ARBETSRAPPORT

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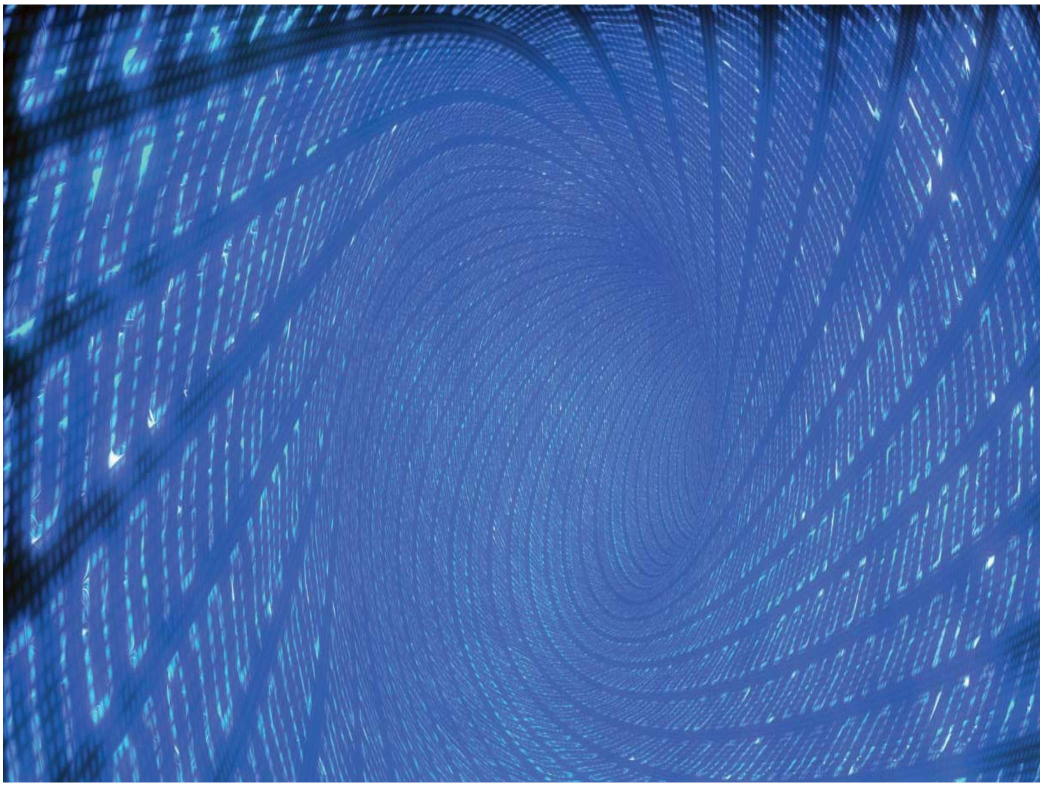

Project no: 34732

D3.1 Initial analysis of drivers and barriers

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INDISPUTABLE KEY

Intelligent distributed process utilization and blazing environmental key

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Thematic Priority: 2

D3.1

Initial analysis of drivers and barriers

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CONTENTS

1 Introduction

This deliverable contains an initial analysis of the main drivers and barriers for the use of Information and communication technology (ICT) traceability technology in the wood supply chain. This includes the possibility to trace individual logs and boards, and to achieve a more efficient information system that facilitates an information flow with the physical flow. The supply chain refers to the distribution channel of a product, from its sourcing, to its delivery to the end consumer. The supply chain is typically comprised of multiple companies. In this document only wood material is considered, from forests to the first processing step of a secondary manufacturer.

The analysis is divided into four general aspects: technical, economic, environmental and organisational as a generic introduction followed by applied aspects from different parts of the value chain. Where relevant, differences between hardwood and softwood as well as between Scandinavian and French conditions are pointed out. The document also accounts for specific information and priorities of the Indisputable Key case study industries.

The purpose of this document is primarily to help planning and prioritisation of the remaining work in work package (WP) 3 of Indisputable Key and partly also other work packages in the project. The document sets up potential pathways for future work to be done in the WP3.

2 Technical aspects

In general ICT for traceability comprise a large palette of different solutions with different advantages and limitations. All detailed technical aspects related to the methods for marking are handled within WPs 4 and 5 and questions related to IT infrastructure and databases in WPs 2 and 6. Hence, the technical aspects are treated only briefly in this document.

If no economic limits are considered, the various technical solutions will probably have the ability to solve most of the problems of marking and tracing all individuals. Taking economic, environmental and process restrictions into account makes the technical challenge much tougher. To be implemented in larger scale a feasible solution must provide a proven benefit (economic, environmental or social) of the entire system.

A few general statements about the marking and reading technology are:

- Reliable and fast labelling read/write procedures, data security, dirt, vibrations, shock, humidity, process resistance, environmental and process friendliness etc. have to be taken into account. Low reliability leads to loss of traceability but also possible misleading information which can be more serious (data for one log is attributed to another). This is a possible barrier to implementation.
- Technical solutions to prohibit "anti-RFID" activities like data virus, illegal or un-authorized change of information, data theft, physical or information system sabo-tage or piracy, blocked reading capability etc. have to be considered.
- Technical solutions must be flexible enough, as to be able to adapt to different wood properties / heterogeneities / dimensions / grades and to existing equipments in firms.

Application of a RFID device to the harvester may consume time that delays the harvesting process. This decrease in productivity cost between 1-4 cents per second depending on the basis for calculation. The total cost for the harvester is approximately 40-120 Euro/ PMH (productive machine hour) and a reduced cost only incorporating salaries and operations is about 40 Euros. The risk for increased downtime due to new equipment is also to be considered. An increased downtime caused by applicator equipment of 1% will increase the hourly cost per PMH with 0.5 -1%. Hence, equipment reliability is of utmost importance. Marking of boards in a saw mill is already today achievable at the speed of production, e.g. by using code writers, and thus not seen as a primary source of increased downtime.

Marking of wood products or intermediate products (logs, boards etc.) can be done on different levels, which is exemplified in Figure 1. In the following chapters, the requirements for marking traceability will be discussed with this figure as a reference.

- Type 1 is when all logs/boards are marked with a unique ID so that their attributes can be traced. For full traceability of every log/board this is the solution required.
- Type 2 is when all logs/boards are marked not uniquely but with some part of group membership (e.g. assortment, stand of origin, quality etc.). This can potentially be technically simpler since the requirement on information content in the marking is lower. One example of this type of marking is the colour marking of logs done by CTL-harvesters (cut-to-length) in the forest today.
- Type 3 is when a selection (random or systematic) of logs/boards are marked with a unique ID, e.g. when a sample (e.g. certain percentage) of logs in the forest are marked with transponders.
- Type 4 is when a selection (random or systematic) of logs/boards are marked not uniquely but with some part of group membership as for case 2. It represents the lowest level of marking for traceability.

Combinations of presence and absence of different types and levels of physical marking may be used as information carriers, especially when combined with other confidently detectable log characteristics, e.g. log diameter, log length etc. An example may be as follows:

a. Saw logs of sufficiently valuable individual log information (customer requirements) are marked type 1.
b. Remainder of saw log assortments not representing sufficiently valuable unique log characteristics are marked type 2, while a randomly selected subset of 1/200 of these are marked type 2 and 3 for production control.
c. Fuel wood (when applied) not representing sufficiently valuable unique log characteristics are marked type 2, while a randomly selected subset of 1/1000 of these are marked type 2 and 3 for production control.
d. Pulpwood (when only one pulp assortment) is representing remaining logs that does not have to be marked except for 1/1000 for production control.

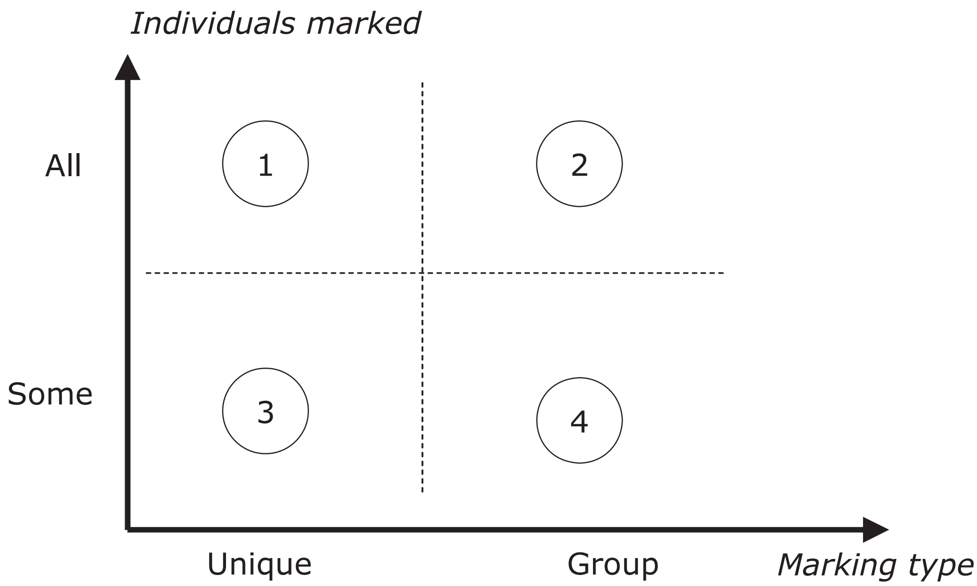


Figure 1. Illustration of different levels of marking of logs, boards etc.

The information chain in a cut-to-length (CTL) system usually have at least the following links: customer requirements – planning of harvesting operations – customers orders – harvesting, bucking and sorting – forwarding – piling at roadside – haulage to destiny – wood yard and stock management at industry. Increased efficiency of the forest to industry logistics, regarding destination of general assortments (saw logs and pulpwood) has been an important driver for the development of CTL systems, while different possibilities to improve the allocation of suitable wood properties to meeting costumers' needs have been increasingly emphasized during the latest decade.

Today information is not traceable down to individual logs. When the information chain remains unbroken and data is connected to the relevant unit of wood (log, pile, assortment, etc.) valuable information can be enriched and utilised both for successive procedures and final product declarations and to give feed back to the previous processes along the chain.

With implementation of traceability and integration of information systems the data can be carried forward from the forest. Connecting the forest data information system to the information system of sawmills or other buyers/users enables a much more efficient information exchange between participants, which is a key to many of the benefits described in this document. Development of a more integrated information system along the forestry supply chain can preferably be done in combination with a system for traceability. Today, sawmill information systems contain data from different processes in the sawmill but these can usually not be connected. Hence, an integration of information systems within sawmills is also of great importance.

Possible barriers to development of a more integrated information system along the forestry value chain include:

- Organisational issues linked to the current organisation of participants in the value chain and their dependencies. This is further discussed in a separate chapter.
- Cost of implementation. Economic issues are discussed in a separate chapter.
- Heterogeneity of existing information systems. Technical solutions must take into account different levels of IT integration in SME especially in French hardwood harvesting and processing.
- Low development of information systems in the French forest companies, which limits data collection and processing capacity of the collected data. The latter is often resulting from behaviour of participants in the chain, often contrasting with the one observed in Scandinavia, even when they are using the same harvesters.
- Corrupt information (for different reasons, e.g. misread ID codes, communication problems, uncalibrated measurement equipment etc.).
- The interface to the database/traceability application must be user friendly or it will be a barrier.

In order to avoid duplicate storage of information, data can be stored on the highest possible level, i.e. the level it represents. This can be exemplified by stating that information that is representing a package of boards (i.e. is the same for all boards in the package), like drying conditions, should be stored only once for the package rather than for each individual board. If each board is linked to the package the information can be obtained on board level.

Figure 2 contains an illustration of relevant objects that have information relevant for storing in traceability information system containing data for multiple stages in a whole supply chain including a Scandinavian sawmill. Note that Figure 2 is an illustration of relevant objects and their relations only and do not necessarily correspond to elements in architecture for communication or data storage.

In Figure 2, a stage (e.g. harvesting) is a set of elementary processes or activities and an object is a single product (e.g. board) or a set/collection of products (e.g. package). The lines represent relations between objects and not necessarily a transformation process. A star (*) indicates "many" so that a line with a star in one end is a one-to-many relationship (e.g. many logs from one tree, many boards in one package…). A thick black line is an identity relationship and indicates only a transfer of the object from one stage in the value chain to another. These relationships should be kept in the information system, i.e. information about which log a certain board originates from should be stored.

It should be noted that the number of processes in the saw mill is quite large (sorting, debarking, sawing…) and that the saw mill part of the figure could have been divided into several boxes (as has been done for the forestry part of the chain). However, for clarity the full saw mill is represented by one box in Figure 2.

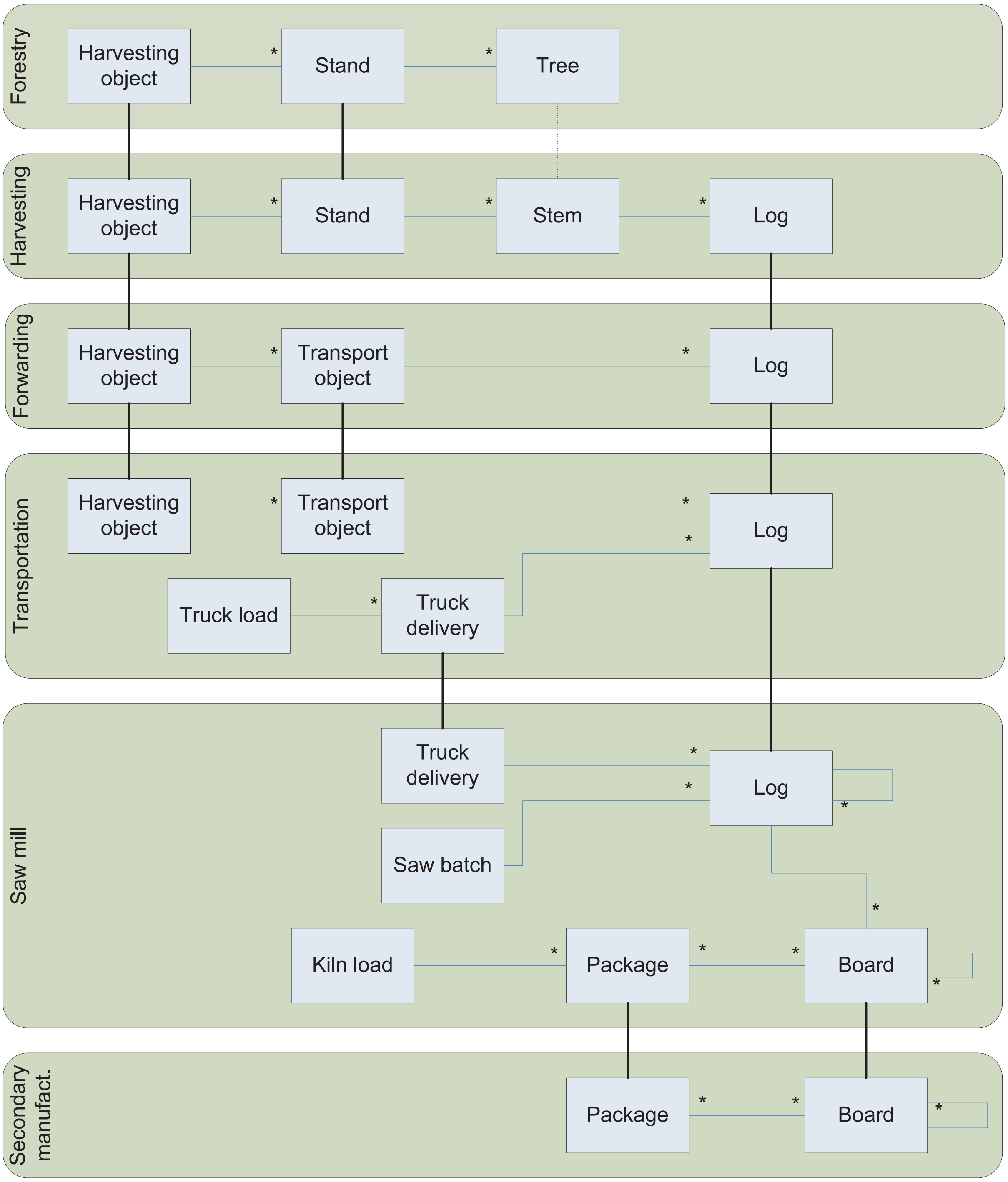


Figure 2. Traceability objects for a Scandinavian sawmill forestry value chain; see text for explanation of symbols.

3 Economic aspects

The implementation of Information and Communication Technologies (ICT) particularly in the field of traceability within the wood chain (forest – sawmills – secondary transformation), as to be applied by individual participants has to generate additional benefits than those that they would receive in a "business as usual" case. In practice, for instance, a cost – benefit analyses (CBA) of different systems and case studies can be used to make an analysis of the economic performance of the traceability system. The analysis determines if the tool is desirable from an economic point of view. CBA is an essential tool for estimating the economic benefits of a project. In principle, all impacts should be assessed: economic, social, environmental, risk (technological…). The objective of CBA is to identify and attach a monetary value to all possible impacts in order to determine the project costs and benefits; then the results are aggregated (net benefits) and conclusions are drawn on whether the project is desirable and worth implementing.

Focusing especially on the economic impacts, the Life Cycle Cost Analysis (LCCA) is an economic evaluation technique that determines the total cost of owning and operating a particular project over a period of time (generally the life period of equipment or a project). In this case, an evaluation of the economic performance of a traceability system covers all costs related to the information system: initial investments (equipments - transponders, readers, etc., indirect – administration, etc.), as well as operating cost (insurance, energy consumption…), maintenance and repairing costs. Other costs such as training can also enhance the total cost of the project. Costs are, of course, clearly potential barriers to the implementation of traceability.

Establishing a traceability tool over a value chain is even more a challenging task, than in simple one business case study. The chain's organisation involves a large number of participants having their own interests, often diverging and sometimes conflicting. Nevertheless, to justify implementation, it is important to ensure that traceability brings benefits for the supply chain as a system, although it may mean a "sharing" of costs between participants. One should however keep in mind that no mechanical fix rule can exist for distribution of benefits / costs among players of the chain. In this case, business and commercial relations between them are a crucial factor.

As a preliminary task, it's important to establish, from a perspective of economics, potential drivers and barriers for the introduction of traceability ICT in the wood supply chain. In front of a large number of relevant factors, a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis allows to draw a more precise picture of the situation. SWOT analysis is a tool for auditing an organization / chain and its environment. This analysis is made taking into account the impact of a certain change (here implementation of traceability) for enterprises in the chain. It is the first stage of planning and helps players to focus on key issues. Strengths and weaknesses are *internal* factors, whereas opportunities and threats are *external* factors. Strengths and opportunities can be seen as drivers for implementing the technology while weaknesses and threats correspond to barriers. Internal factors are discussed first, followed by the external factors.

Strengths

From a firm's point of view the ICT are tools leading to a more efficient internal / external *communication*, providing a base for a redesign of processes and for changes in strategic positioning for each enterprise. They are creating a new business environment leading to improvements of economic performance, such as increases in productivity gains, and creating a field for a sustainable competitive advantage.

In modern business, the successful firms are those which are able to be *flexible*, to adapt rapidly to changes in their environment (demand of clients, evolution of competitors, etc.). The ICT are gathering information necessary to *base firm's decisions on knowledge* (not anymore on experience only). For example *considering logistics*, the ICT in general, and traceability in particular, allows locating, following and finding goods almost in real time. In practice this means that operators are able to optimise loads, delivery roads (back haulage or "deadhead" empty back trips are the major challenge in the business), and on time deliveries. In this case the traceability tool will allow transporters to decrease costs (price per km, per tonne, per hour, per day, etc.) and thus create a competitive advantage. It brings value to the service.

For *a manufacturer*, the interaction with suppliers is easier: sending of orders takes less time, deliveries are more reliable, which allows an optimisation of processes. For example, reliable deliveries (time, quantity) are crucial for mills running in "a just in time". In addition, the origin of wood (properties) makes it possible to adapt processes in consequence, to optimise the process efficiency, and thus to increase the productivity gains. Similarly, knowing the wood properties allows focusing on the key elements, such as avoiding the variability of raw materials (and process adaptations). In other words, it means *"doing things better"*.

It is reasonable to expect that *several costs will be reduced*: administrative costs (providing orders automatically through the information system, invoicing), operating costs (automatic inventories, management of stocks – knowing where the right log is, automatic registering at the incoming gate, etc.), better procurement policy. The latter means in practice purchasing the right raw materials (wood specificities) thus improving the efficiency (greater yield of inputs, technical characteristics of products suitable for specific secondary transformation). Traceability can enable enterprises also *to avoid some costs*. For example, without traceability an important cost is caused by errors made during registering of data identifying stands and products. At the moment of invoicing, usually by the end of each month, it takes a lot of time to find the source of error (inventories, checking, etc.). The mills are not always aware of this kind of costs. In case of visual grading of logs in forest, followed by forwarding, an appropriate identification system ensures that the right logs are oriented towards the right destinations (no misuses). Similarly, the management of material flows becomes more efficient: in some situations wood logs have to be transported from the stand to the manufacturer (sawmill) within 4 days. The logistic operator will be able to locate and identify the relevant logs or short-logs, under this time constraint.

By identifying the wood properties, mills have the opportunity to establish the link between the quality of products (output) and the raw materials (input). It allows better determining their value, or origin of problems. For mills buying the raw material "on root" (or standing timber), for example, traceability establishes criteria to focus the future purchasing.

Thus the traceability tool presents an important source of potential savings. It carries also potential productivity gains and increases in utilisation capacity rate. Although different between companies, in general *the literature recognises positive and significant relation between ICT investments and productivity* (Stolarick K., 1999; Diop S., 2002).

The traceability tool brings a potential for *reduction in transaction costs*. A communication standard facilitates a connection with the suppliers (and clients), making orders simpler to send and payments easier to make. In addition, it facilitates the researching of buyers/sellers, the exploring of stands in forest, etc. The French wood chain is characterised, especially the forest harvesting, by a large number of participants. An objective and accepted system would facilitate their transactions: for example some participants are disputing the reliability of measurement systems and of quality classifications of logs (due to the high heterogeneity of forests), resulting in difficulties of appropriate payments.

Traceability is also leading to a decrease in *anonymity* within the supply chain, and thus a risk of opportunistic behaviour among players. It decreases information asymmetries between participants. In a long established relationship, the risk of opportunistic behaviour is low, but even in such case traceability gives the right visibility to each participant.

The ICT gives the place for changes in *strategic positioning* of firms, in other words for changes in raw material supply or in organisation of the business. Indeed traceability brings an important amount of information, and allows taking decisions on a knowledge basis. In this sense it is a tool facilitating decision making. It also eases the coordination between decentralised elements (delays in deliveries, etc.). Similarly, the use of information systems drives organisation to change. In order to implement and use the tools, operators will carry on additional skills. All this leads to *"doing things in a different way"*.

Traceability is a tangible mean to establish the guarantee of origin (raw material certification for example), thus leading to an improvement in *quality of the product*. The latter benefits from the "differentiation" position on the market, usually providing an additional value.

The empirical studies in the literature (Brynjolfsson E. at al., 2000) recognise that a combination of ICT introduction within the process and organisational changes are resulting in an increase in a *multifactor productivity*. Some studies even suggest that the greater benefits from the ICT are obtained when complementary to technical changes (hardware, software, etc.) there are also investments in organisation (improvement of processes, working practices, etc.).

The implementation of the traceability tool leads to important potentials in terms of cost reduction, productivity gains and quality improvements. A combination of these factors creates a potential for a sustainable competitive advantage. At each level of the chain (logs, transport, sawn wood, etc.) these impacts are reasonable to expect, thus influencing the whole value chain (adding value to the products). If these additional benefits are shared all over the wood supply chain (for all participants and not only at the end of the chain) the economic driver will be much stronger.

Weaknesses

Among the internal weaknesses for the integration of a traceability system, the most obvious one is *the cost of investment***,** and the mill's financial capacity to obtain the relevant equipment (hardware, software). Similarly, the *technology needs also to be mature* and reliable. Exchanged information is essential for running the business, so their security has to be ensured.

The *incoming technology has to be adopted* by the business environment and the chain. On one hand, the firm must dispose of *the appropriate human capital*, containing not only necessary skills in order to fully exploit new potentials, but also presenting a willingness to adapt to changes, to integrate new technologies. On the other hand, it is necessary that the new and old systems become *interconnected*. The task is even more challenging as the equipments was bought gradually during years, on a step by step approach. The new information system is connecting different levels and different equipments; nevertheless the exchange of information has to be possible within and between organisations. In France for example the development of information systems is low.

The traceability will collect and bring a large amount of information, which in order to be used has to be *appropriately treated and managed*. Above the necessary technical support the firms must have the appropriate *expertise.* In other words, the collection of information might not be a problem, but rather its treatment. For example logistics present great potential gains in efficiency, but the appropriate management and appropriate treatment of information is a pre-requisite for the success. If the company misses these elements in practice then it will be forced to inject complementary investments (equipments, human capital, etc.), representing *adjustment costs* not always planned at the beginning of projects. Finally, the implementation of new systems has to be lead by the management, and particularly the business executive.

Traceability brings a potential for improvements in quality of products. But in practice entrepreneurs are *unable to appropriately quantify in monetary terms* the benefits of traceability systems. It is a new business technique, so lessons from experiences are difficult to extract. In other words, relevant data on economic impact within the chain does not exist at the moment. Improvements in decision making, reliable delivery time or guarantee of wood origin for example are strictly related to the quality, which covers the *"intangible" dimension* which is hard to quantify. Additionally, the literature suggests that the *results in productivity* take some time before becoming visible. All this brings difficulties to appropriately determine the return-on-investment (ROI) rate, indispensable to decision making.

The *behaviour of participants* involved is also determining. The participants should have a *willingness to pay for additional information (or would not want to pay because they benefit of asymmetric information)*. The interdependency between the stakeholders creates a potential risk that if one of the key participants does not see the benefits from the tool the downstream users might loose some information. Finally, there is always a risk of *non-collaborative* *approach*, which might increase the transaction costs. In practice some companies are reluctant to communicate business data. In order to interest the participants, traceability should cover the most valuable pieces of logs.

Looking at external factors, the relevant elements are less numerous:

Opportunities

These are notably twofold. On one hand, *new developments* in traceability technologies (hardware, software, etc.) might bring new solutions and lower prices. For example evolutions in RFID technologies might bring additional advantages, lower prices of transponders, longer distances of signals, etc.

The implementation of new traceability technologies might lead to creation of *new products, or of new market opportunities* for already existing products (environmental certification, guarantee of origin, etc.).

The openness of the supply chain to new practices implemented in other sectors presents opportunities to overpass barriers, to speed up developments, techniques, etc. In this regard, the wood supply chain can benefit from lessons learned on traceability implementation in the food sector.

Threats

Among external threats, the most obvious is a *collapse of the market for wood based products*, where instead of appreciating additional quality of products (through traceability) consumers strongly switch their purchasing towards substituting materials (plastics, etc.).

Another threat comes from the technology. While *technology risks* exist in practice, such as to involve cost of protection and repairing (information viruses, sabotage of transponders, labels, readability, unauthorized use or change of information, etc.), they will present an obstacle for real applications.

In order to be implemented in practice by companies, traceability has to bring additional benefits. On the other hand, different levels of traceability will involve different cost amounts. For example while investment in a specific information system might be the same for an individual tracing as well as for a lot tracing, operational cost might be different: time spend on registering of a delivery will be longer if each log has to be recorded. In any case, traceability has to bring a clear economic value to the company, if the tool is to be implemented. Considering tangible effects of traceability, the most obvious method is to use the process metrics and to quantify in terms of technical costs the difference between “businesses as usual case” with cases reflecting different traceability levels. The method requires to decompose the processes on the key operations (terminology): forestry (planning, harvesting, forwarding, stock management), transport (planning, loading, transportation), sawing (planning, reception, unloading, stock management, sawing, sorting, drying, stock management, etc.). Thereafter the impacts in terms of time and materials (operating costs, productivity, etc.) will reflect the costs differences (and corresponding business savings) between various options. A combination with the life cycle costs analysis will signal the cost differences over all time period of the project. Nevertheless, the method is highly depending on the availability and on the quality of data. In the literature this issue is highly recognised as the major obstacle. Similarly, the time effect, when an operation represents at the beginning only costs, but raises gains in future, needs to be considered.

When it comes to intangible effects the quantification is even more challenging. In order to estimate the willingness of participants in the chain to accept at first and pay in a second stage for traceability a particular survey should be run. The method evaluates the amount of money that participants could pay, for a change in quality of product. It is therefore a monetary measure of the benefits.

Table 1. Summary of SWOT factors on implementation of ICT / traceability in the wood chain

Strengths:	Weaknesses:
○ More efficient internal / external communication ○ Gathering information to base firm's decisions on knowledge (greater flexibility, optimisation of flows, of loads, etc.) for a sustainable competitive advantage ○ Easier interaction supplier-costumer (cheaper sending of orders, deliveries on time, etc.) ○ Optimisation of processes: adaptation to the wood properties, avoidance of variability of inputs ("doing things better" leading to higher productivity gains). In parallel it enables the mill to trace the origin (location) of wood and to determine the cause of quality problems (and to avoid them in the future) ○ Traceability enables enterprises to avoid some costs (administrative, operating costs), to save some costs (invoicing, inventories, errors, stock management - recording of movements in real time, location of products – easier to find the right log for production, logistics), and to focus their purchase policy on the right materials ○ It establishes the link between inputs and outputs (better pricing), as well as a proof of guarantee of origin. Better supply policy: identification of individual logs, enables to determine their value, and so to control supply costs ○ The ICT reduce transactions costs (easier connections, payments, research of appropriate materials costumers / suppliers) and if standardised it provides an objective and commonly accepted system (measurement) ○ It reduces the anonymity within the supply chain and defines respective reliabilities / rights ○ It brings an opportunity for strategic positioning (organisational changes, human capital, etc.) leading to "doing things differently" (multifactor productivity) ○ Intangible effects: improves the quality of products (wood certification, longer product life, etc.) ○ If these additional benefits are shared all over the wood supply chain (for all contractors and not only at the end of the chain) the economic driver will be much stronger	○ Cost of investment (information system, transponders) as well as maintenance, repairing, etc. ○ Maturity and reliability of implemented technology ○ Adoption of the technology by the environment (human capital, interconnection with systems already in place). Needs for new investments? ○ Similarly, different information systems between participants of the chain (heterogeneity, inter-operability) make interconnections more difficult ○ Collection of information might not be a problem, but its treatment (selection) and management (use) might be (human capital expertise) ○ Risk of adjustment costs (hardware, software, human capital – training) ○ Difficulty to quantify intangible impacts ○ Results in productivity take some time before becoming visible ○ Difficulties to quantify the return-on-investment rate ○ Attitude of participants involved in the chain: willingness/capacity to pay for additional information; collaborative approach; willingness to exchange the data ○ Interdependency of a large number of participants, with different interests ○ Non-cooperative approach: increase of transaction costs
Opportunities:	**Threats:**
○ New developments in traceability technologies (hardware, software) ○ Creation of new products/service or new markets ○ Openness to new practices	○ Collapse of market for wood products ○ Technology risks (readability, unauthorized use or change of information)

4 Environmental aspects

A general and holistic approach to analyse environmental impact from different products or process alternatives is to evaluate environmental consequences using a life cycle approach, in order to avoid sub-optimisation. A quantitative approach to assess the environmental impacts is to use system analytic tools, where *life cycle assessment* (LCA) is ad hoc regarded as the most important, widely spread and applied environmental system analytic tool. The framework of LCA is defined in the ISO standards ISO 14040, 14044. In this chapter, the interest to communicate individual product information is discussed as an alternative to the traditional LCA approach, using yearly averages.

Environmental performance of a wood trade product is generally associated and communicated with information based on

1. Up-stream environmental impact. This means that each individual product value chain has the potential to compete with the same or other wood based products, as well as other products made of substitute materials.
2. Down-stream environmental impact. The possibility for material-recycling or energy recovery from different by products like off-cuts or the product it self at the end of life, is also of interest and indicate the importance of down stream activities.
3. Product use and end-of-life. Information about product content and use phase emissions are needed. The product content is an important aspect for e.g. improved end-of-life treatment of discarded wooden products and may depend on the presence, characteristics and amount of chemicals introduced in the wood product (preservative, glue, coating etc.).

By using LCA the potential for optimisation of the entire life cycle consequences are possible.

Wood is a natural resource powered by the sun, which is the foundation for an ecological sustainable material. Wood is in that respect renewable. However, this inherent aspect has to be complemented with well-managed forestry and harvesting to be sustainable and thus justified for market communication. This means that ecological sustainable forestry has to deal with biodiversity among other aspects. In a full sustainability perspective also social and economical aspects have to be accounted for.

One of the most interesting opportunities opened by introducing a traceability system is the possibility to collect information related to an individual product or a product batch. This gives, at least in theory, possibilities for a more or less a real-time optimisation and monitoring of environmental impact. A more established approach is to analyse the average environmental impact of product manufacturing using annual information. This average based approach corresponds to current practice for forest certification and for life cycle assessment (LCA) and LCA based environmental declarations (so called type III declaration according to the ISO 14025 standard).

Increased traceability gives additional information with reference to environmental impact related to the products life cycle manufacturing steps, such as the wood origin and forestry. Knowledge of wood origin is important for forest certification and the chain of custody (social aspects such as labour conditions). This is a valuable aspect on some environmentally sensitive markets, but also interesting concerning legalities, economy, social issues and labour conditions.

The interest from traceability is obvious concerning harvesting and well managed forestry, but not necessarily in such a way that an information system is required by individual stock, logs, sawn timber etc. Downstream in the value chain, after the harvesting, forest and product certification does not necessarily require an information system for tracing individual stock items. Instead a more pragmatic batch-based system is accepted by the certification systems in the downstream wood value chain, for instance at a sawmill or glulam plant. The requirement from the certification body is that of the amount of certified wood in and out from a wood working plant is in balance. Therefore, certification is today not a guarantee that a specific product is in fact made of wood that ‘actually’ comes from a certified forest.

Nevertheless, it is important to note that the capability to trace down a specific product to its origin would probably reinforce the confidence of the consumer in the system.

Initial identified general *environmental* drivers to support a traceability system are:

- An increased market interest for specific product environmental performance demands an implementation of a sophisticated information system, if the information shall be gathered in a cost-effective way. In economic terms this means that there is a willingness to pay for this information from the final users.
- The ecological assets of wood products can gain credibility when they are based on information based on precisely monitored processes and products.
- Products with lower environmental impact from manufacturing (better environmental performance) may be better paid for (versus the average product of the same kind).
- An important driver for traceability would be the possibility to go one step further in the Environmental Product Declaration (EPD) towards certification that take into account for the full life cycle that involve the functionality and therefore the quality of wood products. Full traceability for a final product could be a way to demonstrate the compliance of the product with a defined level of env. quality versus alternatives.
- Well managed forestry and harvesting, typically verified by a certification system, is strong evidence that the product is an ecological, social and economical sustainable alternative. The information system will support the traceability of these environmental properties in the value chain.
- An information system based on traceability may, as discussed in several places in this document, help increasing the efficiency of the whole supply chain (improve the final product quality, improve product yield, minimise by- and co-products of lower quality), which also will improve the over all impact in a life cycle perspective.
- An information system covering a value chain has the potential to improve the over all environmental performance of products manufactured, because it gives, at all stages of the life cycle (different production stages, use, end-of-life) the possibility to choose the best available ecological option. The analysis of environmental performance can also be used for benchmarking.
- The carbon balance of a wood product, a wood batch or a forest stand together with its products could be established through traceability. Even though the forestry's quality of being carbon neutral or positive is a consequence of management (Ågren. G, Hyyvönen, R. I, 2003), the current opinion is that the carbon balance and the resulting impact on climate change are in favour to wooden products in relation to other materials (plastics, metals concrete etc.). The perspective of the development of carbon balance approaches (a system providing detailed and robust information) in industry and services, and of the monetization of green house gases (CO_2 etc.) and sinks will facilitate a better accounting of this strong asset of forest and wood products. It may also be an interesting system to help making choices for optimizing this carbon balance of wood products, in terms of utilization of the product, choices of transport etc.
- The information about which chemicals have been used and what is their concentration in the final product is an important environmental aspect in the production process, service life of the product and for waste handling, which is strongly supported by traceability. Concerning so called *substances of very high concern* (SVHC), pointed out in the new European chemical directive REACH, it is mandatory to inform about such product content in the business-to-business value chain up to 0.1 weight %. In general the knowledge about product content may allow the user to make environmental considerations, also including the foreseen use conditions. Moreover, one major market for timber is the construction products market; there the European Construction Products Directive sets an essential requirement which is the information on the possible emission of dangerous substances that could affect health and environment. In the same way, in the field of

packaging (pallets, crates), there are requirements for information on the chemicals content for end of life management of the item or for food contact ability.

- There exist general market movements where industry and final consumers starts to act in a more environmentally conscious manner. Also new EC strategies, like the integrated product policy (IPP), support environmental aspects as a more important part of the business.

Identified barriers for actual implementation of a product-individual based information system from an environmental point of view are:

- End-users lacking interest in sustainability issues.
- Most customers only ask for environmental legal requirements and specific product environmental performance is yet not established as standard requirement in procurement. Today, analysing the environmental impact of an individual or batch of products is not an established approach, since no strong market requirement exists.
- Increased economic value of carbon due to trading systems for mitigating global warming might lead to reduced cuttings and hence reduced need for a traceability system (Backeus et al, 2006),
- Companies consider that environmental aspect in existing product declarations and forestry certifications are handled with an already running information system that is good enough for these purposes (why an improved information system is not required if it means extra costs).
- The variation intervals of values for environmental data provided by a product-individual based information system may be of the same order of magnitude as the uncertainty of environmental data from side activities like energy production, transportation models, process additives production etc. This would reduce strongly the interest in individual traceability.
- It is sometimes argued (in marketing) that the fact that the product is made of an environmentally friendly (renewable) material is good enough as environmental argument for most customers, so in that context the drive to improve other environmental aspects may not be adequate from a market perspective.
- The information system implies that electronic components may be involved and consumed. Such negative environmental aspects of the use of these products (hazardous substances, energy) should be considered and included in the environmental assessment (as well as in the cost-benefit analysis).
- Increasing the number of assortments and enriching certain raw material properties may increase the haulage distances, which increases environmental effects from transportation. However, this may be balanced by a gain in the efficiency in the industrial production processes and the final product perspective, due to the improved raw material.

A final remark concerning environmental related drivers and barriers is that the industry itself has the possibility to utilise environmental performance of wood based products more proactively in the market dialogue and to integrate these kind of arguments into business strategies (business push). This will support development of improved traceability system where different value chains may improve their competitiveness through improved products.

The increasing focus on global warming will have influence on future requirements on traceability. It may be required to apply a more site specific or site dependant impact assessment approach, which will increase the interest for a system with the capacity to trace individual items. For this reason the market acceptance and currently developed method should be better analysed within the project. It would be highly interesting to integrate the impact of a traceability system in an improved (site dependent) impact assessment to meet the objectives of the Kyoto protocol (greater efficiency of raw materials combined with more efficient logistics would decrease transport needs, and so CO_2 emissions). This aspect will be investigated and evaluated in the project.

Another aspect to evaluate in the project is the possibility to handle biodiversity for the forestry in the LCA in a streamlined way, since it may be a strong environmental driver in the future. Nevertheless, the absence of consensus on biodiversity indicators might be a difficulty to this objective achievement. Also a negative aspect with an increased fertilisation in the forestry that may lead to an increased eutrophication, is a site dependent problem that should be handled (better in LCA than today) in order to avoid problems and improve environmental impact. This aspect is relevant for any forest management that is concerned with high production and artificial enrichment of nutrients. Increased fertilisation may be reality in the near future, considering that forests will be even more important as an energy source. Still, the possibility to handle these kinds of information will also depend on the capability for foresters to provide it.

There is a need to find the right cost-benefit balance, i.e. to know the level of detail needed for each environmental objective/driver. Table 2 contains an overview of the type of traceability (cf. Figure 1) needed for different environmental drivers. This necessity to find a balance is required also for other indicators.

Table 2. *Initially suggested* levels of marking in relation to Figure 1 (indicated by traceability level in the table below) *in relation to different environmental drivers and barriers*

	Knowledge level, unit of interest, Traceability type according to Figure 1	***Driver***	***Barrier***
❑ Forestry certification	❑ Stand/forestry Type 1	Public pressure, International laws and regulation. Profits and access to markets.	End consumer's lacking interest. High cost, Technical imperfection.
❑ Climate change*	❑ Stand/forestry Type 2	Interests in cost efficient traceability.	Products alleged lacking relevance to the issue. High cost, Technical imperfection.
Production improvements ❑ Manufacturing plant (company level) ❑ B2B	❑ Individual/plant Type 1 ❑ Batch or average/product Type 2 or 3	Hot spot assessment, to avoid expensive choices in the prod. chain Costing to individual pieces.	Lacking interest. High cost. Technical imperfection.
❑ Product content	Batch/average Type 1 if chemicals occur, else 2 or 3	Cost efficient way of individual marking.	High cost, Technical imperfection.
❑ Waste treatment	Batch/average Type 1 if chemicals occur, else 2 or 3		Remaining RFIDS
❑ Information on wood properties	❑ Individual (sampling)/forestry and/or sorting	Cost efficient way of individual marking.	High cost, Technical imperfection.
❑ Improve over all manufacturing supply chain efficiency, including time, transport logistic and product quality	❑ Individual → batch/LC** Type 1→4	Hot spot assessment, that is to avoid expensive choices in the production chain. Cost assignment to individual pieces.	High cost. Technical imperfection.

* No methodology developed and therefore no classification/calculation rules.

** Adequate to handle in the entire life cycle.

In order to make optimisation and improvement of environmental performance possible, an information flow related to the physical product, which does not use average data more than necessary (see Table 2) is required. However, if this kind of data shall be used in an EPD or LCA in general, an average may be the adequate way to report and communicate the environmental data. Furthermore, in these cases, a standard deviation can be calculated that may indicate a potential improvement.

So, concerning the goal of the project, the target must be to at least measure the impact from these activities that significantly contribute to the **individual** product's environmental performance and potential improvements in a life cycle perspective (see the two last rows in Table 2). Therefore, in future, some data might still be collected at a yearly level, some at an individual product level and some at an intermediate level (batch, week, month etc.). The planned field tests in the project will give better understanding concerning this matter and improved decision support concerning this matter for future implementation plans.

5 Organisational aspects

Most of the organisational aspects discussed in this chapter are not directly related to the level of traceability (cf. Figure 1) and are valid for all alternatives unless otherwise stated below. No attempt to quantify the driver and barriers are made since this is extremely difficult for this kind of questions and also very case specific depending on the organisation and staff of a particular company.

A system of information is based on 4 pillars: operators (human factor), software, hardware and procedures. An appropriate technical solution only gives no guarantees for an efficient system of information. The technical solutions should be flexible enough as to adapt to local organisations. At each step of the chain responsibilities/tasks of each participant should be specified and justified.

“Human factor” The "human factor" is easily underestimated. There are many persons involved at different stages of the value chain. New systems require an appropriate communication/training of operators. The latter will need internal and external support: it is not up to operators to solve technical problems that might occur. Low training level of operators is a possible barrier to implementation of new advanced solutions in the supply chain, especially during an initial phase. Some people would not be able to adapt themselves to new technologies (inertia).

In addition, it is important that the management of the company implementing the traceability lead the introduction of the new technique. If an operator cannot see or understand the benefits of the additional work and responsibilities connected to the implementation of a new system (especially if the benefits do not arise within his own working area) then it is difficult to convince him. An explanation should be given to the operators, as to ensure their constructive involvement. The human factor can also be a driver for change. Individuals interested in new technology can make implementing the technology in an organisation easier.

Roles of participants Development of a collaborative solution between participants of the supply chain is a possibly strong driver that can generate large benefits but there are several barriers to overcome. Management of the change, to develop cooperation, is a process that will take time and effort. This barrier is potentially stronger in France since the current data exchange is less developed than in the Nordic countries. The size of enterprise can be also an explanation: small enterprise does not have sufficient market power and considers information to be one of the unique means it possesses to be independent and/or have an influence in the business to business level. On the contrary, the dependency of a large client can oblige to integrate changes required by the mill.

Today, the roles are well defined for each participant of the wood supply chain. New technologies can change this organization and certain participants can feel being more “under control” (loss of autonomy if one tells them what they must do). The current organisation of participants can also lead to a fear of exchanging data (data is power). Weak confidence or lack of confidence between participants is a strong barrier but it can also be a driver, particularly for companies in the end of the value chain, since traceability means better control of the operations of suppliers (information asymmetry).

The drivers and barriers associated with exchanging data and being “under control” are potentially more important for a higher level of traceability (cf. Figure 1) since it means that more detailed information is exchanged.

Standards Acceptance of the communication standard by users/vendors is crucial. In the past many standards were made without being applied in practice. The standard needs to be simple and flexible enough to use[1]. If it comes off to a highly complicated tool, then it will be difficult to accept by users. This is primarily a question for the ICT vendors.

[1] The standard developed in the project is an information system standard intended for the data flow between participants. The intention is to make it a part of papiNet so that it will live on after the project.

6 Applied aspects

This section describes economic, environmental, technical and organizational aspects specifically from different parts or aspects of the wood supply chain.

6.1 Wood allocation

Better initial information about wood properties (exemplified in Table 3), integration of processes along the production chains and improved traceability provide potentials to:

- Optimise wood supply from a *product* perspective.
- Facilitate special assortments for particular solid wood products (like window frames).
- Decrease the amount of off-grade products. Decrease the amount of wood to sawmill that will not pass quality demands on boards.
- Destine the most suitable use as early as possible in the production chains i.e. directly in the forest (e.g. pulp or bio-fuel).

In theory full traceability and full access to all information gathered from the planning to the final product stage can be used to make real optimizations and provide best possible control of production processes and product quality down to the smallest units that are individually treated in the system. However, to get practical solutions the following should be considered:

- The quality of the information on wood properties and process information at the "labelled unit level" (type 1- 4, cf. Figure 1) and the system's ability to use this information to improve the successive steps in a production chain will be crucial for the potential gain.
- To provide the most efficient system, analyses of economic and environmental gain must be taken into account. From these analyses the benefits and costs (in monetary and environmental units) of different levels of marking should be analysed (type 1- 4).
- The potential gain might be indicated by system analysis and simulations including all the major links in the value chain or by multivariate analyses of extensive production statistics recorded by a traceability system and key indicators at different checkpoints along the production chains.
- Commonly wood industry companies have built their business approaches on a mix of main and secondary products. These are based on tradition and experiences concerning the possible outcome of purchasable wood. Therefore attempts to change the wood allocation to suit a specific main product will probably affect the amount and performance of secondary products, including bio-energy for internal use or external sale as well. The consequences of the impact of the change in mix of products should be considered.

6.1.1 Benefits of characterising raw material to improve the production of solid wood products – some examples

In order to indicate the possible benefits of improved wood allocation, i.e. integrating the harvesting procedure into the following industrial procedures, some examples compiled by Wilhelmsson (in press) are reviewed below.

Knot-free window frames – case study (Bengtsson et al., 1998)

Product: Knot-free window frames constructed from finger-jointed knot-free blanks (pieces) of Scots pine.

Situation: Ordinary saw-logs of specified dimensions were used to produce blanks.

Problem 1: Only about 66% of the theoretical production capacity was utilised.

Problem 2: Significant proportions of the blanks produced were not knot-free and were thus unacceptable.

Action: 2nd to 4th logs from relatively fast-growing trees (fertile stands) with a higher internode length (longer distance between branch whorls) than average were selected.

Result: Full production capacity and higher product quality. Appropriate trees can be identified using forest inventory data and models for predicting internode length (Elfving & Kviste, 1997; Wilhelmsson, 2006).

Sound-knot blanks for furniture – case study (Sondell et al., 2004)

Product: Sound-knot blanks of Scots pine for furniture production.

Situation: A specific top-end diameter interval, 192–239 mm, of saw-logs was collected, with no other selection or sorting in the forest.

Problem: Sound-knot blanks had to be screened from an ordinary mixture of sawn boards. The length of these boards could not be optimized to fit the optimal lengths for the furniture production.

Action: By using a model based on diameter ratios (actual d/dbh; Öyen & Höibö, 1999; Sondell et al., 2004) characterising the sound-knot cylinder along the bucked stems, a log class yielding 78% sound-knot furniture blanks was identified. Without this characterisation only 34% of the logs yielded sound-knot boards.

Lumber grades – simulation study (Moberg & Nordmark, 2006)

Product: Ordinary Scots pine lumber graded according to Nordic Timber grading rules (Anon. 1994).

Situation: Production of sawn boards is a function of delivered saw logs.

Problem: Unknown proportions of saw boards sometimes fail to meet specifications.

Action: Forest inventory and tree models enable volumes, sizes and proportions of boards of different quality grades to be predicted. The predictions could be further improved if similar models were used, based on production files from the harvester, thereby increasing the scope to overview and improve the fulfilment of orders and meet customers' requirements.

Sorting of strength classes (C-classes) –simple example from simulation

Product: Structural timber of Norway spruce.

Situation: A sawmill produces structural timber in C-classes, C18 or C24. The difference in price per m^3 of graded sawn boards was 25 €/m^3sawn goods. In a simple example the proportion of C24 is increased from 77% to 91% by enriching the better half of the saw log population with respect to predicted basic density. The revenue for the improved share of C24 was 3,5€/m^3 sawn goods or about 1,75 €/m^3 saw logs all based on a fixed price difference between the different products regardless of minor changes in produced volumes.

Table 3. Solid wood properties of possible interest for improved wood allocation (Wilhelmsson, in press)

Property	Units	Industrial relevance
Log averages		
Diameter (mean of major and minor axis)	mm	Sawing pattern. Yield of primary (beams, studs, boards) and secondary products (chips, dust, shavings).
Ovality (major axis – minor axis/mean)	% of diameter	- " - + reaction wood
Length of log	cm	- " -
Long crook	% of length	- " - + reaction wood
Green density at felling	kg/m³fub+ bark	Freshness criterion when compared with actual density at delivery to industrial site.
Green density at haulage	kg/m³fub+ bark	Transportation weight and freshness criterion at delivery. To be compared with green density at felling.
Basic density (radial average)	kg/m³	Correlates with all strength properties, thermal properties e.g. Modulus of elasticity (MOE) and modulus of rupture (MOR)
Heartwood diameter	mm	Durability, water uptake, impregnability for preservatives, permeability. Emissions of extractives. Affects conditions when optimising kiln drying.
Juvenile wood diameter	mm	Shape stability, MOE, MOR correlated with spiral grain, basic density and microfibril angle.
Latewood percentage	%	Surface strength. Aesthetic
Mean annual ring width	mm	- " -
Internode length	cm	Length of clearwood
Maximum knot diameter at surface	mm	MOE, MOR, Probability of “critical knots”. Surface properties and aesthetic quality.
Average knot diameter at surface	mm	- " -
Number of knots/whorl	no	- " -
Knot angles (average)	°	- " -
Sound knot length	mm	Surface properties, planeability, paintability, aesthetic quality. (Differences in load carrying capacity related to fibre distortions and stress peaks)
Pitch pockets	no./m	Spruce. Paintability, surface properties
Bark thickness	mm	Dimensions and volumes over and under bark
Debarked % of surface	%	Drying rate - freshness criterion and reduction of bark volume
Bark volume	m³	Energy
Bark dry substance	kg/m³	Energy
Bark moisture content	%	Energy
Radial profiles pith/bark		
Distance from pith	mm	Positioning at sawing
Green density at processing	kg/m³fub	Sawing conditions, kiln drying
Basic density along radius	kg/m³fub	MOE, MOR
Microfibril angle	°	MOE, MOR
Spiral grain	°	Shape stability => twist
Loose/Sound knots distances from pith	mm	Surface properties. Processability MOE, MOR, (Differences in load carrying capacity related to fibre distortions and stress peaks) planeability, paintability.
Knot diameter (largest knot)	mm	Surface properties. Processability MOE, MOR, aesthetic quality
Knot diameter (average knot)	mm	Surface properties. Processability MOE, MOR, Aesthetic quality
Knot index	%	Knot area/Total area on four board surfaces
Chip characterisation		To be used by pulp and paper producers, Energy plants
Chemical characterisation		Chemical extraction procedures. Quality control of undesired extractives
Energy values of components		Specification of energy values of different components, dust, bark, chips

6.2 Forest operations

Technically, the information flow caused by keeping track of individual log labels may be handled without serious problems. However coverage and capacity of the mobile network might be a bottleneck. GPS positioning of the base machine and potentially also the felling head may provide an approximate track of standing stem positions, and small piles of logs made by the harvester to facilitate the forwarding process. Harvester measured stem diameters and stem height (bh and stem profile from but end to top end), bucking decisions (automatic or manual), log dimensions, marking type 1-4 (cf. Figure 1) may all be recorded in standardized (e.g. StanForD) production files (e.g. pri). In addition stand parameters like average geographic position of the stand, statistics of tree age (mean and st. dev.), site index etc. from forest inventory systems can be connected to the tree and log information.

There is much to gain if the harvester measurement accuracy (diameter and length) can be increased and certified through improved quality control of marked control logs. These are selected randomly (by the harvester computer) from the ordinary production measured and bucked by the harvester, and self-controlled by the harvester operator. With reliable marking these control logs can be automatically identified, controlled and certified by an auditor at the sawmill. This will facilitate the quality assurance system, for harvesters presented by Arlinger & Möller (2006). Improved measurement accuracy, of both diameter (cross-sectional shape) and length may have a considerable value (5-10% of the saw log price) when specific combinations of lengths and diameters are required. When a correct length is the only critical measure this may still cost a lot as the bucking instructions may add 7-15 cm to the desired length of logs as a safety margin. A decrease of the margin with 5 cm would mean a 1% lower price (for a 5 m log), increased yield and lower processing costs in the saw mill.

Detailed production statistics can be reported to both customers and suppliers as soon as the harvesting operation is accomplished. Mobile communication coverage and capacity will be increasingly important when industry customers and production planners requires a current information flow from harvesters and forwarders.

In case of hardwood harvesting in France, the operation is mainly motor-manual. Consequently, the marking of logs and the management of information flows are different from the ones used by a harvester. Some specific solutions have to be developed for this case such as the application of RFID chips to the logs.

Drivers:

- Improved yield, which will lead to a decreased cost of raw material in the final product. Production cost is, and has been, decreasing faster than the raw material cost, which means that raw material cost is more important. Future cost reduction must focus on better raw material utilisation. Improved yield will also lead to decreased environmental impact per product.
- Increased value added in the value chain. Total revenue should exceed total cost for each operation. This can be accomplished by targeting end use of the product early in the chain. “Value added” is an important KPI.
- General traceability of all log deliveries to keep track of the log properties and harvesting operations to provide a direct communication between the harvester, forwarder, haulage organization, industrial customer and the wood supplier. This will facilitate better use of all the data that is collected in the harvester and forwarder computers.
- Forest industry will benefit from better prognosis for flow of products. The most economic and environmentally friendly level of traceability (individual logs, individual batches/piles etc.) should be identified with respect to each value chain to be served.
- Support of automatic sorting and tracking of logs within delivered assortments. Today, keeping assortments and grades separated in logging operations decrease volume productivity at both harvesting and forwarding.
- Statistical control of the diameter and length measurements performed by harvesters will be facilitated by automatic identification of the logs used for self control of the harvester operation. The saw-log part of the stem can be identified and measurements revised by a controller.
- A great benefit from traceability is the possibility to use the data to validate and improve measurements and model predictions. Measurement inaccuracy or lack of measurements of important properties is a barrier today but better control and feedback from log marking can improve the situation.

- Keep a detailed track of failures and problems, including possible reasons. Traceability can be an important tool to improve the value chains in this respect.
- Improved environmental certification/traceability of the origin of wood.
- Carbon stock or carbon balance real time updating for the forest location (to be used internal for current improvements).
- The forestry standard (StanForD) include a file type (prl, production file load) which facilitates keeping track of stem positions and small piles of logs and accumulate assortments marked type 2 and 4 (fig 1). This may also be utilized to keep track of small groups of logs (type 2 or 4) and possibly unique combinations of traced coordinates and individual log characteristic.

It should be noted that in many cases, e.g. development of processes and products, a controlled sample of traceable logs may be a cost-effective way to detect problems and achieve potential revenues.

Barriers:

- Cost for transponders or other labelling systems. For situations where the cost of transponders can be an obstacle (oak sawmills for example), due to the highly valuated product, the transponder nevertheless has to be technically adapted.
- Reliable, efficient and affordable reading tracking and handling of individually marked logs at harvesting – piling for forwarding - forwarding and piling at roadside is not solved.
- Potential cost for slowing down harvesting procedures (felling, limbing, bucking, cross-cutting). As noted in chapter 2, the cost for decreased productivity in cubic meters per hour varies between 1-4 cents per second.
- Harsh environment (moist, dirt, ice, snow, low temperatures), technical challenges.
- Insufficiently developed measurement systems (set the value of information from the harvesting procedure).
- Speed and coverage of mobile communication systems (GSM, EDGE, NMT-Off-road (450), RSM local network etc.).
- High functionality is crucial. Users must feel confidence and a clear justification to use the system. This may be facilitated by clear feed backs, automatic receipt notifications etc. If this does not work, users will try to go back to the previous system.
- Lack of correspondence between harvesting and forwarding operations is a common problem in forestry practice of today. The main problem is a lack of required computers in forwarders and DGPS (Differential GPS to get higher resolution) in all harvesters and forwarders.
- Cost for system investments and maintenance including development of operational IT-solutions.
- Increased administrative cost.
- Business barriers: Problems to get sufficient pay for the contribution to revenues coming later on in the successive production chains.

Marking of individual logs and bunches before forwarding and marking of piles at landings (roadside) may all be subject to different solutions. Today logging operations based on CTL-harvesters and forwarders are commonly based on colour-marking for keeping assortments separated that could not be securely separated by visible characteristics like species, large differences in diameter and length etc. According to findings in WP 4 reading of individual RFID tags seems to be hard along the forestry procedures. Therefore a combination of individual tags for identification and sorting at the sawmill and labels facilitating efficient logistics from harvester to sawmill will be needed. The existing systems will probably be sufficient in many cases, but improved group marking systems for forestry logistic purposes may be of interest. Modern forwarding procedure standard will facilitate the harvester to forwarder and forwarder to secondary haulage procedures (input from pri-files including coordinates of felled trees, output as prl-files) (Möller & Arlinger 2006)). High quality DGPS may work as virtual positioning of the bunches, and at least theoretically they may be possible to follow virtually further on in the chain. Existing systems and routines for forwarding and piling may also stay sufficient when utilised in lines with the StanForD procedures. New colour marking systems resistant to tough conditions and automatically readable at the sawmill may also facilitate group marking.

Table 4. Marking of individual logs and group of logs with respect to different situations. Y=Yes, possible if economically feasible.

	Level of marking according to figure 1			
Situation	**1. Unique marking of all logs**	**2. Group marking of all logs**	**3. Unique marking of some logs**	**4. Group marking of some logs**
Individual log properties within assortments measured at harvesting	Y	Y	Y	Y
Individual log properties within assortments predicted at harvesting	Y	Y	Y	Y
Track of bunches before forwarding		Y		Y
Track of bunches in piles at landings		Y		Y
Control and audit of measurements, quality assurance, production control, lead time control etc.			Y	Y
Analyses of statistical relationships between native properties, processes and products, predicted properties		Y	Y	Y
Connection to specific harvesting object		Y	Y	Y
Track of average log properties within assortments at the harvesting object level		Y	Y	
Track of average log properties within and between assortments at a regional level			Y	Y

6.3 Logistics and transportation

Efficient logistics covers fulfilment of customer's demands. These could be expressed in terms of "just in time", development of quality indices based on native wood properties, freshness etc. (used as carrots and sticks) and total cost per unit. Traceability will improve the possibilities to control and check the system. For many of these purposes packages are commonly the smallest unit, and consequently reliable marking of packages may be sufficient for many purposes (Commonly level 4 might be sufficient). As in many other parts of the process a statistic sample of uniquely marked logs (level 3.) is of large interest for system control and current improvements. Below a list of drivers and barriers:

Drivers:

- Better control of stock in forest, at roadside and in log yards can be used for increa-sed efficiency in logistics and transportation.
- Better control of storage time in forest, at roadside and in log yards to keep control of wood freshness.
- Tracing provides possibilities to decrease lead times.
- In hardwood sawmills, the stock management is important (cf. Ducerf case). Traceability would enable them to rapidly locate the appropriate logs among a huge amount of raw material.
- Similarly, traceability will enable companies to have a better control over stocks in forest (at road-side). Some companies are avoiding as much as possible to have stocks on the log yard, especially when the time constraint on wood freshness is weak (maturing of wood). Traceability gives them opportunity to operate in direct flows only: the appropriate logs are located and the supply is reliable, at the right moment. With a better knowledge of stocks, it is easier to plan the supply chain in case of interruptions.
- Traceability enables to pay for transport at the real kilometre (distance from loading to unloading) instead of payments by trenches (25-50-100 km).
- At reception gate, the registering of deliveries (of truck, logs, etc.) can be automatic by an electronic portal, allowing gains in time.
- Optimisation of flows: greater appropriateness between forest – transports – mill.

Mobile communication systems (GSM, EDGE, NMT-Off-road, RSM local network etc.) coverage will be increasingly important for haulage optimisation and for communication of available information, planning of optimal destinations etc.

Barriers:

- Marking of individual logs does not solve the logistics. Typically its only providing an opportunity to sort and select individuals that should be primarily directed to the same destination.
- Reliable, efficient and affordable reading, tracking and handling of individually marked logs at roadside, loading and unloading is not solved.
- Harsh environment (moist, dirt, ice, snow, low temperatures), technical challenges
- High functionality is crucial. Users must feel confidence and a clear justification to use the system. This may be facilitated by clear feed backs, automatic receipt notifications etc. If this does not work, users will try to go back to the previous system.
- Lack of correspondence between forwarding and haulage operations due to lack of vehicle based computers.
- Cost for system investments and maintenance including development of operational IT-solutions.
- Increased administrative cost.
- Business barriers: Problems to get sufficient pay for the contribution to revenues coming later on in the successive production chains.

6.4 Saw-mill operation

There are three main types of situations where traceability can be used for production improvements: trouble-shooting, optimization and development/research.

Trouble-shooting This case occurs when a certain product quality property (suddenly) starts to deviate from the target value and especially if corresponding customer requirements are not fulfilled any more. There are then improved possibilities to trace this deviation to its original causes. If for instance the final moisture content for a certain product has changed, or the standard deviation increased, then this may perhaps be linked to a specific kiln. By concentrating the investigation efforts upon this kiln makes it easier to find the initial cause - in the form of an erroneous temperature measurement or the like.

For a batch kiln the value of one timber batch is typically 20000€. If for instance 10% of the value is lost due to a kiln malfunction, then each batch dried in that kiln before the error is identified represents a loss of 2000€. This is not very much compared to a traceability investment, but it should be remembered that there are normally also other costs associated with a deviation of the kind mentioned. It should further be taken into account that the majority of customer complaints are moisture content related. However, other not so frequently occurring deviations may represent a much higher cost per event.

Optimisation

Even if the quality requirements for a certain product are fulfilled, there are normally possibilities to further improve the quality or the production methods. For instance, twist is an important quality aspect regarding boards for the building sector. By measuring the spiral grain angle on the log or on the single boards, the twist in the final product can be predicted to some extent. This gives a possibility to identify boards prone to twist and to later in the production chain divert these for a special treatment in connection with the drying process.

A method - that already has been used at sawmills - is to measure the grain angle on the block surface, using a laser/camera technique, in connection with the sawing process and to apply a colour mark on those pieces that are determined as prone to twist. The marked (centre) boards are then detected and diverted before the stickering process and stickered separately and further placed as bottom packages in the kiln stacks. This will reduce the amount of final twist for these boards by up to 50%. In a real case reported in (Uusijärvi 2004) a payback time of about half a year was found. This calculation included investment costs for grain angle measurement, marking, detecting and additional operating costs, as well as the improved final product quality. In theoretical calculations the centre board quality increase has been estimated to about 1.60 €/m^3. This short traceability chain within the sawmill is thus clearly feasible. It requires that all centre boards are measured, but that only those requiring a special treatment are marked, which corresponds to type 2 or 4 in Figure 1.

A further developed method is to dry the prone to twist boards in a pre-twisted position, i.e. twisted in the opposite direction compared to their inherent twist direction. This can bring the *average* final twist down to a level close to zero. The payback time for this case has also been estimated to about half a year (Salin et al, 2005). For a sawmill that consider twist as a major quality problem the methods described here should represent a strong economic driver for implementation of a traceability chain, at least within the sawmill.

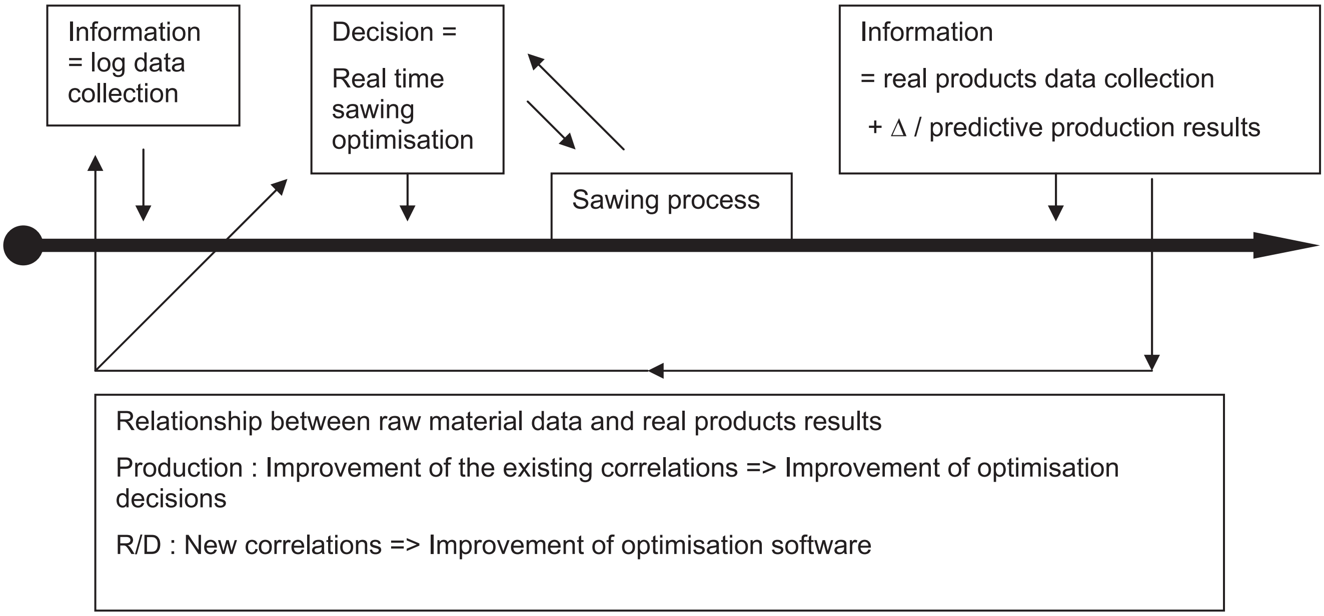
It is an important but difficult task to determine the optimal threshold value for a characterisation as "prone to twist". By tracing the observed final quality level back to the corresponding treatment method this task can be simplified. In many cases of this kind, tracing of only a fraction of the product flow is enough to obtain a reasonable basis for optimisation (Level 3 or 4 in Figure 1). This kind of procedure - including statistic tools - can be standardised in the form of a "continuous test sawing" procedure. However, if the measurement needed for the optimization is done upstream in the production process, traceability of every board in the sawmill may be required to identify the boards that require special treatment in a later stage (Level 1 or 2 in Figure 1). It should be noted that this type of optimization could equally well be called feed-forward control.

There are several basic variables that characterize the properties of a board. The most important for Scandinavian softwood are basic density and heartwood content as well as moisture content for dried boards. Many secondary properties are affected by these. Unfortunately basic density is difficult to measure and there are no good methods suitable for an industrial environment. The heartwood content can however be measured or estimated and boards at least labelled as having a “low” or a “high” heartwood content. This can be done by laser/camera techniques or simply from the sawing pattern, for instance by handling the inner and outer board pairs differently for a 4 ex log sawing pattern. This knowledge can with a traceability system be connected to a single board and thus allocated for a specific product.

The heartwood content of a green board is at the same time an indication of the amount of moisture in that board. This may to some extent be used for optimisation of the kilning process (See also the next section).

In an optimisation process (as a predictive system), the level of the real improvements of production results is directly related to the ability to connect properties of the raw material to process efficiency and properties of the products. This connection is the only way to upgrade the optimisation process in real time.

Example of the sawing process:



Development/Research Wood as a natural material shows a high property variability and also non-trivial correlations between highly different parameters. Such correlations can be determined only from very extensive databases, but may be very valuable as means for selecting the optimal raw material for a specific product. A window frame manufacturer would like to have boards with a longer average distance between knots. It is not a trivial task to determine suitable "rules" that applied to the forest-sawmill chain will give a more valuable raw material in this respect. A traceability system gives however bases for such research work.

There is a need to be able to determine whether a board is “easy” or “difficult” to dry. Heartwood content (or green MC) is however not a sufficiently sharp indicator in this respect. However, in combination with other variables a better result may be obtained. Density would clearly be one of the most valuable additional variables in this context. Databases created with a traceability system would be a valuable source for a statistical determination of a set of variables that combined could be used for the estimation of easy and difficult to dry boards. After that the traceability can be used for the splitting of the product flows into different treatments. The benefits would be a lower standard deviation in the final moisture content and possibly a lower energy demand. With the introduction of traceability systems a need for a reliable density measurement has increased.

One important board quality aspect is related to deformations. These are normally not directly seen before drying and there is thus a need to detect critical boards before the drying process. The deformations generally increase as the final MC decreases. Boards should thus not be “over dried” and preferably allocated for final products in such a way that deformation problems are minimised. The deformations in this respect are cup, bow, spring and twist.

Twist, which is the most important, has been discussed above. Cup is related to the position (distance from the pith) of the board in the log from which it was sawn. Knowledge of this position can thus be used if this type of deformation is crucial. Bow and spring are related to compression wood and grain pattern disturbances, but the correlations are not very strong (including measurement inaccuracies). Again a traceability system may be used for the determination of suitable sets of variables (measured earlier in the production chain) that combined give a more reliable index for predicting bow and spring severity.

Other possible drivers for sawmills include

- Improved environmental certification/traceability of wood origin.
- Improved logistics, control of lead-times, finding “lost” packages.
- To develop and improve special niche products requiring special wood properties.
- Possibility to de-centralise the grading by scanning for different wood features at positions in the process where they are most visible and make the final decision when all features are counted.
- Better management of stocks: simpler, more reliable and less expensive.
- Revenue from different batches of logs can be separated.

There are two main types of barriers regarding implementation of a traceability system, technical and the "human factor".

It is obvious that many technical requirements have to be fulfilled in order to obtain an unbroken information chain in parallel with the physical material flow. The target is a 100% correct marking/reading etc. of each log, board, etc. at each stage of the chain. This is, however, in principle an impossible task. The key question is if the amount of failures can be accepted or not. Within the sawmill the critical parts are probably 1) reading (RFID) tags for individual logs in log piles and related problems, as well as marking and reading individual boards (dirt, snow, end cutting), and 2) the pacing system, i.e. connecting log data to the boards sawn from the log. It should be remembered that both the marking and the reading have to be successful in order to bring the information forward.

The human factor as a barrier (and driver) has been discussed in section 5.

Planing of boards can be considered either as a sawmill operation or as a secondary manufacturing step. A special feature related to planing is that identification marks on surface being planed are lost and that planed surfaces normally are visible surfaces that should not be marked. See also section, 6.5.

6.5 Secondary manufacturing

In many aspects the same comments apply to the “Secondary manufacturing” of wooden products as to “Sawmill operation”.

- Better knowledge about raw material history and properties can be used to optimize secondary manufacturing processes and to track quality problems.
- Improved information on the ecological quality of the product (to be delivered to the customer) and certification /traceability of wood origin. It should be noticed that this actually requires an unbroken chain from end to end, from the forest to the end user, i.e. level 1 or 2 in Figure 1.

In general terms, wood is sold from forestry to primary breakdown (usually a sawmill) and further to secondary and tertiary etc. manufacturing, before being bought by the end user. Tracing might be applied inside one company, or to transfer info from one company to the subsequent. Even if a perfect tracing should involve the full chain from forestry to end user, both the amount of available info and the complexity of tracing increase with the number of processes/companies. Therefore it seems reasonable to start simple, i.e. with tracing systems inside a company and between two subsequent companies. With a project of forestry origin, this implies starting with the forestry – sawmill chain. Accordingly, only a brief analysis of the secondary production processes will be given.

A sawn (and dried) board is considered the product at the sawmill, but as a raw material for the secondary manufacturing. The board might be split and cut to several pieces, laminated or joined to compound units, planed, and/or otherwise treated. Thus the ‘identity unit’ will change in all possible combinations:

- One to one (e.g. a planed beam)
- One to many (e.g. outdoor cladding)
- Many to one (e.g. gluelam)
- Many to many (e.g. carpentry)

In addition, in modern wood-working, no pieces are used without planing or otherwise smoothing the rough sawn surface and adjusting the dimensions, thickness, width and length. While a sawn surface (from primary breakdown) is suitable for directly printing ID codes, these codes will be removed during further processing. And those fresh surfaces will be visible in the final product and no printing allowed.

As a consequence, both the ID technique and the overall idea of what should be a tracing (or traceable) unit encounter other challenges than is found in the forestry – sawmill part of the chain.

7 Priorities for case studies

This chapter contains specific information and priorities for the project case studies and examples of business cases for introducing traceability technology. In the terminology used here, a business case is a particular benefit given by implementation of traceability and integration of information that justifies the investment. A case study may have several business cases. The Indisputable Key project involves the following case studies, which are further described in separate sections below:

- Sveaskog – Malå – Norsjöfönster, Sweden
- Scanpole, Norway
- Eidskog-Stangeskovene, Norway
- Raunion Saha, Finland
- Scierie Ducerf, France
- SK Rol Pin, France

Chapter 7 will be used as the starting point of a living document, revised during the course of the project to incorporate information that will become available as the project proceeds. Typically, the estimated return of investment and the economic evaluation of the business cases have been difficult to assess at this stage of the project.

7.1 Sveaskog – Malå – Norsjöfönster, Sweden

Sveaskog is the largest forest owner in Sweden. The company manages some 4.6 million hectares of land, including approximately 3.5 million hectares of productive forest land. Using its own raw material assets as well as purchases and exchanges, Sveaskog is an independent supplier of saw logs, pulpwood and biofuel to sawmills, pulp mills and energy facilities. Sveaskog's long-term goal is to raise the value of its forest assets through market-driven, eco-focused and sustainable forestry.

Malå Sawmill is one of Setra Group's sawmill in Northern Sweden producing timber based on pine. It has several systems that produce important quality data, such as 3-d log measuring systems, automatic green sorting system, fibre direction sensor, heart wood sensor, and moisture in-line sensor in final grading. Malå Sawmill also has an almost full automatic system for logistic control of stacked packages and final packages.

Norsjöfönster AB is a wood production company using raw material from the Malå saw mill.

7.1.1 Specific business cases

The following business cases have been identified that can demonstrate the value of the traceability chain, which will be established in Indisputable Key.

1. Forest → sawmill → window manufacturer. Optimisation of internode length, knot size/type and basic density will lead to improved yield at the window manufacturer.
2. Forest → sawmill → "Other". Traceability of origin will lead to improved control of origin (compared to FSC/PEFC) and a higher value of final products.
3. Minimize downgrading of sawmill products by improved understanding of the cause of quality problems caused by bad harvesting instructions, bad harvester maintenance and log handling in the forest. Examples:
    - Harvester feeding rolls may cause damage to the logs due to too high hydraulic pressure in combination with aggressive spikes
    - Uncertainty in length and/or diameter measurement on harvester causes logs that are meant to "cut to length in certain diameter interval" to mismatch specifications. This can lead to that the log has to be used for a different product than intended which can make the value of the log much lower for the saw mill. Alternatively the

length uncertainty can force the saw mill to order logs that are longer than really needed to ensure that the raw material needed to fulfil customer orders is delivered.

4. Minimize downgrading of sawmill products by improved understanding of the cause of quality problems. This is a sawmill internal business case that is considered to have a very short return-of-investment. Examples:
   - Better tools for follow-up of quality problems can allow a tighter control of the process through decreased variation. This can be used to decrease safety margins. If both ends of the log diameter interval for a certain saw class can be reduced with 1 mm (e.g. from 220-230 mm to 219-229 mm) it decreases the amount of raw material used by approximately 1% while still producing the same products. This yield improvement is very significant for a saw mill using 450 000 m^3/year at an average price of approximately 500-600 SEK/m^3.
   - Traceability allows a much faster detection of dryer problems (such as those caused by using uncalibrated temperature sensors for process control) through quality control of boards, which will decrease the volume affected by the problem.
   - Boards with similar properties should be dried together, to minimize downgrading due to wrong/uneven moisture content
5. Minimize production problems by improved understanding of which type of logs and/or boards that cause problems in handling. This is a sawmill internal business case.
   - Logs with compression wood produce boards that will have sweep, bow or spring. Logs with large grain angle produce boards that will twist. Both kinds of distortion cause problems in handling. A typical problem caused by to much bow stops production approximately 1 minute and requires operator interference. For some raw material (certain types of logs) this can happen as often as twice every hour, but the average is (far) lower.
   - Logs with compression wood can also cause a breakdown in the saw line. In order to avoid this, thicker saw blades are used. With better control of problematic logs a thinner blade could be used, which would increase yield. This effect is difficult to quantify.
6. Maximize value yield by being able to find and direct the right log to the right product to the right customer, from log to board. It has been estimated that by installing improved measurement equipment, product value can be increased significantly (approximately 20% for 15% of the products and 10% for 30% of the products) by better raw material allocation. These measurements can be made even better by the feed-back possibilities offered by a traceability system. Examples:
   - Direct logs with green knots to "green knot assortment" and butt logs to "heart wood assortment".
   - Direct logs with resin pockets away from panel assortment.
   - Increased amount of heartwood content and increased basic wood density may be of value (durability) for specific customers (e.g. a minimum wood density is required for the production process of door frames at Norsjöfönster.
7. Maximize productivity by early in the production chain rejecting logs and boards that anyway will be rejected due to low quality. This is a sawmill internal business case.

7.1.2 Installations

To be able to manage these business cases different kind installations of traceability hardware and software are needed. Not all needs full traceability of all individuals (Figure 1) even if that gives the most freedom to manipulate, find and use the information in all data produced. Software installations needed are almost the same for all cases. It is mostly the size and speed of the data base that differs and that will thus not be specified in each case.

The numbers below refer to the same numbers above.

1. To optimise internode length the harvester driver, who actually sees the tree, can assign trees/logs with large internode lengths to a certain assortment. An alternative is to use models for estimation of internode length deployed in the harvester.

   At the log sorting station it is possible to get a hint of internode length.

   The automatic green sorting is able to grade “window” boards as a special grade.

   Hardware installations needed are: group marking at harvester or log sorting and at green sorting (type 4 in Figure 1). Code readers are needed at log sorting, green sorting and final sorting.
2. Certification of origin requires only a group mark (type 4 in Figure 1) of all logs and boards belonging to the certified population. A colour mark or a short number might be sufficient.
3. As the causes for downgrading is unknown, a full traceability is needed on a sample of the production (type 3 in Figure 1). If not all logs and boards are marked, it is important that the sample is randomized, and not biased by some factor that might be the cause of the problem.
4. See 3.
5. See 3
6. To be able to direct and control the whole production from log to final product, a full traceability chain is needed on all logs and boards (type 1 in Figure 1).
7. To do this, an investigation similar to 3 has to be performed in order to learn which type of logs and boards cause problems.
8. Similar to 2, so only group marking is required (type 4 in Figure 1).

7.2 Scanpole, Norway

Scanpole buys raw material, i.e. pole logs, from the Scandinavian forestry and produces preserved power-line poles (see www.scanpole.com). Poles are produced and sold in ca. 40 main varieties according to dimension (diameter and length) and quality.

Impregnation with preservatives requires that each part of a log is drier than the fibre saturation point. This involves open-air drying for one full season, or open-air pre-drying for a shorter period. Log dimension, time in stock and climate (usually seasonal average) is used to estimate the moisture content. At present this information is available at a statistical level for each pile.

7.2.1 Specific business cases

The following main objectives have been defined:

1. The primary objective is to improve the logistics by identifying the precise position of each log/pole in stock with given quality and dimension. Each single log must be identified and marked but it is enough with marking after the arrival to Scanpole.

   Consignment lots are produced from dry logs according to the customers' quality/dimension specification, but unfortunately the accuracy in retrieving single logs is mediocre. By combining customer specification with inventory specification,

   a. inventory turnover will increase, reducing the need for capital,
   b. the risk of quality deterioration for logs in stock decreases,
   c. the present practice of using oversized logs to fulfil customer specifications should be reduced.

The current cost for capital tied in stock is 3.5 MNOK/year. There are also other advantages expected from an overall upgrade of inventory information systems.

Reliability of system is critical; malfunction might be worse than no system. Naturally, the system must be profitable; revenue must exceed cost of system and transponders.

2. At a second stage, a follow-up and feed-back system for the quality of harvested logs will be ventured. Varying sampling levels might be considered: ad hoc subsets of logs to analyse certain cases, all logs from a subset of stands, or tracing of all logs. Marking in connection with harvesting is required.

   A better control and feed-back system will allow a more precise description of pole log features, and fine-tuning of dimension-quality-price relations. But for the forestry - Scanpole feed-back system the commercial benefits remains to prove manifest. It can be noted that the estimated costs for poor raw material control are 100 000 NOK/year.

7.2.2 *Installations*

For this particular Scanpole inventory application, the technology must be adapted to the factory production flow, e.g.

1. ID must be applied to the logs during scaling,
2. direct reading during loading/unloading and other operations should be possible,
3. the ID must survive peeling, drying and impregnation, and
4. an appropriate reading distance must be combined with ability of both log separation and reading multiple logs simultaneously

Inventory system requirements are:

5. Automated ID application during log scaling; loading info about log dimension into the data-base DB
6. (Barking; DB loading date of barking might be optional, since barking coincides with scaling)
7. Positioning soft- and hardware application giving local (at least) or global coordinates with accuracy to describe and retrieve individual logs with vehicle and hand-held instruments
8. Vehicle mounted single- and multiple log ID reader
9. Vehicle mounted computer for read/write DB info, e.g. DB loading of position and date for start of open-air drying by reading the ID during piling of each log
10. Software to estimate the log MC at any time (one week resolution)
11. Hand-held ID reader (or visible tag) to identify piled logs for inventory control
12. Automated ID reading and DB loading at the time of 1) peeling, 2) in/out of kiln, and 3) in/out of impregnation; or at least assigning log ID from peeling to identifiable kiln & impregnation batches.
13. Software to transfer info between various applications

7.3 Eidskog-Stangeskovene, Norway

Eidskog Stangeskovene AS has 57 employees and is owned by the local authority and Stangeskovene AS with 50 % each. The company consists of two production units, one sawmill at Aurskog and one sawmill at Eidskog. The unit at Eidskog will be the testing sawmill in the project for Eidskog Stangeskovene AS. The sawmill at Eidskog uses only spruce with top diameter above 20 cm. ESAS`s main products are external and internal panel in various profiles, and structural timber. Last year the sawmills produced about 135 000 cubic metres, and manufactured approximately 30 000 cubic metres in the planing mill.

7.3.1 Specific business cases

The main benefit of traceability in the saw mill identified by ESAS is to be able to mark and separate inner and outer boards from different sawing patterns (2x, 3x, 4x). Topical sawing pattern is: 2x: 50mm – 50mm, 3x: 44mm – 32mm – 44mm, 4x: 44mm – 44mm – 44mm – 44mm, 4x: 38mm – 44mm – 44mm – 38mm. The sawmill is making different products from the inner and outer boards. Panels are made from the inner boards, and structural timber from the outer boards. These two products require different drying processes. This case does not require marking on individual level. Group marking of centre boards is sufficient. A rough estimate of total expected earning in this case is 10 000 €/year.

Tracing packages through the whole process from green sorting to the final packages, can help the sawmill to improve their stock management. The sawmill sees advantages in having control of the volume and length of each board in each package. This can also improve product quality, e.g. special drying process is required for some products. This requires marking on package level. Expected earning in this case is 0.3 € pr. cubic meter sawn wood at Eidskog. Total production of sawn wood at Eidskog is 35 000 cubic metres. Hence, the estimated total expected earning: 35 000 cubic metres x 0.3 € pr. cubic metres = 10 500 €.

The volume and length of each board is measured and stored during the packaging process.

7.3.2 Installations

Tracing boards: The sawmill need to install new software in the control system for the SE saw to make it able to communicate with marking equipment. Some marking equipment connected to the saw is needed to mark the boards. Automatic or manual code readers are needed in the board sorting station.

Tracing packages: Equipment for marking the packages after the green sorting, and readers to trace the packages through the whole process is needed.

7.4 Raunion Saha, Finland

Raunio Sawmill is a medium-sized sawmill in the municipality of Koski in south-western Finland. Production is 180,000 m³ per annum, and about 75% of production is exported. In 2006 the company had a turnover of EUR 44 million. Raunio Sawmill produces lots of specialist products. A specialist product in sawn timber means a variation from the standard in length, thickness, width, grading specifications, level of drying, packing or some other characteristic.

7.4.1 Specific business cases

The area from which the logs come effects the quality distribution of the timber. Since not all boards in a package come from the same area, it would be beneficial to be able to trace back to the origin of each board. Also, for the same purposes, it would be useful to know from which part of the stem a log is taken. Access to information about origin of a log and position in stem would facilitate optimisation of raw material allocation.

To reach this objective, individual marking is not required, since there are only two different variables that are considered interesting:

1. Area of harvesting. (ten groups: ten different areas)
2. Log place in stem. (three groups: butt log, middle log and top log)

Required level of marking in log tracing is 2 (cf. Figure 1) Logs must be marked in the harvesting site, because it is possible that logs from different areas are mixed up in storage (road side or log yard). Internal traceability is needed to carry on the log information through the whole production chain (green sorting -> drying -> final sorting -> packaging). Required level of marking in board tracing is 1 (cf. Figure 1).

Internal sawmill traceability can also be used for improving the drying, e.g. by finding reasons for problems, like cracks and twists. Also for this objective the required level of marking in board tracing is 1 (cf. Figure 1). Examples of questions that are relevant are:

1. How long has the board been in storage before the kiln?
2. Which kind of kiln was used and what was the board position in the kiln.
3. Where in the package was the board located?

Successful application of traceability is estimated to increase the profitability of Raunio sawmill with about 5 %. It is, however, difficult to estimate how much of this increase that relates to log traceability and how much that relates to board traceability. Altogether profitability increase might be 5 % or even more.

A possible barrier to implementation of traceability at Raunion Saha might be heterogeneity of existing information systems.

7.4.2 Installations

Log reading system is needed in log sorting for better control of stock and in saw infeed for moving log information to the boards.

Board marking in needed in green sorting and in final sorting (because of trimming). Board reader is needed in sticking, final sorting and packaging.

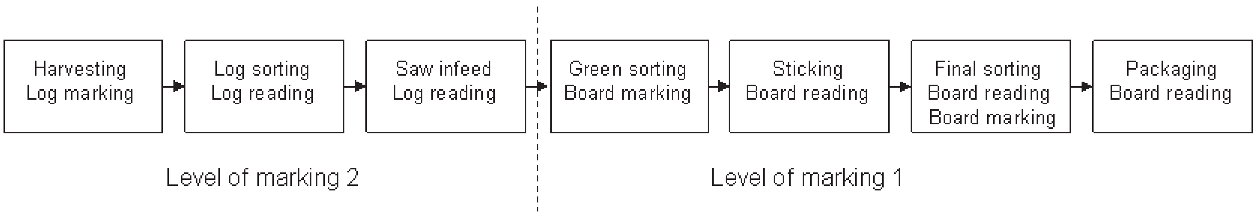


Figure 3. Raunio Sawmill installations.

7.5 Scierie Ducerf, France

Ducerf SA, created in 1885, is one of the biggest hardwood sawmills in France recording an annual consumption of the roundwood around 40 000 m3 (of which 80% is oak, and the remainder concerns Beach, Ash, Cherry Walnut, Chestnut, Lime tree). The Ducerf group is also one of the first French sawmills being PEFC eco-certified.

The company buys most of its timber on root, and is engaged in all harvesting operations from stands to the sawmill. With the recent investments in sawing equipments, Ducerf is targeting two main goals: increases in productivity and in quality. In order to control wood moisture content, the drying capacity is more than 3 000 m3 managed by the high skilled staff specialized in this particular field. Due to the fact that hardwood has a very long drying process (up to 2 years), and a large number of items (320), it becomes crucial to manage the stock volume of the sawn wood (18 000m^3 on 10 ha) as efficiently as possible.

The use of new technologies to trace and to follow operations related to an individual / object level seems to be a very good way to guarantee the achievement of environmental as well as of quality objectives of the company.

7.5.1 Specific business cases

For the moment, three business cases have been identified for Ducerf.

1. The first business case relates to the stock management. The volume of sawn wood in stocks (18 000 m^3) is stored over 10 hectares, during 6 months up to 2 years. More generally, the client's order does not command the supply of raw materials, due to the large amount of stocks that are necessary.

Movement of stocks:
10 boxes ➔ Predrying: 2 boxes (+ 2 under construction) ➔ Drying: 10 boxes

Each movement of a pack is manually registered into the information system. The overall amount of movements registered by the information system, excepting forestry, is around 250 000 per annum.

Twice a year, an inventory mobilizing 8 persons (4 x 2) during one week takes place. In addition, checking and verifying, taking 1 week and 1 more week for resolution of errors, is organized. The most frequent errors come from manual encoding into the information system. In parallel the movements are not recorded when they occur, sometimes the outgoing movement can be registered before the incoming. All in all, the management of stocks represents a significant cost. A possibility of tracing, following and locating of an individual pack, using an automatic tool, offered by the project, is a clear incentive/opportunity for Ducerf. As defined in the contract the priority for Ducerf is this point.

2. The second concerns the setting of an identification technology of each log in the incoming sawmill. This identification information will enable to obtain an aggregate traceability per material quality, so in the future the company will be able to be much more precise when buying standing timber. A pacing-system must be added in the first crosscut saw to reach this goal.
3. The third business case is the installation of technologies to obtain a whole traceability. This implementation should enable to optimise the Ducerf process, and will be done according the return on investment. It implies to add six pacing-systems in the actual process.

From these elements a rough estimation of potential benefits for the sawmill from traceability implementation can be written as follows:

- Inventory: labour costs savings on a yearly basis
    - The current situation of inventories (8 persons during one week, twice a year), and the registering stage during inventories (1 person during 1 week) can be improved significantly.
    - Errors of manual registering represent 2% of total (300m^3 of 16 000m^3); to solve these errors it takes one full time equivalent job over a week each year. Traceability could reduce these costs in future.
- Operational costs savings:
    - If a manual registering of movements (250 000 per annum) becomes automatic, it will lead to additional labour time savings; but at the moment they are difficult to quantify (average time for registering * 250 000 operations per year). Thanks to the traceability system the location of logs will be automatic: in practice this means that time spent searching for the right logs in the mill will be avoided, bringing labour costs savings.
- Raw material savings: the mill is buying the wood “on root” and takes care of its mobilisation from the stand to the mill. In the raw material processing, inside the sawmill, Ducerf note a difference between the input and the output volumes. This difference is about 0.5% of raw material per annum (150 to 200 m^3):
    - Applying a tracing system should improve the productivity by reducing the losses in the Ducerf process.

For instance by optimising the rate between the edger saw and the crosscut, and improve the productivity of 1%, it would be possible to gain about 170 000 € per year.

These potential benefits are of course to be balanced against costs brought up by traceability (investment, maintenance and operation costs), too early to be quantified at this stage.

7.5.2 Installations

At the moment, for management of its database, the company is using Visual Fox Pro and must migrate to a SQL server centre. The raw management process used by Ducerf can be represented as shown in Figure 4.

To reach the goal of a whole traceability, several adaptations to the current process must be done:

- Add 6 pacing-system (in order to be able to read the information about the input object, and write some other chained information over the output object) in the process, as described in Figure 4.
- Adapt the information system to these new data. This also covers integration of an appropriate language of exchange.

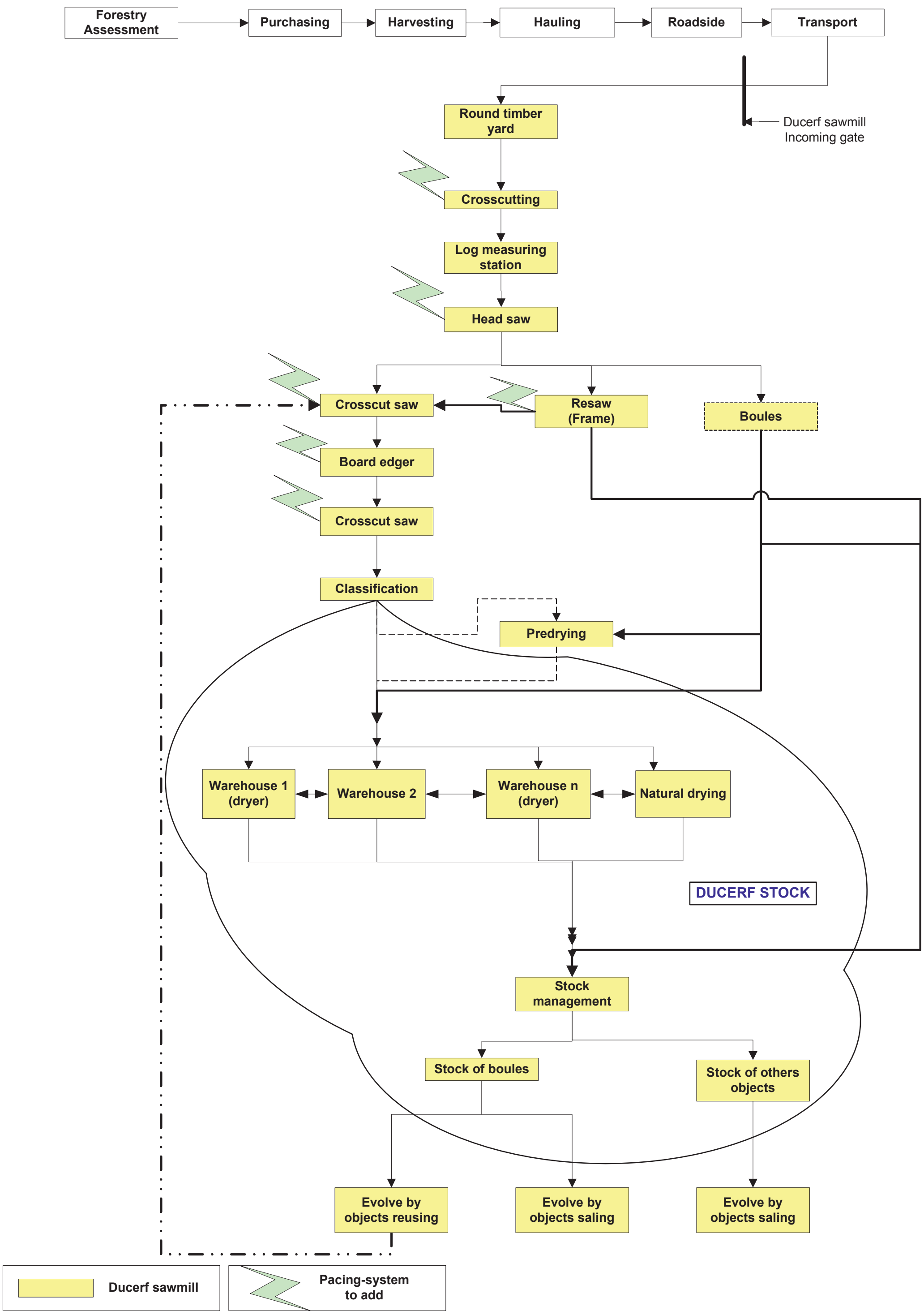


Figure 4. The raw management process used by Ducerf

7.6 SK Rol Pin, France

SK Rol Pin produces plywood directly from logs. For several years, the company is closely working with CIRIS engineering, improving equipments (scanning, measurement etc.) and optimising the production process. The internal information system is in continuous improvement (currently 4th version).

The wood supply is entirely provided by one supplier SK COMPTOIR DU PIN, a wood supply company belonging to same group (SMURFIT KAPPA). The latter is dealing with supply from forest dealers and harvests itself some stands. SK Rol Pin consumes 15.000 t/month of wood logs classified in two grades (choice 1 and choice 2). The site produces 76.000 m³/year of plywood for a sales turnover of 36 M€/an. Only the maritime pine is used. The supply area is regional (Landes de Gascogne).

The company is running without stocks of roundwood on the log yard, with direct logistics flows only. In case of a non-conform delivery, wood is unloaded on the log yard.

7.6.1 Specific business cases

1. The stands are harvested, by loggers or harvesters (cut to length system – CTL). The products are sorted by the harvester, then separately forwarded and transported. In the mill, wood is weighed and thereafter discharged directly on the conveyor deck of the de-barker and log scanner. The first and the last logs are marked with painting (a chronological number). This number makes possible to establish the link with the data of the weighing and information on wood origin.

   The system of marking by paintings is reliable only at 85%. Information is lost in certain cases. The method is considered as insufficient to establish the link between the origin of wood and characteristics of the delivery, measured by the scanner after debarking. In addition, it is not sufficiently reliable to use the system for payment of suppliers. If 100% of the deliveries were identified in a reliable way, it would be possible to pay the deliveries on the basis of under bark cubic meter measured by the scanner, instead of a payment based currently on gross ton with bark.

2. The explanation for 15% of not identified wood lots comes from various sources of errors:

   - Bad inscription of the number by the conveyor;
   - Bad second reading of the number of the short-logs by the operator of the de-barker or lack to register a new number of the delivery (2 deliveries under the same number);
   - Mixture of deliveries on the quay.

   The causes of non-conformity of the delivered short-logs (0.9 to 1% of all deliveries) comes in 70% of cases from too short lengths / cuttings which are explained by:

   - Errors of measurement of harvester,
   - Sorting errors during forwarding.

   The marking of the short-logs by the harvester and their identification at forwarding / loading would strongly reduce the sorting errors.

3. The process: after de-barking, the short-logs are classified in three categories (choice 1, choice 2, mix) and are gathered in sorting boxes before being softened (by sprinkling them with hot water) then peeled. Thereafter, the veneers are sorted in three classes according to the moisture content, [3 choices (choice 1, choice 2 and mix) X 2 rotary-veneer lathe (long wire and wire through) X 4 classes of moisture].

   The veneers are then dried. From the drier, a sorting is carried out in five quality grades. The traceability of veneers between the rotary-veneer lathe and the classification by quality is not assured. A solution of marking veneers throughout this stage of the process would make it possible to improve its control and to follow-up the quality of wood/choice of the wood and the teams involved.

So the potential benefits of implementing a traceability system at SK Rol Pin (and possibly its unique supplier SK COMPTOIR DU PIN) are of three types:

- To make sorting of the short-logs at the forwarding / loading stage more reliable, which would decrease the number of logs of unacceptable quality
- To make the traceability of information from the harvesting stands to the scanning system of the mill 100% reliable, which would also facilitate payment by wood volume under bark
- To conceive a system of traceability of veneers between the entry of the short-logs in the peeling line and the sorting of the dry veneers.

7.6.2 Installations

The current material flow at Rol Pin is shown in Figure 5

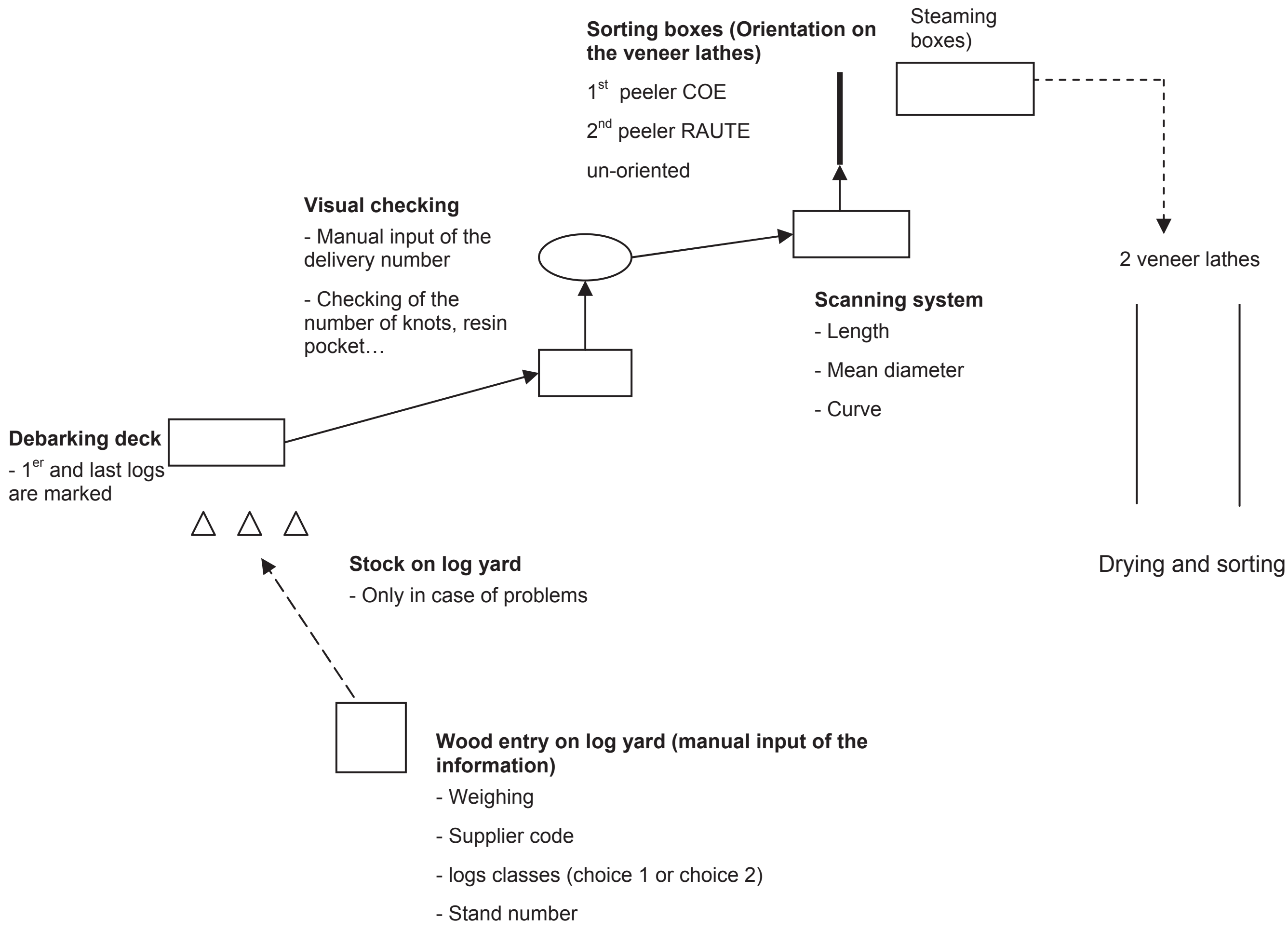


Figure 5. Material flow at SK Rol Pin.

At the present level of the project, it is not necessary for Rol Pin to go deeper into details on the internal information system. Nevertheless, two important points for marking systems are at the mill entrance (link with forest data) and after the peelers (link between dry veeners and log quality). A problem remains between the debarker and the peeler.

8 Summary and focus of further work

A general guideline for further work is that all development work undertaken in the project should be based on a commercial perspective and include a cost/benefit analysis for some or all of the three topics economics, environmental and social aspects.

The key fields for further work in WP3 of Indisputable Key are:

- Improved knowledge and selection of wood properties and its effects on
  - value chain efficiency
  - product value

  The work must use a system perspective to account for effects in the full value chain.
- Tools and methods for calculation of cost/revenue from production of boards or other wood products from logs from certain supplier/origin.
- Decrease downgrading/customer complaints in sawmills by improved knowledge about history of product and new tools for trouble-shooting.
- Improved stock management and logistics in sawmills and at the pole manufacturer.
- Improved transportation efficiency primarily from forest to sawmill but also from sawmill/secondary manufacturing to customers.
- Improved knowledge of origin of individual boards and how it can be used for increased environmental performance and market communication.
- Identify the most efficient (in monetary and environmental units) levels of marking (1. Unique marking of all logs, 2 Group marking of all logs, 3. Unique marking of sample logs, 4. Group marking of sample logs, depending on available quality of information (e.g. accuracy and relevance) and the value of this information for the subsequent processes and the impact on value of the final product.

In addition to these bullets, it is important to develop general tools for quantification of value chain performance from economic and environmental perspective through identification of key performance indicators. This is needed in the final assessment of the project and its effects on supply chain performance.

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