting into the end of a log and made of artificial wood compatible with pulping processes

The readability of the novel transponder was tested in the laboratory. The reading range was tested for transponders inside moist logs. The measured reading range was approximately 2.5 m in laboratory conditions. Actual reading distances varied, but the typical reading distance was adequate for deployment of the transponder in the field.

1.4.3.2 Transponder applicators

Two transponder applicators – a manual tool and a prototype of an automated system integrated into the harvester – were developed to insert the transponder into the ends of logs. The manual tool is simply a transponder holder that is welded onto the blade of an axe. The transponder is hit into the log end, and its wedge-shape design helps to embed it securely and deeply into the wood (see Figure 16).

Figure 16 Manual transponder application

IK also developed a prototype system to mark the logs automatically with transpnders during harvesting operations (see Figure 17). The application of the transponder had to be fast to avoid any additional delays in the harvesting rate.

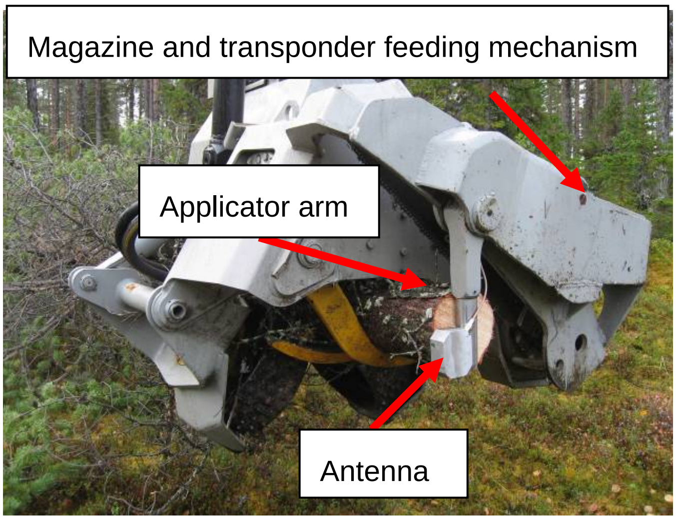


Figure 17 Prototype transponder applicator in the harvester head

The applicator magazine contains approximately 60 transponders that are fed to a transponder holder in the applicator arm. A hydraulic cylinder pushes the applicator arm down and the log is pressed against it so that the transponder is pushed into the log end. The harvester RFID reader reads the ID code of the transponder and the ID-code is inserted into the PRI-file that contains the data on the log obtained by the harvester.

With the manual applicator an experienced user can mark approximately 100 logs per hour. The observed success rate in tests of manual application was about 95% (a small percentage of tags were not fully embedded in the log or they broke when they hit a hard knot in the log end).

Tests of the automated applicator were also carried out in the field. The harvester operators reported that the additional step of adding a transponder to each leg added an extra three to four seconds per log. The log has to be pushed against the applicator arm to force the transponder into the log end; the log is then moved back to allow the transponder to be read. It also took about two or three minutes to refill the transponder magazine. Overall, the automated RFID insertion system added about five to seven seconds to the log processing time – a significant delay that future research should address.

1.4.3.3 Harvester RFID reader

The harvester RFID reader reads the ID-code signal of the transponder after it has been embedded into the log. However, the outdoor conditions often encountered in Nordic countries and the physical environment in the harvester head makes it very difficult for an RFID reader to detect and correctly read the the code. Along with the difficult conditions of low temperatures, rain and snow, the RFID reader must also be able to cope with:

- repeated shocks and vibration during harvester operation;
- physical impacts;
- the proximity of large metallic bodies.

The RFID reader for the harvester developed in WP4 features a novel adaptive RF front end that mostly compensates the effect of nearby metal on the reader antenna. The electronics for the reader are enclosed into a robust metal casing that is dust- and waterproof. The electronics are connected to the reader antenna in the applicator arm via an RF cable.

The harvester RFID reader was tested under severe conditions – high levels of vibration and shocks as specified in the ISO 15003 standard. The reader had to cope with vibrations of 20 m/s^2 at frequencies of 10–2000 Hz and to shocks of 500 m/s^2. These kind of shocks occur up to 1500 times per day – each time the harvester head comes into contact with the tree stem as the log is cut from the stem.

The harvester reader was tested for survival and operational accuracy and reliability; it operated for several months under these harsh, but typical, conditions. The reader performed extremely well under all conditions, although at temperatures below -20°C the reader needed frequent rebooting.

1.4.3.4 Sawmill readers

The sawmill is almost as challenging an environment for RFID readers as the outdoor forestry harvesting sites. The sawmill creates a harsh industrial environment with vibrations, saw dust and fluctuating temperatures. The movement of logs through production lines means that sometimes RFID readers may be knocked by moving logs.

RFID readers were used at two locations in the Setra Malå sawmill: at the receiving log sorter and at the saw intake (see Figure 18).

Figure 18 The RFID reader assembly over the conveyor at the saw intake (left) and the antenna frame at the log sorter (right)

In the log sorting station two reader assemblies were tested: the same set-up as at the saw intake (i.e. above the conveyor) and a frame surrounding the conveyor with three antennas.

1.4.3.5 RFID system performance

The transponder reading rate was tested in two sawmills (Setra Malå in Sweden and Raunio Sawmill in Finland). Both mills used the same readers and a similar set-up for their antenna. Readability was close to 100% (see Table 3). The logs were marked with transponders in the log yard using the manual applicator. The log sorting tests were done in Sweden and the sawing test in Finland.

Table 3 Readability test results

Test	Number of transponders	Reading rate
Log sorting test 1	164	100%
Log sorting test 2	164	99.4%
Sawing test	143	99.3%

It is obvious that a transponder can only be read if it has survived within the log – only functioning transponders can be detected and read. It is therefore difficult to determine whether the failure of a reader to detect a transponder is caused by a ‘dead’ transponder or a problem with the reader. The transponder survival rate tends to dominate the readability statistics.

By February 23, 2010, a total of 2579 transponders had been read in the log sorter and 989 transponders had been identified at the saw intake at Malå sawmill. The estimated theoretical reading rate for fully operational transponders in logs using the reader set-up described above is 99.95 % (i.e. in theory an average of one log in 2000 may be missed by the reader even though the transponder is operating normally) although this could not be verified since the total number of marked logs was not exactly known.

Reliable readability also depends on how logs are spaced on the conveyor and the speed at which they move. The reading of a transponder takes a certain amount of time and this can vary – reflection and scattering of the radio signal by metal objects in the vicinity of the reader cause rapid variation in the strength of the signal and therefore in how long it takes to read.

The association of measurement data for a log and its RFID code relies on a synchronisation between the time it takes to measure a log and the time it takes to read the transponder. However, if logs are spaced closely together (0.3–1.0 m) or if it takes the reader longer to read a transponder, this synchronisation may be lost – the measurement data then is ambiguous because it no longer clear which log contains the correct transponder. Table 4 summarises examples observed synchronisation rates and the effect of synchronisation on transponder readability.

Table 4 Log synchronisation rate in test runs

Log marking	Reader location	Number of read tags in the test	Unique measurement results for the readings	Log synchronisation rate
Automatic, in forest	Log sorting	285	268	94.0 %
Manual, in log yard	Log sorting	218	207	95.0 %
Automatic & manual, all logs for 26 Jan 2010	Log sorting	812	754	92.9 %

The results show that a log identification rate of approximately 95% is feasible with the current reader set-up.

1.4.4 Work Package 5 - Wood object coding/decoding and object data communication systems

Key results

- A prototype ink-printer device that can be integrated into the sawing blade of a harvester to print (at a very low cost) two dimension barcodes or data matrices on the end surface of a log.
- A visual code reader that can be mounted on a log sorter, achieving readability rates of at least 95%.
- A manual and automatic marking device and visual code reader for printing two dimensional data matrices on boards.
- The use of luminescent nanoparticles in marking inks to improve visual code readability rates.

Find out more

More technical details about the code printing and reading technologies are available in the following public deliverable reports:

D5.4 Code-reader prototype

D5.8 Saw integrated micro printer prototype

D5.9 Documentation of saw integrated micro printer

D5.10 Mill log code reader prototype

D5.11 Documentation of mill log code reader

To make traceability possible a method is required to identify individual items (logs or boards) at key points in the wood supply chain. The items must therefore each be marked with a unqiue code which can later be 'read' by the tracking system.

It is obvious that as items are processed by downstream manufacturers they may be destroyed or consumed. A log, for example, is cut at the sawmill into many boards; the marking code on the log is destroyed, but each new board can itself be marked. The marking on the boards allows the board to continue to be traced through the supply chain and also connects the individual associated data (IAD) for the boards to the IAD for the original log from which they were cut.

A successful traceability system therefore relies on several technologies to mark a range of different products through the wood supply chain with a unique code. Technologies are also required to 'read' the code accurately and reliably. Finally, as codes are merely 'keys' to access IAD, it is important to establish a robust data management structure for the entire traceability system.

1.4.4.1 SIMPLE (Saw Integrated Micro Printer for Log Ends), mill code marking and reading device

SIMPLE is IK's alternative to an RFID system. This cost effective system has been designed, developed and field tested within WP5. The SIMPLE system comprises an applicator, a reader and a database structure (Figure 19). Trials show that the cost of marking is as low as €0.002 per item. Moreover, the marking of items and the reading of codes is entirely automated and integrated into current processing procedures; there are no time costs associated with the marking and code reading steps.

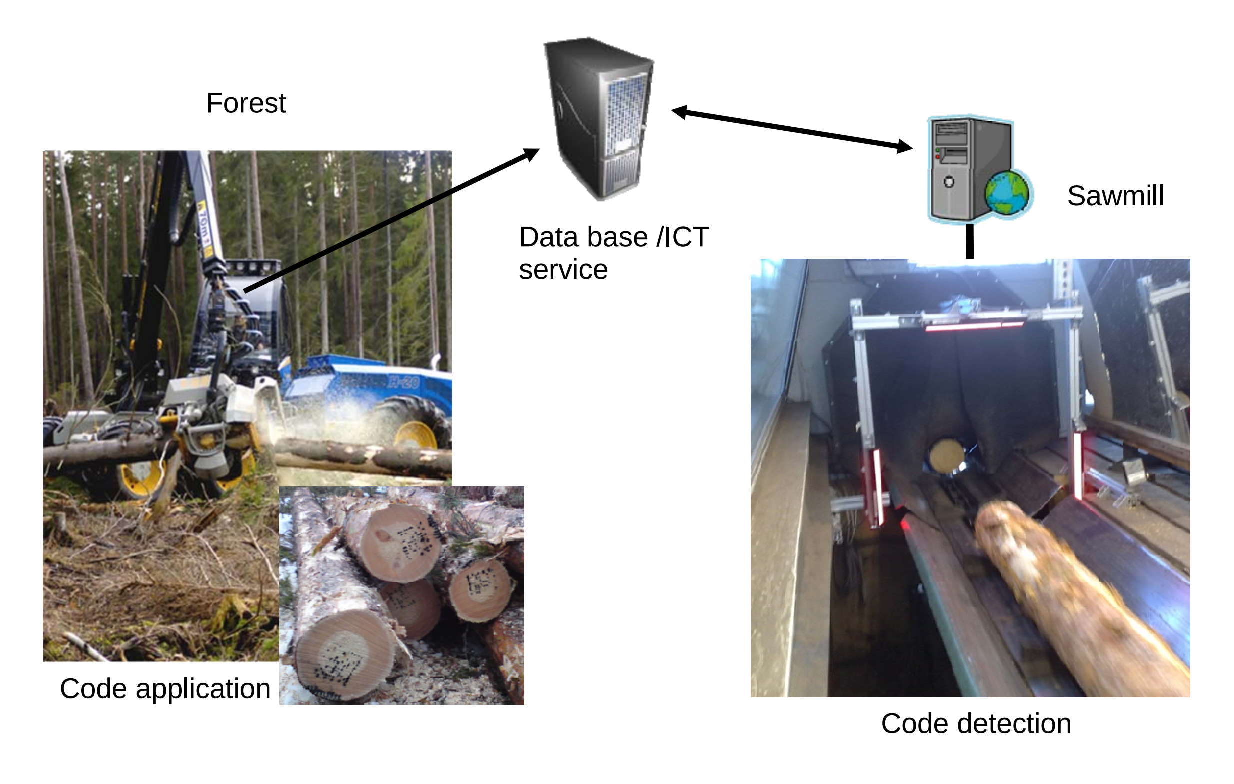


Figure 19 Log traceability from the forest to the sawmill by the aid of log marking, reading and database communication

Figure 19 outlines the integration of log traceability between the forest and the sawmill using the SIMPLE system. The physical ID code is a two dimensional barcode matrix; a total of one million unique barcode patterns is possible.

The two dimensional code is applied to the base of a log by the harvester when the log is cut in the forest. The physical ID code is associated with a unique logical ID code (a unique digital reference number) and information about the log. The data file is stored in the harvester and transmitted to a central database, either via a mobile communication system (e.g. GPRS) or by using a daily download of the data from the harvester (using a manual transfer via a memory stick or by linking the harvester to the central database over a network).

The marked logs are transported to the sawmill. The detection system is placed in the log sorting station. It uses an digital optical system to picture the base of the log and image processing software to read the unique matrix pattern. This log identification is in line with log scanning equipment which takes other measurements of the log.

When the log's barcode has been read, the code then allows the sawmill to access and download the data measured and stored at the time of harvesting for each individual log. The data from log scanning and measuring at the log sorting station and the data recorded by the harvester can then be associated with the SIMPLE matrix code and stored in the sawmill's own database.

This log traceability data allows the sawmill to trace the movement and processing of individual logs within the sawmill.

1.4.4.2 Applicator

The WP5 work team wanted to develop a technology that could automatically apply a unique physical ID code to logs during the haresting operation without an interruption of the harvesting process.

A method was developed to apply the code marking to the top end surface of each harvested log. It involved the incorporation of a controlled ink pump system with values; the ink was channelled through grooves etched into the saw blade and nozzles attached to the blade marked the log as it was being cut. The technical details regarding the development of the novel printer technology is available in the public deliverable D5.9 'Printer documentation'.

The ink used for the marking code is already commonly used by harvesters for much simpler log marking that is currently used by some forestry operators.

Various options for the physical ID code are available. Along with the two dimensional matrix code described so far, a system has also been devised to apply a much simpler line code using the cutting motion of the harvester's blade.

The design of the code marking equipment is modular and the need for adjustments and installation onto the harvester has been kept to a minimum. The applicator consists of a control unit and the marking device. The control unit is well protected inside the harvester's cutting head (aggregate); whereas the marking device is located on the sawing unit. Data communication is established via the existing CAN communication interface between the applicator control unit and the harvester control system (Figure 19). A specially designed interface allows the harvester operator to activate the application of the code.

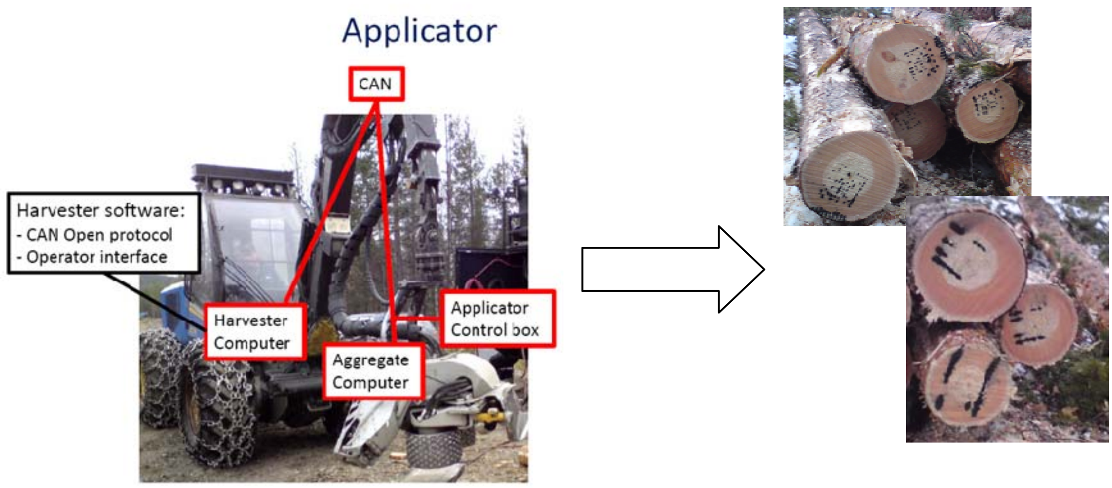


Figure 20 The integration of the code applicator into the existing harvester contol system. Two dimensional codes of dots or/and lines are printed on top end of log.

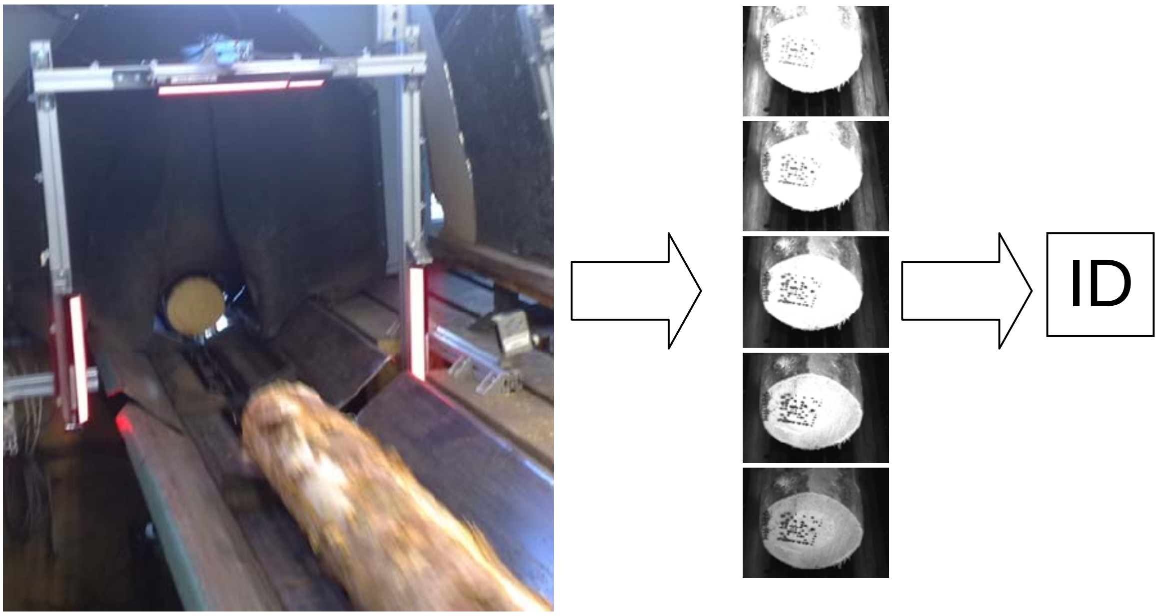
In the project's prototype implementation, the CAN Open standard was used to integrate the applicator module with the existing machine control system.

The applicator system is initiated when the harvester is started. It is activated automatically and applies a code when a batch of logs is processed by the aggregate.

The code is applied automatically and is stored in the harvester together with the associated information about the log, according to the StanForD standard. This data can be transmitted to forest owners, sawmills or other actors in the wood supply chain as required or requested.

1.4.4.3 Detection equipment

The detection equipment is an optical system combined with image processing software. A digital image of the object is captured and is further processed by software tools to decode the visual pattern captured on the digital image. The major components of the detection equipment are a camera, lighting, a trigger sensor, a power supply, a computer, software and the system's rig which integrates it into the log sorting machinery (see Figure 21).



Note: Multiple digital image capturing enhances the possibility of getting one good image. Images are transmitted to the detection computer for software processing/decoding.

Figure 21 Detection equipment installed at a log sorting station at a sawmill.

As the log passes the detection equipment a photoelectric sensor triggers the camera and lighting to capture multiple images of the log's end surface. The images are processed by specially developed image recognition software which is able to locate the two dimensional code within the digital image, then read the unique matrix or line pattern. A successful reading of the physical ID code then allows the log's associated data to be accessed by the detection computer. The detection system is also synchronised with the sawmill's log scanning system so that the log's harvesting data and scanned measurements can be combined and connected to the printed code.

1.4.4.4 Field test

The SIMPLE system was assessed in December 2009 in a field test at a final cutting site a few kilometers outside Malå in Sweden. The tests used a customised barcode. A total of 217 logs were marked in the forest and read at the sawmill. A detection rate of 87% was achieved; the length of each log recorded by the harvester and the sawmill were compared to verify that the code on logs was being recognised accurately (see Table 5).

Table 5 Difference in log length between forest and sawmill measurements.

Variable	SDC limits length	Test result length	SDC limits diameter	Test result top diameter	Test result butt diameter
Percentage within ± 4 mm for diameter and ± 2 cm for length	> 60%	77%	>50%	65%	18%
Standard deviation	< 3.0 cm	2.55 cm	< 6.0 mm	5.02 mm	15.42 mm

The results in Table 5 indicate that the measurement deviation between the forest and scanner is within limits specified by SDC for the length and top diameter. It was found that a system error produced poor results for the diameter measurement at the butt end of logs.

The SIMPLE system proved to work well as a prototype. It is an ideal system for the high volume, low value output of softwood forestry because the physical ID code is applied cheaply during processing by the harvester without any time loss.

A tree can be processed into four or five logs in less than 30 seconds. If it took even one additional second to mark each log, this would add up to a substantial loss in time (and therefore output) for the forestry operator.

The SIMPLE markeing system can apply a code for a cost of as little as €0.002 per item. This low cost could be a determining factor in its uptake by forestry and sawmill companies.

1.4.4.5 Other marking and reading systems

1.4.4.5.1 Matrix marking (with printer) and reading for boards

IK partner Tallinn University of Technology (TallUnit) was responsible for the development of a system to mark and read a visual code on boards and a visual code for logs in a French forestry operation.

Along with a board marker and reader system, the R&D activity at TallUnit also produced a data adapter for sawmills, a data communication and synchronisation system for sawmills and system monitoring interfaces. TallUnit also developed a robust handheld log code marking device and a log code reader.

The board marking system exploits a touch dry marking technology that can apply an 8x18 matrix code (see Figure 22 and Figure 23) to wet or dry wood surfaces automatically.

Figure 22 Slightly modified 8x18 two dimension data matrix code

Figure 23 Board code marking system

Figure 24 Code matrix printed onto a board end

The board code reader is a smart camera-based system (see Figure 25). The system incorporates automatic imaging, code detection and image processing, with decoding algorithms that have been adapted for for wet and dry fresh sawn wood surfaces. The reading system also includes an option for the automatic analysis of code quality. There is support for Ethernet-based networking between several readers, between a reader and a code marker and between readers and an adapter.

The code reading system has also been set up so that operators can remotely access monitoring and control software. There are options for the system to send out alerts according to defined triggers (for example a specific code value or a particular quality parameter).

Figure 25 Board code reading system

1.4.4.5.2 Line code marking for logs and use of luminescent nanoparticles (LNPs)

TallUnit developed a reading system (see Figure 26) for codes marked on logs according to the specific requirements of Smurfit-Kappa Rolpin Company in France.

The system consists of a colour camera integrated with networking interfaces and a complex automatic image processing algorithm (see Figure 27) that was suitable for processing infrared images of sawn wood surfaces. The system also included additional options for readability analysis and remote monitoring and control software (for maintenance and development purposes).

Figure 26 Code on the log end

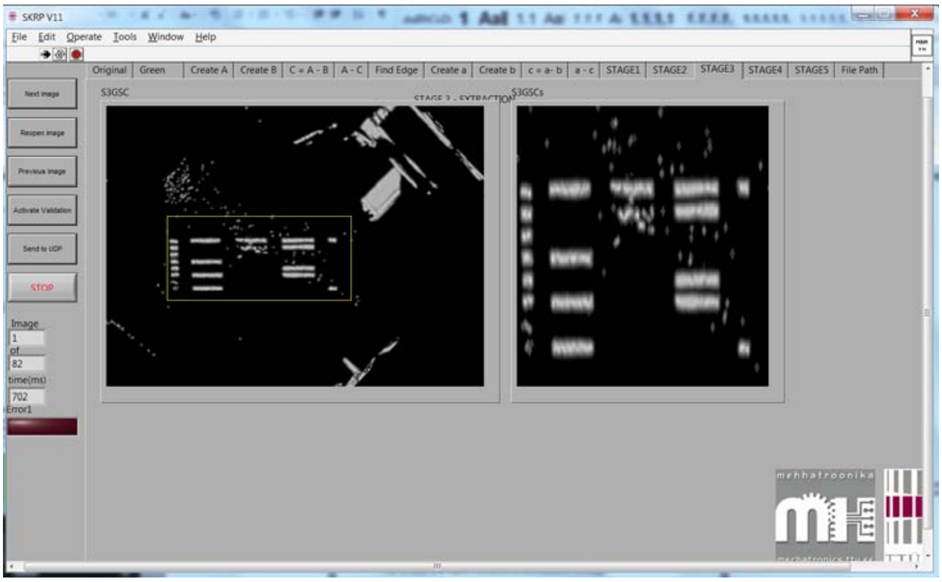


Figure 27 Log code reader user interface

The codes for these logs were marked using a handheld marking device (see Figure 28). The robust device is optimised for use with paints and luminescent nanoparticle (LNP) mixtures for simplified dot or line code marking. It has been designed for use in storage yards or rough field marking.

The device has an independent power supply, PC connectivity, embedded storage of coding information and an option for fast nozzle replacement.

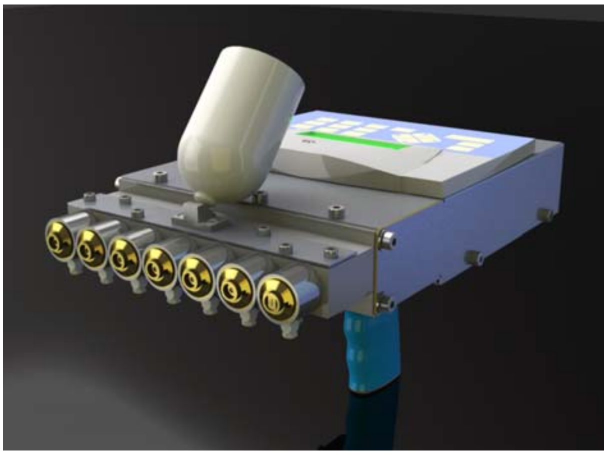


Figure 28 Handheld marking device

It is possible for the marking and reading systems to work in real-time via an adapter and synchronisation system (see Figure 29). The data adapter manages communication between code markers and readers and the production line control system. It also stores data associated with cut boards.

The synchronisation software ensures that the sawmill's production line control system has access to the information on marked and read codes in real time.

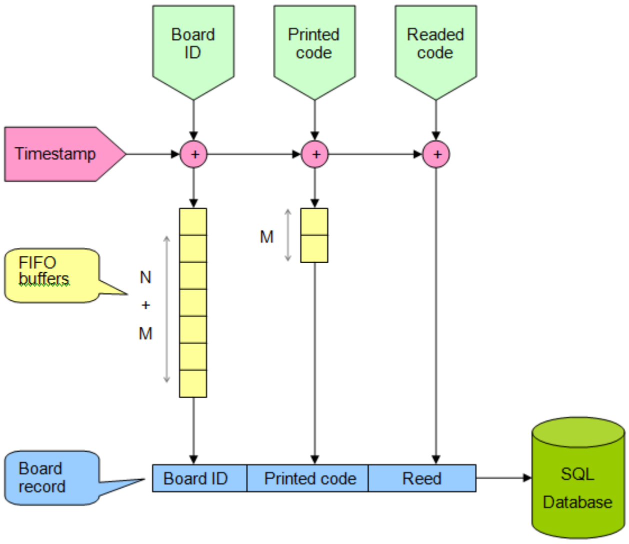


Figure 29 Real time synchronisation system

TallUnit was also actively involved in the IK demonstrators (see Section 1.4.6). Every system being trialled during the industrial demonstrations was first tested rigorously under laboratory conditions.

The biggest technology installation took place at the Serta Malå sawmill in Sweden. Laboratory tests of the system in a marking-reading set up resulted in readability rates of 99.5% to 99.9%. The tests were followed by extensive on-line tests that produced reading successes of 90% to 95% using machine vision algorithms. It was possible to improve read rates to more than 95% by using code quality parameters, improving the mechanics of production lines or using a luminescent code marker.

TallUnit was also involved in the installation and demonstration of log marking and code reading at the Smurfit-Kappa Rolpin Company demonstrator site in France. The lab testing phase investigated a number of options for code marking. The demonstrator involved the use of LNPs in coding paints which produced a read rate of 75% following a 'rough' installation, but with the potential to increase readability up to 95% with further refinement.

1.4.5 *Work Package 6 – Software modules for integration*

Key results

- A service solution called Traceability Services that allows operators in the supply chain to access traceability data to analyse and manage the performance of their operations or the supply chain.
- Integration of data sources and repositories and the capture of supply chain information using the EPC Gobal standards.
- Near real-time collection and visualisation of economic and environmental supply chain data.
- Plug-in architecture to integrate Traceability Solutions with other third party applications.

Find out more

More detail about the Traceability Services software is described in the pubic deliverable reports D6.8 'Traceability Services system architecture' and D6.9 'Traceability Services Key Features and overview' available for download from the project website (www.indisputablekey.com).

A traceability system makes information on individual items available at different stages of a supply chain. This information may be incorporated into automated systems to improve the processing efficiency of items, perhaps sorting similar items together for bulk processing, or optimally adjusting processing parameters for individual items depending on their specific properties or 'heritage' from further upstream in the supply chain.

In the forestry and wood production chain, measurements and processing data are associated with individual logs or boards. Logs or boards can be identified automatically at any point in the processing pathway using some kind of unique ID marking recognition system. The ID code is the access key to all the data available for that item.

It is possible to gather data on item automatically by integrating all the systems that generate data, for example harvesters, log sorters etc. By capturing and storing all the data in a central database, it becomes easier to share it up and down the supply chain.

WP6 has used the EPC Global standards as the basis for developing software to share data within the IK traceability system. The extension mechanisms of the EPCIS specification have been used to add process and measurement data to the supply chain events.

The WP6 team also built a new interface and data definition layer – called CaptureMeasurementTransaction – which can be used to derive harmonised data from all the different devices of the traceability system (e.g. RFID readers, barcode readers, data matrix readers, x-ray scanners etc.) that measure the properties of the physical object or process.

IK partner Tieto developed a software prototype called Traceability Services (TS) for the analysis and management of the supply chain's performance and its sustainability. The software is based on globally agreed supply chain performance management standards. The TS software incorporates a plug-in architecture so that third party applications can interface with the software using the Query and Capture interface.

Several publications have been produced about Traceability Services and extensions to existing standards.

1.4.5.1 System architecture

TS acts as a repository for traceability data associated with individual items (i.e. logs, boards etc.) and supply chain processes. The traceability data stored in the TS Repository databases is made available to other applications.

The connection of business data with item data and observations is possible using any application-specific format.

TS offers various services that use this integrated data. In the IK project, data has been ‘pushed’ using the real-time push mechanisms of the collaborative message system (CMS) and the message handling system (MHS) which can be configured to route information about any detected ‘event’ within the supply chain to any capturing applications that have implemented the EPCIS Capture interface.

The topology of the TS implementation in IK is presented in Figure 30, see D6.9 Traceability Services Key Features and overview. TS uses a ‘software as a service’ (SaaS) model. TS and the applications for the SWSC demonstrator were physically run on the same hardware.

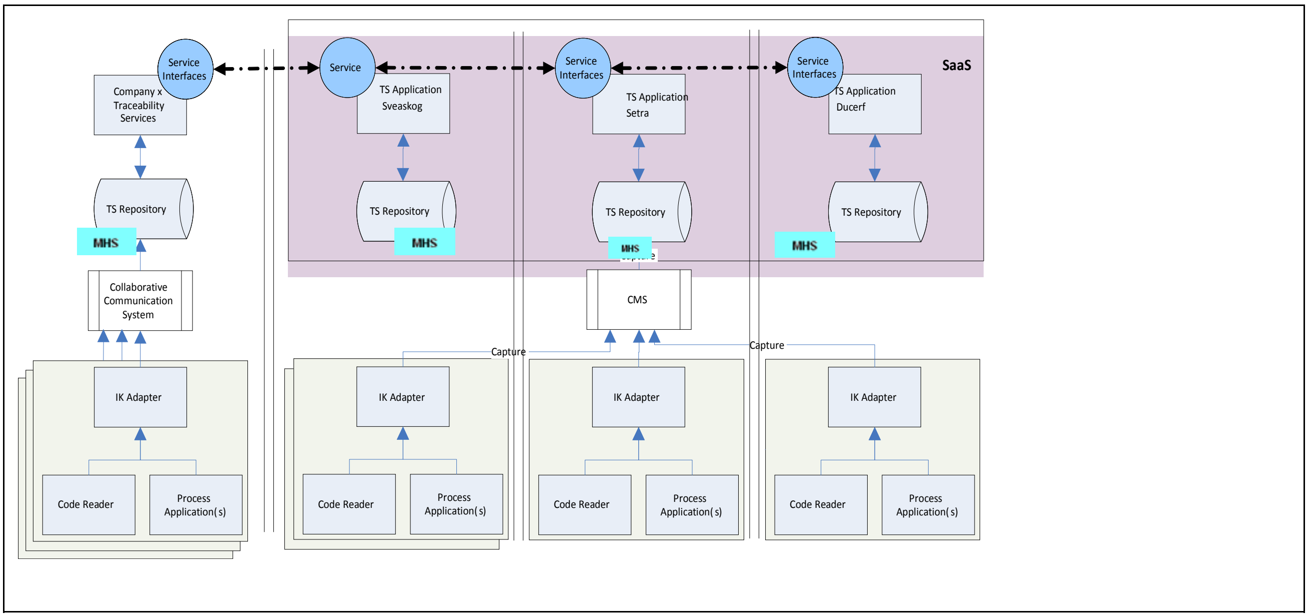


Figure 30 Topology of Traceability Services in IK

Using the SaaS model, Tieto hosted the TS software; the services were accessible securely over the web. The SaaS model offers savings for companies by reducing the costs of hardware maintenance, support and software licensing and enables the user to benefit from software that is continuously improved and updated. The SaaS model also makes it possible to provide all stakeholders in the wood supply chain with a powerful traceability information services at a low cost. TS could also be installed physically at the site of an industrial user.

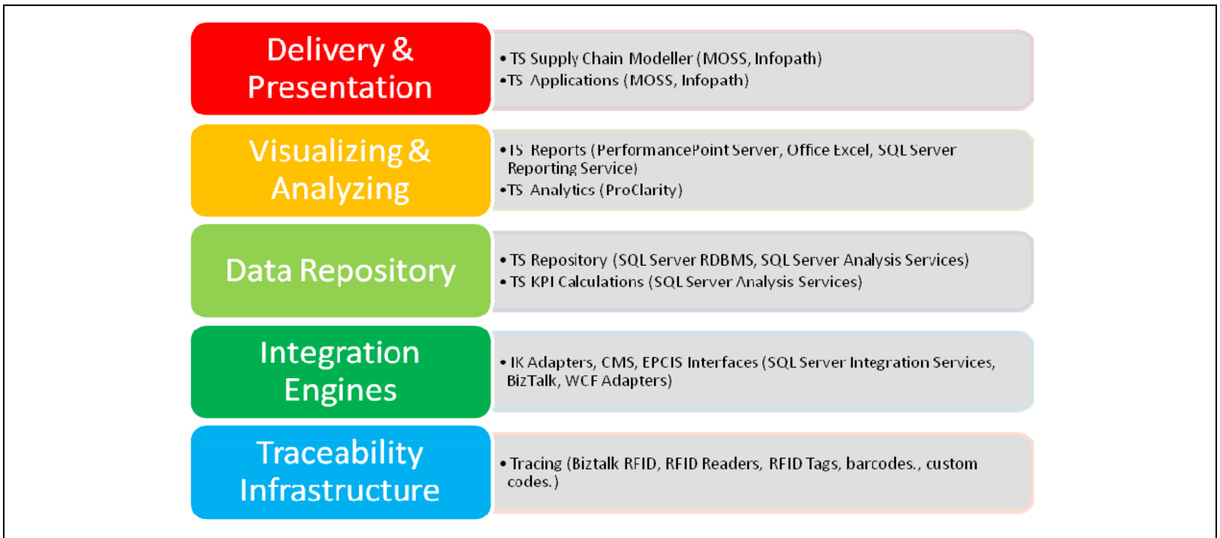


Figure 31 Application architecture and overview

1.4.6 Work Package 8 – Demonstration of systems and benefits

Key results

- The field testing of various traceability components developed by IK, including code marking and reading technologies, the IK architecture and analysis and control applications.
- Performance improvements at all three sites.
- A more reliable supply led to a payback of 6% of the cost of materials (Rolpin demonstrator).
- More efficient processing and post-project deployment of full traceability system at Ducerf site.
- Traceability improves the selection of appropriate raw material at log sorting for a secondary manufacturer, improving yield by more than 10% (SWSC). Economic benefits could reach €700 000 per annum across the supply chain.

Find out more

More details on each of the three demonstrators and the associated business case studies for deploying traceability are available in the public report D8.4 'Documentation of demonstrations and possible market impact' available for download from the project website (www.indisputablekey.com).

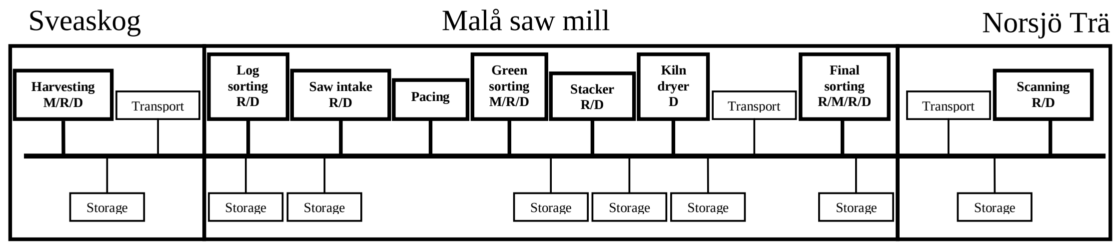
IK ran three major demonstrations of its supply chain traceability solutions, including the integration of physical code marking and reading technologies and the use of item associated data (IAD) to improve the environmental and economic performance of participants.
The demonstrations tool place in:

- Malå, Sweden, for the Swedish Wood Supply Chain (SWSC);
- Labouheyre, France, at the Smurfit-Kappa-Rolpin veneer production site;
- Vendenesse-les-Charolles, France, involving Ducerf.

1.4.6.1.1 SWSC demonstrator

The SWSC demonstrator involved the full wood supply chain, from the forest, through the sawmill to a secondary manufacturer (see Figure 32).

The purpose of the industrial demonstrations was to test the progress of the R&D activities in the field and also generate data on the benefits of traceability to its users. Benefits were indeed demonstrated at each of the three sites.



Note: Bold text shows where marking (M), reading (R) and data collection (D) is needed to deliver all the expected benefits of the demonstrator.

Figure 32 Schematic picture of SWSC

At forestry sites log marking with RFID and ink printing were both demonstrated. The trials using RFID tags showed that the tags could be read successfully at the harvesting site. The log RFID codes were associated with each log's data in the harvester's data file. At the sawmill, the equipment for receiving and sorting the logs was able to read the RFID codes and thereby access data on the log's measurements taken by the harvester.

When logs reached the saw intake in the sawmill the log ID codes were again read by an RFID reader device. The log data was then associated via a pacing system to board data. Physical board ID codes were printed on each board's end (see Figure 33).

Figure 33 A freshly marked board

The demonstrators included readers for printed board ID codes at several places in the sawmill. Board code reading took place at the stacker and in the final board grading step, allowing boards to be connected to their associated data prior to processing at each of these points.

After final grading, a new board code was printed at the board end, to make it possible to trace the board to the secondary manufacture, where the code is read and connected to the result of the cut optimising scanner.

Figure 34 outlines the logical architecture at the SWSC demonstrator.

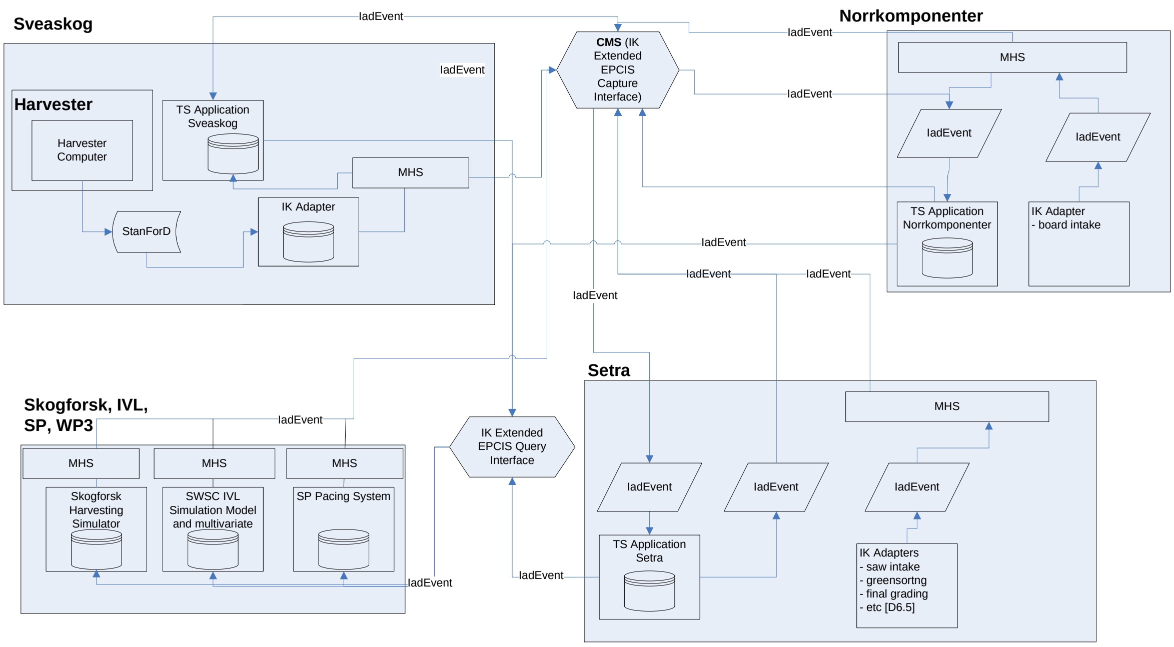


Figure 34 Logical diagram of software modules for the SWSC demonstrator and data flows

Calculations using results from the SWSC demonstrator suggest that the traceability system could generate economic benefits of up to €700 000 per year.

1.4.6.1.2 Comparing yields from different log types

It is possible to grade logs at the log sorter into different categories, depending on different features and properties of the log (e.g. diameter, taper, bumpiness, ovality and crookedness). Logs with different features are suitable for different types of board and consequently different end products.

By sorting the raw material in the log yard and channelling individual logs into different processes, it should be possible reduce the wastage of the raw material and also lower processing times.

Figure 35 shows the result from a test with approximately 380 boards cut from 190 logs. A multivariate model correlated the features and properties of the original log with the yield that the secondary manufacturer obtained from the board. Using this information the logs were then characterised as “suitable” or “unsuitable” by comparing the yield with log type.

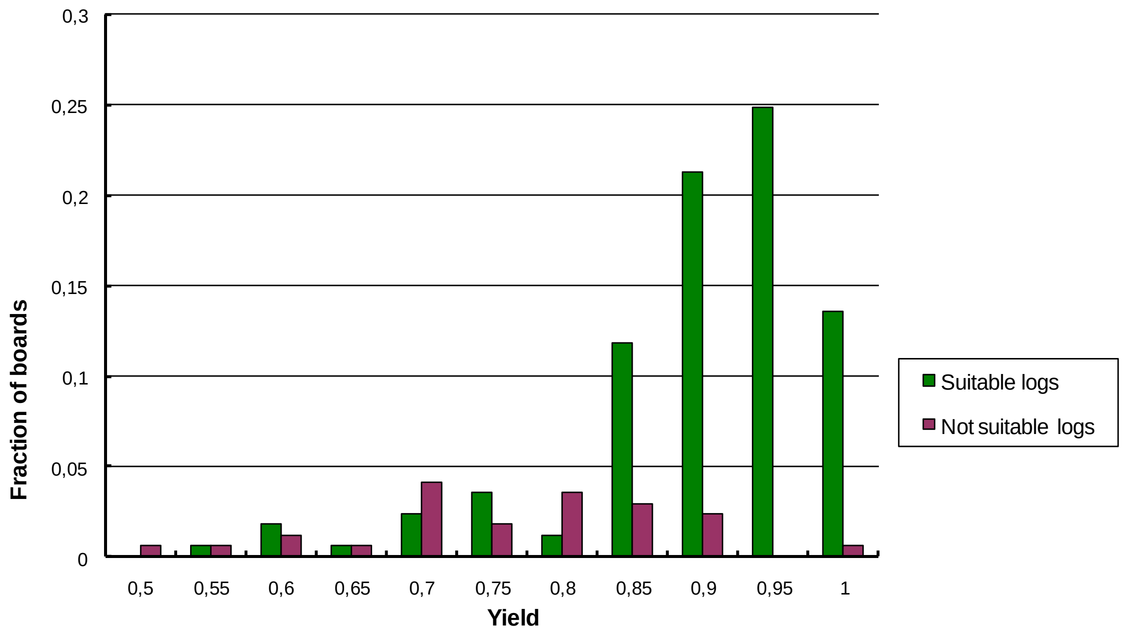


Figure 35 Yield comparison for different log types

Note: . The average yield from "suitable logs" is 88% and 73% from “unsuitable logs”.

1.4.6.1.3 Rolpin demonstrator

At Rolpin, a traceability system was deployed on site to track items from log reception to the peeling process involved in veneer production. Prototype marking and reading stations were developed that could be integrated into the industrial processes at the site (Figure 36 and Figure 37).

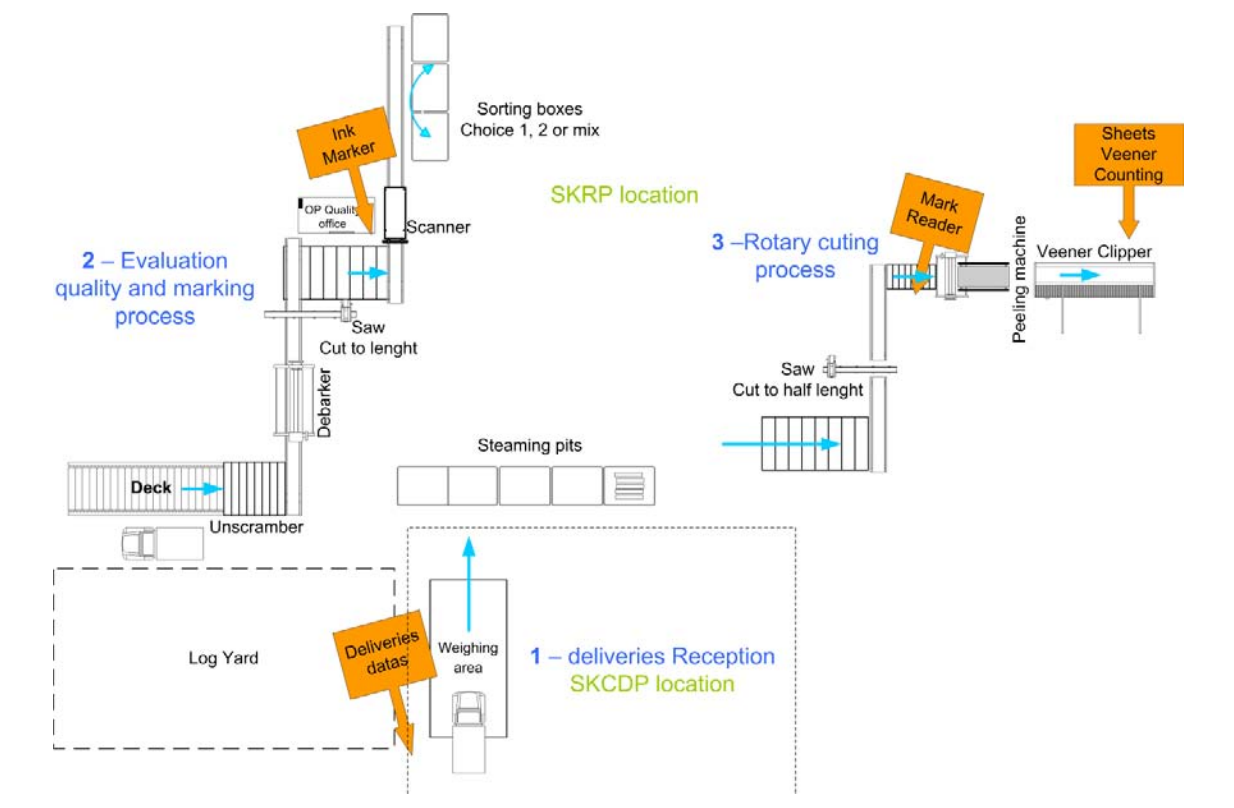


Figure 36 Location of the traceability components on the production line

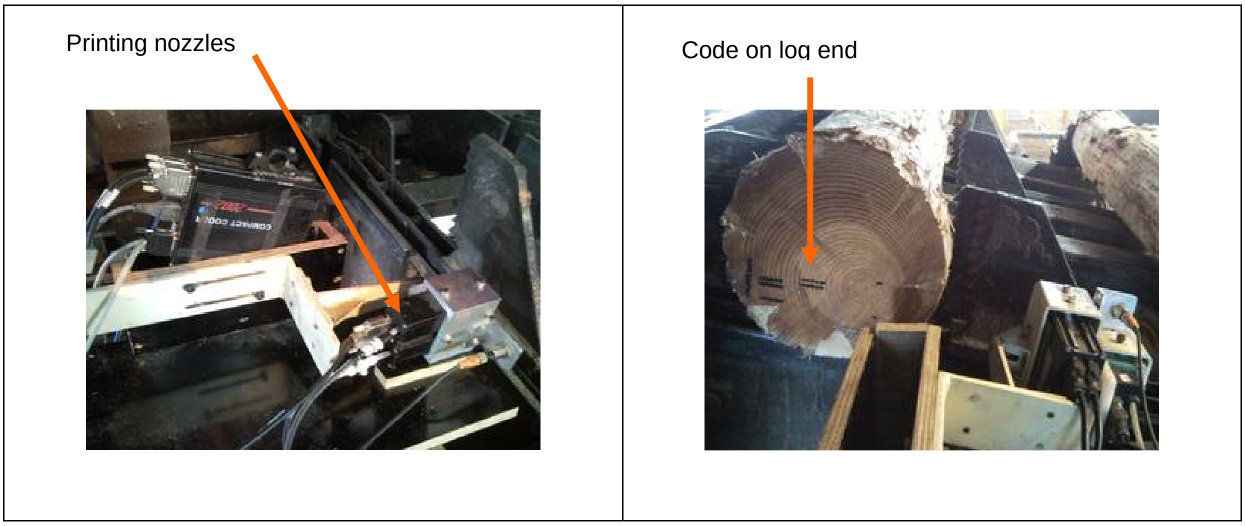


Figure 37 The marking station

Each log was marked individually so that information related to it could be collected along the production line and associated with the final resulting veneer. This demonstrator tested an innovative marking technology that used luminescent nanoparticles (LNP) (see Section 1.4.4.5). This alternative non-RFID approach was necessary because the softwood sector is high volume and low value; plywood production (which requires the production of veneer layers) is extremely competitive and a low cost solution was required. Other marking techniques were not able to meet these criteria.

The prototypes for LNP marking and code reading demonstrated that the system has excellent readability when illuminated with a laser of specified wavelength. Improvements will continue to be implemented so that the equipment can be commercialised.

The use of traceability established a link between the wood supplier and the seller of the veneer. In the production of veneer, peeling is a difficult procedure and it is important that machines are correctly ‘tuned’. The calibration of the peeling machines was checked by comparing the predicted yield of veneer with the actual yield. An actual yield that is lower than the predicted yield suggests that the peeling machine is not functioning optimally (for example, the logs have not been centred in the machine, see Figure 38).

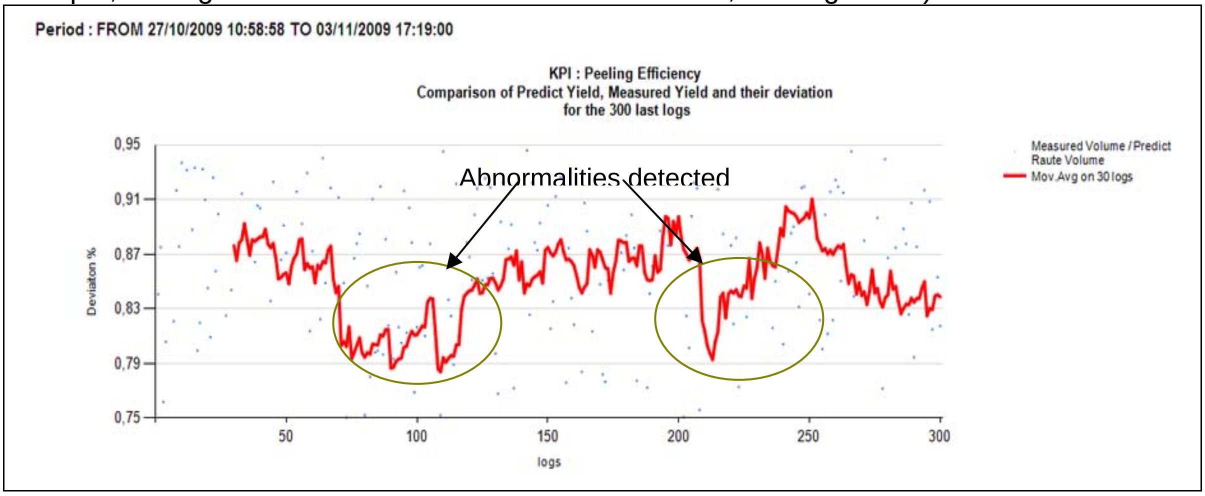


Figure 38 Gap between actual and predicted yield in real time

At the Rolpin site, the deployment of traceability generated competitiveness gains not just for the company, but also its wood supplier. The profits were shared and expressed as a percentage of the yearly raw material cost for Smurfit-Kappa-Rolpin. In this demonstrator Rolpin experienced gains of 6% and its supplier saw gains of 1.5%.

The traceability data helped to show that the quality of veneer logs varied significantly between different sellers which made it easier for Rolpin to negotiate an fairer price for the logs it bought from each supplier, based on the quality of the veneer output.

1.4.6.1.4 Ducerf demonstrator

The IK demonstration at Ducerf aimed to use traceability to improve the management of wood storage, from the end of the production line to the loading of final products for transportation to a customer (see D8.4).

A barcode system was introduced to trace items within the storage area. The barcode was applied to each individual item coming off the production line. This barcode could be read by a handheld barcode reader which used wireless networking to communicate with the central database (see Figure 39). Every item was scanned as it entered or left the storage area so it was possible to know in real time the position and quantity of every product in storage.

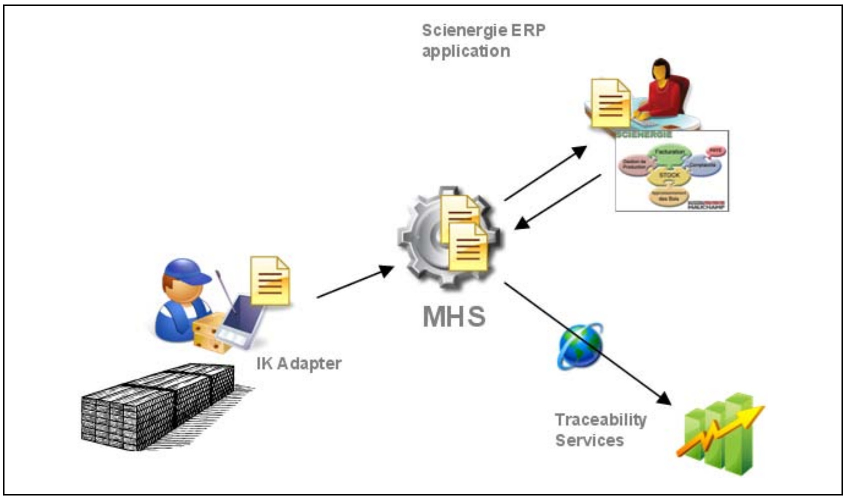


Figure 39 Diagram of the traceability system installed at Ducerf

Ducerf found that the traceability system improved its inventory management and could reduce its manpower costs by as much as 60%. It also helped the company to get a better insight into its storage operations, bringing additional benefits to the company in terms of its organisation and planning. The added benefits have not yet been quantified.

1.4.7 Work Package 9 – Training and dissemination to improve uptake and exploitation

Key results

- Training materials and workshops for users of technologies developed by IK.
- Awareness-raising seminars and workshops targeted at actors in the wood supply chain.
- A web-based simulation tool for the wood supply chain.

Find out more

Some training and documentation materials (public deliverable report D9.1 'Material for internal training' and D9.7 'Final pedagogical content, including a glossary') are available for download from the project website (www.indisputablekey.com).

Before companies are willing to adopt new ICT-based systems it is important for them to know that they will receive adequate training on how to use the new technology and leverage maximum advantage for their organisation.

WP9 was included in the project because it was recognised that potential users, especially SMEs, would require a lot of information so they could make an informed decision about implementing traceability. They would also require support and training on how to use the system and take full advantage of its benefits.

The assumption underlying WP9 is that the implementation of any traceability system – through the entire supply chain from the forest to secondary producers or just within a small part of the chain – would require all the people involved in the production chain to have a basic knowledge about the traceability system and its potential for improving environmental and economic performance.

Each user also needs to have advanced knowledge about how to make the most of the traceability system for their own operations. Some users may need to know how to run and handle devices directly connected to the traceability system in their business.

At another level, the people who supervise these operators must know how to ensure an unbroken flow of information between adjacent actors in the chain;

Businesses will also need to understand how they can best use information for a certain object (e.g. a log or a board) that has been collected further upstream. They need to see how this information can be integrated into automatic or manual optimisation procedures within their own operating unit.

The wealth of data made available by the traceability system should also be used to analyse more holistic optimisation activities that could be applied to the chain as a whole.

Two parallel and complementary activities were undertaken in WP9. There were:

- the delivery of seminars and the production of teaching materials to provide appropriate training for all stakeholders involved in the deployment of a traceability system at an industrial site;
- the development of training modules regarding the implementation of traceability in the wood supply chain.

Beginning with the latter activity, the WP9 team designed materials that first addressed the specific needs of the consortium. These materials have since provided the basis for modules on traceability that have been incorporated into existing courses and educational activities offered by some of the IK partners. The materials have also been adapted for bespoke training session for representatives and industrialists from the forestry and wood processing sectors.

The IK training materials are available for download from the project website (www.indisputablekey.com). The report D9.7 'Final pedagogical content, including a glossary' contains a catalogue of all the public material generated during the project. The report also highlights the pupose of the different training components.

Additional materials available to the public

The IK website also hosts a variety of additional informative materials, including an illustrated glossary, a simulator and interactive videos (see Figure 40)

The online glossary of technical terms related to traceability provides people at all levels of involvement with useful information that can help them to understand better the IK documentation and literature.

Figure 40 Indisputable Key online glossary

Information videos are also available on the project's website (see Figure 41). Most of these look at how traceability solutions implemented in the different project demonstrators and the benefits that the system delivered.

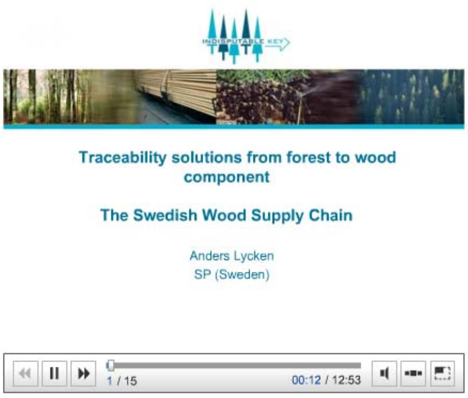


Figure 41 Reference Case Video available on the project website

Following the end of the project, the consortium has developed its IK Offering, exploiting the substantial knowledge of the project's partners regarding traceability, its deployment and the range of technology options. The project's experience as a training provider is also highlighted in the offering.

1.5 Degree to which the objectives were reached

The technical objectives, as presented in Section 1.2, were all achieved during this project. The technological solutions were all specified, designed, installed, put into operation and monitored. The performance of each technology was analysed, discussed and described. The project has recorded how the technologies it has developed could be improved and what functionalities would prove to be beneficial to foster commercial uptake and implementation.

The first objective sought to develop a **user-friendly IAD-based tracing technology** for wood supply chain management and wood production operations. The idea was for the traceability system to cover the entire supply chain from the forest to the secondary manufacturer. Work toward this objective spanned the entire project. The potential for such traceability to reduce total supply chain costs by up to 20% is still to be investigated in practice, since it has not been verified from the IAD collected automatically during the project. The quality of IAD and the volume of data both need to be increased before it is possible to take full advantage of the supply chain management and analysis software developed in WP6.

The second objective looked to develop a **flexible and cost-effective communication architecture** that would allow traceability data to be exchanged and used between supply chain actors. The project defined an open standard for communication and created an open source environment for data exchange. The *Indisputable Key Architecture and Communication standard* is freely available for download from the IK project website (www.indisputablekey.com).

The project more or less achieved its objective to develop **reliable and cost-efficient code marking and reading** systems and components, with 99% readability rates and costing less that €1 per m^3 of unprocessed (raw) wood. Systems were developed for both logs and boards. The “SIMPLE” coding system for logs has demonstrated a code detection rate of almost 90% using a custom made, simplified barcode pattern with 4095 unique physical combinations. This kind of code could be used to distinguish between different assortments of logs (e.g. spruce or pine, timber or pulp log), but also to identify a few individually marked logs per day.

The code marking system for board has 10 million unique ID codes. Code detection rates reached 99.5 to 99.9% during laboratory testing. This readability dropped to 95% in the industrial setting, mostly due to vibrations blurring the visual capturing of the code pattern.

The project cannot prove that it has achieved its ambitious objective to develop **robust RFID transponders for automatic attachment to logs** in the forest with a **target price of €0.1 to €0.2 per transponder** within the next five years. A prototype transponder designed to meet all the technical specifications was developed and manufactured. Calculations based on widespread, but by no means ubiquitous, use of the transponder suggest that the target price is achievable. However, the robustness of the device has not yet been demonstrated on a large scale. So far around 2000 transponders have been used and it seems that the robustness is already surprisingly good. However, this anecdotal evidence needs to be assessed scientifically in a bigger trial.

More tests are required to demonstrate objectively that the project achieved its objective to develop a novel **disturbance tolerant RFID reader** that can be integrated in to forest machines and reach a read accuracy of 99.5% after preliminary tuning and testing. Tests in the field suggest that the reader works surprisingly well in adverse weather conditions, although it appears to crash at temperatures below -20°C due to a malfunctioning component. The antenna component of the reader also needs further development so that it is fully reliable for the detection of RFID tags in the forest.

The project fully met its objective to develop a groundbreaking micro machined **code marking device that was an integral part of a harvester saw blade** and that could mark items at a cost below €0.01. Indeed, the cost of paint for this code marking device is only €0.002 per item, but the readability of the code is significantly below 99% at present.

The project also had an objective to integrate **real-time, entity specific, environmental and economic KPIs** that could be used for the holistic optimisation and responsible eco-management of forest and wood resources. These tools have been developed and demonstrated; a simplified simulator is available on the project's website.

A possible next step, and an outstanding task of the project, is to use the data generated by the project for environmental product declarations (EPDs) to analyse the environmental impact for individual products. If similar and exchangeable products could be shown to have different environmental impacts, the concerned buyer most probably would select a low impact product. The use of EPDs could therefore help to reduce the environmental load of forestry and wood processing by encouraging companies to adopt better environmental management practices.

2 Dissemination and use of knowledge

Key results

- Redesigned website to highlight the post-project IK Offering and focusing on traceability solutions for supply chain and operational management in the forest-wood production chain.
- Publication of 21 scientific papers, four PhD theses and 13 Masters dissertations.
- Participation at more than 60 events including trade fairs, conferences and seminars.
- Publication of more than 30 press articles, mainly in a variety of trade publications.
- Generation of more than 70 new contacts and business leads.
- Good awareness of the project among actors in the supply chain.

The overall objectives for project dissemination have been to support the business goals of the partners, profile the business potential for traceability solutions, deploy traceability between the partners and create awareness of the project among interest groups including the general public.

Dissemination target groups have been identified:

- **End users:** final users of technology and services produced within the project (e.g. sawmills, logging companies, logistics operators etc.).
- **Integrators:** companies able to integrate components produced within the project in packages ready to be sold to the end user (e.g. constructors, IT companies selling packaged solutions including hardware and software).
- **Influencers:** actors who can influence, recommend or request end users to buy IK solutions (e.g. NGOs, policy makers, user groups etc)
- **Extended audience:** any company or organisation able to support the project. This group is moving according to strategic alliances needed to guarantee the success of the project.
- **Scientific community:** Research institutes, universities etc.

The timing of dissemination activities and the messages communicated through the dissemination programme are important elements of the project's communication strategy.

The project adopted a variety of tools for its dissemination including the IK website, press articles, posters, events, etc. The project defined a communication strategy and an action plan to use these tools in the most efficient way. The main tool for dissemination was the project website (www.indisputablekey.com). The results of specific dissemination activities have been evaluated and corrective actions taken.

Our analysis suggests that many dissemination activities have been successful, but the late arrival of exploitable results has pushed the project's focus on dissemination to the very end of the project. However, the project is well-known and the dissemination efforts have generated opportunities for exploitation and new development projects. In particular, a proposal to refine the ink marking technology for harvesters has been submitted to the Woodwisdom net call.

Future developments after the end of the project's funding period have been discussed. The website will remain as a central resource for promoting traceability solutions and giving testimonies from users from all stages of the wood supply chain. Future dissemination activities need careful segmentation so they are targeted to the specific needs of different actors in the supply chain.

Transforming the European wood supply chain

It is particularly important that the results of the project are communicated to SMEs. Most of the 340 000 companies in the European forestry and wood industries are SMEs.

IK could help these companies address some of the many challenges facing the wood industry today. Companies need to secure the supply of raw material in a sustainable fashion, respecting the social and environmental importance of forests. Investment in product development is also required so that the industry can compete with alternative materials used in construction, furniture and other types of product. The financial crisis has also had a major impact on the industry and many companies are struggling to survive.

The climate change debate is also affecting the industry, although not necessarily in a negative way as wood is perceived as an environmentally friendly material.

The project has generated many results which have potential for future scientific or commercial exploitation. Notable results that should be taken forward include new technologies for marking and reading logs and boards, an architecture for the exchange of supply chain data, software for monitoring and analysing the data, and several models that enable predictive simulations of different aspects of the wood supply chain. All these results are necessary components found within a full supply chain traceability solution. The project has generated a considerable volume of scientific output, measured in terms of patents, articles, papers and theses. There are many opportunities and areas for further research and development that can improve and extend this project’s findings.

The partners representing potential suppliers have made detailed plans for the exploitation of the results; in some cases further development and industrialisation will be needed. The industrial companies in the consortium have informed the project partners of their plans.

The strategy for exploiting the results is based on a mapping exercise that matches IK solutions to the challenges and drivers in the market. The marketing messages will be strengthened as more information and metrics become available on payback times, the return on investment and other business benefits of traceability for individual companies. The IK deomonstrators will be used as reference cases, even though some of the demonstrated technologies were only prototypes.

Uptake in the market will be driven by the perceived benefits of traceability for individual companies, rather than for the overall supply chain. Businesses in this sector have stated that they want to improve their own operational efficiency; if IK solutions can achieve this with a good return on investment then it is likely that the technology will be adopted. Expansion of traceability to upstream and downstream firms will probably only happen later, once a business using traceability has used the system to optimise its internal operations. However, it is important that the option for supply chain integration is kept open by building any tracing system on the IK architecture.

The responsibility for exploitation activities is taken on by individual partners, although there may sometimes be occasions when partnerships between consortium members would be beneficial.

2.1 Exploitable knowledge and its use

The project was planned so that the full traceability system consisted of integrated ‘modules’ or components which could function independently of one another, or provide traceability through the supply chain by linking up their data.

The main components developed by the project were:

- technologies for marking and reading logs and boards;
- technology to generate individual associated data (IAD) by which the identity of an object is combined with information on its properties or characteristics (e.g. length of a log);
- infrastructure for safe and efficient collection and exchange of data;
- pre-defined key performance indicators for aggregating data to analyse performance;
- software for analysing and monitoring the traceability system and the supply chain;

- models for predicting the properties of wood;
- models for evaluating, simulating and optimising supply chain scenarios.

The results and outputs that have the potential for commercial exploitation have been packaged together as “IK Solutions”.

An overview of the solutions is illustrated in Figure 42.

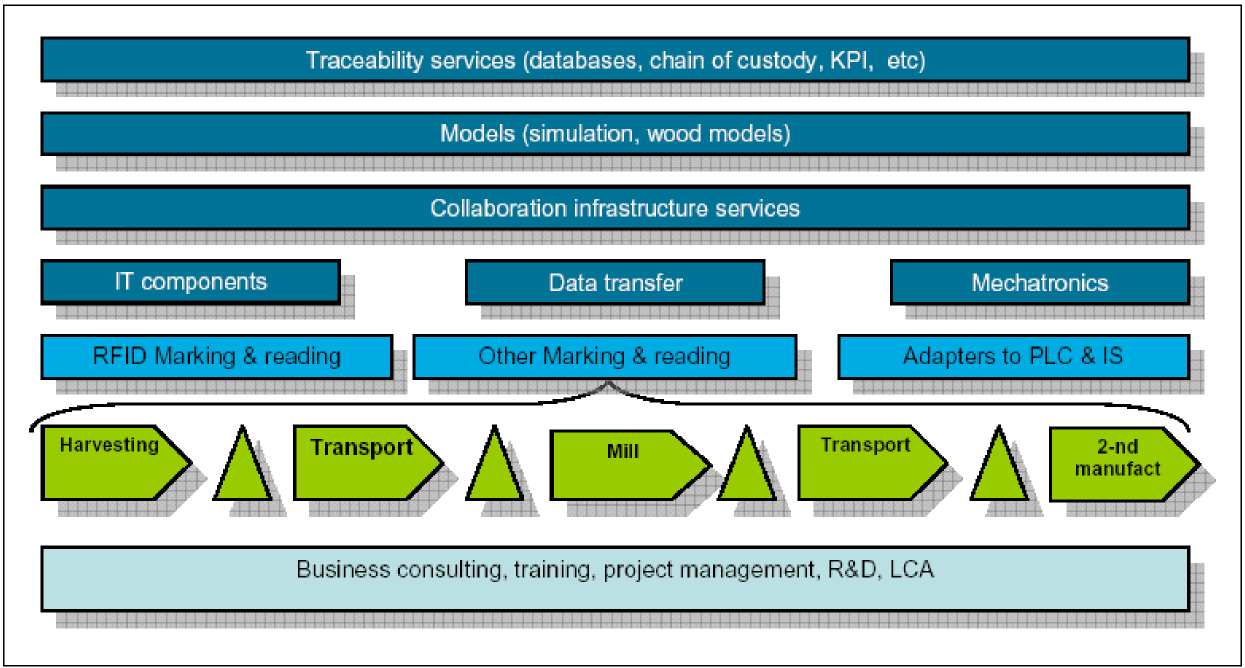


Figure 42 Overview of solutions

The most important component solutions developed by different Work Packages in this project are detailed in the following section.

2.1.1 Component solutions available for exploitation

2.1.1.1 Semi-passive transponder

Wood freshness is one of the main factors influencing th efficiency of production methods and the quality of a final wood product.

The semi-passive transponder allows operators to monitor automatically the moisture content of wood where the transponder is inserted into wood.

Monitoring moisture levels is also possible with traditional active transponders powered by a battery source. But the cost of an active transponder makes it less attractive for log marking purposes. Since the semi-passive transponder generates power in an electrolytic process using moist wood as the electrolyte, only two electrodes embedded in the transponder are needed, lowering the cost compared to active transponders. When the log is fresh and the transponder is active, the semi-passive transponder has a greater reading distance than passive transponders.

Partners involved

- SP

Planned exploitation

- SP plans to license the patent to transponder manufacturers (offered first to IK participants).
- To make exploitation possible a prototype has to be developed and tested under realistic conditions. It is therefore necessary to see if there is sufficient interest among potential users and manufacturers of such a product.

- Technical challenges include the design, rational manufacturing and reliable functioning whilst embedded within a log.

Possible obstacles which might prove to be barriers to commercialisation

- The existence or development of similar or competing technologies or solutions, although there is no known competitive technology.

Need for further development

- Further additional research and development work, and further collaboration to test the feasibility and value of the device.

IPR status

- Intellectual Property Rights protection measures: PCT International Publication number WO 2008/127192 A, see http://www.wipo.int/pctdb/en/wo.jsp?WO=2008127192

2.1.1.2 Woody tags and woody pads

The invention relates to a specially designed protective radio-frequency transponder and its use to mark living trees fulfilling special end-user requirements. Transponder developed during IK comprises a casing manufactured from lignin based materials ('artificial wood') and a radiofrequency transponder covered by the casing. The casing material is made of wood components themselves and while produced with lignin, a natural protective agent of wood, the transponder would also function as a safe and protective implant in the tree storing information related to the tree that is important for the forest owner, the forest workers or other operators in the supply chain.

Partners involved

- TUT (developer and licensing of patents)
- Confidex (marketing, production and sales)

Planned exploitation

- Wounds are currently patched with a protective paste. This paste does not facilitate storage of information in the tree.
- Certain plastic RFID tags for marking woody material do already exist (e.g. PINO tags by Confidex), but unlike woody tags, they are not suitable for marking living trees. The presence of plastics could jeopardise certain end-uses for the tree.

Possible obstacles which might prove to be barriers to commercialisation

- Existence of similar products on market, but the special properties of the woody tag should help to distinguish it especially for use in living trees.

Need for further development

- Casings of different shapes and sizes are needed for different uses which will require a redesign of the internal RFID component.
- A bullet form could be used to fill holes drilled by foresters, blocking the wound and also containing information about the tree or the wound.
- A tag in plate form could mark trees, for instance in an arboretum or park. Embedded information could be relayed to visitors or foresters.
- More work and material development could help tags to be more compatible for other end-uses (e.g. furniture).

IPR status

- Claim made by TUT.

2.1.1.3 RFID technology for marking and reading logs

A new RFID transponder specifically designed for log marking has been developed. The new wedge-shaped transponder meets stringent specifications to withstand vibrations, shocks and severe weather. Reading distances reach several metres and the transponder has the potential for a low prince point. The new transponder is pulping compatible, biodegradable and designed for automatic or manual application into logs.

An RFID reader has been developed that can be installed within the harvester head and able to withstand the extremes of the working environment.

An automated transponder applicator (ATA) was developed, but needs significant development and the partners do not intend to take exploitation further. A manual applicator (MTA) was also developed and is almost market-ready.

Partners involved

- VTT (transponder patent licensing, transponder reader).
- Confidex (marketing, production and sales of the transponder).
- Rottne, Dasa Control System, Bohult Maskin, VTT, SP (automated applicator and control, integration software).
- Bohult Maskin, SP (MTA).

Planned exploitation

- The transponder will soon be marketed by Confidex.
- The commercial potential of the harvester reader is dependent on the automatic applicator as the reader is needed to read the log IDs after they are marked with RFID transponders.
- The ATA needs significant development to speed it up and reduce its maintenance requirements. It is probably not patentable technology.
- MTA could be used for test sawing, manual felling, to mark special logs and to mark piles of logs with the owner’s ID.

Possible obstacles which might prove to be barriers to commercialisation

- Development of competitive products, although none known.

Need for further development

- None identified for transponder.
- Further development is required prior to commercialization of the RFID reader, especially the addition of more functionality and options so it can compete with more general purpose RFID reader designs.
- The size of the reader needs to be reduced.
- The automated transponder applicator also needs to be improved to have a larger transponder magazine and to function faster (currently the transponder application adds two to three seconds per log to the harvesting process).
- The material of the MTA and the finalized design need to be agreed.

IPR status

- Two patent applications covering also the manual applicator (MTA) have been filed: FI20086222 and FI20086223. Ownership agreement between SP, TUT and VTT has been signed, with VTT administrating the patents and their licensing.
- A patent application for the adaptive RF-front end has been filed prior to the harvester reader development in IK.

2.1.1.4 Ink-based system for marking and reading logs (SIMPLE)

An alternative method for log marking and reading developed by IK uses an ink-based technology. A printer can be integrated into the harvester cutting head (aggregate). A two dimensional matrix code can be applied via the saw blade of the harvester. This code is detected using optical image recognition (digital camera plus image processing software). A manual ink marking device was also developed to imprint extended barcodes on log ends.

Partners involved

- KTH

Planned exploitation

- The technology can be used to print a matrix code (up to two million unique IDs) or simple code structures. Simpler code structures have higher detection rates.
- Numerous applications are possible, for instance to improve logistics between the forest and the sawmill, reduce illegal cutting and automating log measurements.
- Forest owners, the machine manufacturer and sawmills will have to be involved to take this to market. The cost for this method can be as low as €0.002 per code.
- A follow up project has been proposed to refine this technology and take it closer to market.

Possible obstacles which might prove to be barriers to commercialisation

- None identified

Need for further development

- Prototypes are not near commercialisation, but improvements are on-going.
- Studies are looking at whether the use of UV/IR pigments could improve code detection rates under difficult conditions.

IPR status

- Claims in progress.

2.1.1.5 Ink-based marking (with LNPs) and reading of boards

A technology for printing matrix codes on wet and dry board ends has been developed. The use of luminescent nanoparticles (LNP) in inks has been shown to make the reading of marked boards by smart cameras more accurate.

IK demonstrated the use of LNP in a pre-feasibility study. The durability and reliability of LNP marking was shown, as was its potential cost effectiveness.

Partners involved

- Rolpin, FCBA

Planned exploitation

- Development of industrial devices for LNP marking and reading.

Possible obstacles which might prove to be barriers to commercialisation

- Alternative marking and reading systems.

Need for further development

- The project demonstrated the feasibility of the technology in a real world setting. Further research is still needed to optimize the LNP marker, the reading device and its illumination system. The LNP ‘ink’ foumulation also needs to be refined.

IPR status

- IPR claimed by Rolpin and FCBA.

2.1.1.6 IAD synchronisation

Careful studies are required to ensure that the automated readouts from board scanning and measurements are associated with the correct individual object. The idea is to synchronise items in production with their location and data about their properties in real time. Companies can analyse this data to adjust processing parameters and improve yields, reduce production costs and save energy (e.g. by lowering drying times).

Partners involved

- TallUnit, Hekotek, Tieto, SP Trätek.

Planned exploitation

- Sawmills are the main target as these have the greatest potential for cost savings from the use of real time IAD.

Possible obstacles which might prove to be barriers to commercialisation

- Need to improve ID code reading rates (currently around 90%).

Need for further development

- Improving reading rates.

IPR status

- Involves bespoke studies and consultancy at each individual sawmill.

2.1.1.7 IK architecture

A specific architecture has been developed which provides the infrastructure for the collection and exchange of wood supply chain data. The architecture is based upon existing standards as including EPC Global (transponder codes, protocols), papiNet (XML-messages) and StanforD (communication with forest machines). The project has defined a specific IAD message, which has been accepted as an integrated part of the papiNet standard.

The architecture also contains a collaborative messaging service (CMS) which allows multiple actors in the supply chain to exchange confidential data securely.

IK Adapters have been developed that make it quick and easy to plug in existing systems into the traceability system as well as collect traceability data through the system.

The collaborative message system (CMS) and the message handling system (MHS) are both components that could be integrated into other architectures requiring data exchange.

CMS IPR rights claim is currently in process (Tieto).

Mauchamp owns the rights to the MHS IPR.

2.1.1.8 Traceability Services

The Traceability Services software allows users to monitor KPIs and analyse the supply chain data. The software has been designed to run as a service (Software as a Service, SaaS model) to meet the requirements of both small and large businesses. The software is highly scalable and would be provided on a subscription basis, so would require virtually no upfront investment costs. Tieto, which developed the system, is already commercialising the software and has made several potential customer contacts.

Partners involved

- Tieto

Planned exploitation

- The solution will be offered as a service (SaaS, Software as a Service). The pricing model is based upon the use of the system.
- The solution will be a part of Tieto's regular offering, primarily targeting the forest industry, but also other industry sectors will be approached.
- To support Tieto's sales activities for this product, the company plans to promote EPC Global and papiNet standards as well as publish some scientific papers.

Possible obstacles which might prove to be barriers to commercialisation

- Competitive products.

Need for further development

- Further work is needed in commercialisation of the solution and building delivery capability.
- Several partners have been identified as possible cooperation partners for further exploitation.

IPR status

- Tieto has copyright to the source code and software design.

2.1.1.9 Predictive models and simulations

Existing theoretical models that can be used to predict the properties of wood from certain parameters have been developed and fine-tuned in the project. Models that look at the drying of poles and wood have also been improved.

These models and simulations are:

SPace: SP's software for matching logs with boards based on properties measured on logs and boards (e.g. length). The software will be licencsed to sawmills to trace boards back to their original log.

PoleDry: This software was developed by SP and Jarl-Gunnar Salin. It predicts the drying rate for logs especially for drying poles in a log yard. It needs adapting for logs with bark. The user interface also needs to be made more user friendly. The software will be sold to forestry and pole industries.

Supply chain simulation: This is an event driven simulation model of the wood supply chain, permitting an analysis of production yield, and environmental and economic key performance indicators (KPIs). It will be used by IVL as part of its consultancy package to companies in the wood supply chain.

2.1.2 Scientific exploitation

The results and knowledge from the project have been provided the basis for:

- patents (four submitted);
- scientific articles (nine);
- scientific papers (21);
- theses (four PhDs and 13 Masters dissertations);
- white papers (written on the results from WP3 and WP6);
- participation in conferences (in the areas of RFID and wood science);
- new research projects or projects in the planning stages (four at various stages);

In addition to the patents, more than 20 IPR claims related to software copyrights have been made.

2.1.3 Summary of exploitable results

The full list of exploitable results is presented in Table 6.

Table 6 Exploitable results

Area	Product	Sector	IPR status	Owner
RFID	Log transponder	Forestry	Patent filed	VTT, SP, TUT
RFID	Semi-passive transponder	Forestry-wood	Patent filed	SP
RFID	Woody tag	Forestry	IPR claimed	TUT
Ink	LNP	Forestry	IPR claimed	FCBA, Rolpin

Area	Product	Sector	IPR status	Owner
Software	Traceability Services	All	IPR claimed	Tieto
Software	CMS	All	IPR claimed	Tieto
Software	MHS	Wood industry	IPR claimed	Mauchamp
Software	IK adapters	Forest-Wood	IPR claimed	Tieto, Ciris
Software	Light traceability solution	Wood industry	IPR claimed	FCBA
Software	SPace	Sawmills	IPR claimed	SP
Training	Consultancy	Forestry-wood		FCBA
Environment	Consultancy	Forestry-wood		IVL, FCBA
Business management	Consultancy	Forestry-wood		FCBA
Models	PoleDry	Wood industry	IPR claimed	SP
Models	Simulation	Forestry-wood	IPR claimed	IVL
Control of measurement systems and predicted properties	Quality certification system for harvesters	Forestry – industry	System architecture open	Skogforsk
Artificial wood	Woody pad	Forestry	IPR claimed	TUT

2.2 Dissemination of knowledge

2.2.1 Publications

The project's deliverables are a rich resource and present a wealth of information that should be disseminated to all stakeholders in the European wood supply chain, including forest owners, sawmills, manufacturers, large companies and SMEs, universities and research organisations.

Many of the deliverables have been designated as restricted or confidential documents. However, much of the material within these documents could be placed in the public domain.

An analysis of the deliverables qualified their potential as sources for further dissemination materials such as:

- abstracts – a few lines outlining the main findings or results in a deliverable, but cleaned of any confidential information (this can often be easily achieved through an extended executive summary);
- white papers – where a deliverable is used as the basis of a white paper given to target group and summarising the key findings or knowledge;
- scientific papers – whereby the deliverable contains valuable material for a scientific, peer reviewed paper;
- transfer session – where it would be valuable to communicate the deliverable results to an invited or targeted audience;

- downloadable document – a version of the deliverable that is cleaned of confidential information and placed in the download area fo the project website.

The results of the analysis are presented in Table 7.

Table 7 Dissemination of knowledge

Work Package	Abstract	White paper	Scientific paper	Transfer session	Downloadable document
WP2	4	7	2	6	15
WP3	5	6	8	3	6
WP4	2	1	4	6	3
WP5	9	4	7	0	5
WP6	1	4	3	3	5
WP7	0	0	0	0	3
WP8	2	0	0	0	1
WP9	1	1	0	4	4

2.2.2 Final seminar

The project's final seminar was held in Paris on 22-23 March 2010. More than 70 delegates attended including 18 people from outside the consortium. The first day involved presentations from all the participants, especially from the users of the developed technologies and systems. The idea was for everyone to hear about the real benefits experienced by individual companies and for whole supply chains. Further contacts were established with other potential end users from the pallet and packaging sector, as well as technology integrators and research institutions interested in further collaborative research.

The second day fo the seminar involved presentations with more technical detail from experts involved in the development and deployment of traceability technologies. The day involved participation from experts in traceability from other sectors (e.g. automotive industry, government).

The seminar concluded that the involvement of people must not be ignored as it is people who must ultimately choose to adopt and be able to use the new solutions. There is little point in managers assessing the financial or even environmental benefits of a new system if the people who will have to use it are not consulted and made part of the process of change.

Consortium partners and other outside participants have continued to discuss ways to facilitate the mass uptake and adoption of new technologies into this and other industrial sectors.

2.3 Publishable results

The project produced the following publicly available reports, which contain more technical detail about the project results and technologies outlined briefly in this report:

D1.24	Final Report
D2.11	Documented Management Model
D2.12	The communication standard
D2.14	Relationship to existing RFID standards documented
D3.1	Report on initial analysis of drivers and barriers
D3.2	Existing models and model gap analyses for wood properties
D3.3	Report on selection and definition of environmental and economic KPIs
D3.8	Environmental product declarations (EPD) for selected products
D3.9	Optimal wood allocation
D3.10	Economical, strategic and political perspective of supply chain performance
D3.11b	Environmental and economic impact of implementation of developed approach and on further possibilities and challenges in wood chain traceability
D4.10	Forest RFID transponder and reader design
D4.11	Forest RFID system operation
D5.4	Code-reader prototype
D5.8	Saw integrated micro printer prototype
D5.9	Documentation of saw integrated micro printer
D5.10	Mill log code reader prototype
D5.11	Documentation of mill log code reader
D6.8	Traceability system architecture and overview
D6.9	Traceability services, key features and overview
D7.5	External website for “Indisputable key” -> www.indisputablekey.com
D7.8	ERA activities report
D8.3	Demonstrations
D8.4	Documentations of demonstrations and possible market impact
D9.1	Material for internal training
D9.7	Final pedagogical content, including a glossary