Barcode and RFID Technologies: Alternatives to Log Stamping for Wood Identification in Forestry?

Daniel Timpe
PREFACE

Radio Frequency Identification, often abbreviated to RFID, is sometimes described as “the technology that will replace bar codes.” An RFID-tag communicates with its surroundings via a radio signal. Unlike a bar code, the tag does not have to be “visible” or be accessed in order to be read. The technical challenges involved lie, as always, in minimising costs and improving the performance, reading distance and durability of tags, readers and the integral system. It is easy to understand that tags and systems must be optimised both regarding their purpose and the market for which they are intended. RFID-tags for use on oilrigs in the North Sea have very little in common with the “tags” on Gillette’s razors!

Daniel Timpe comes from Germany, has studied in Holland and is now completing his studies at the Sundsvall Campus of Mid-Sweden University. In the spring term of 2005 Timpe, with the support of his supervisor, Reader Mats B Klint, decided to examine the logistic and technical possibilities for “tagging” forest raw materials. SCA Forest AB became the industrial partner and FSCN the platform for his research.

Timpe makes two observations in his essay, which is presented here as an FSCN report. Firstly he shows that the manual marking of roundwood is the most time-consuming of the non-value adding activities that must be carried out in the logistic chain from forest to user. Secondly he claims that RFID, in an applied version, could be a good candidate to replace marking stamps, at the same time as possibly enabling the transfer of valuable information in the logistic chain of the forest industry.

Perhaps RFID has not always been associated with wood fibre research and the paper industry. At the FSCN, however, in the group for Media Technology a natural connection has been developed between electronics, paper technology, printing technology and business studies, since 1999. This study illustrates the advantages of our multidisciplinary approach. Good ideas thrive and relevant questions are formulated when different perspectives meet one another. It is therefore natural that research into RFID at Mid-Sweden University, in the form of “paper-based” electronics, printed antennas and smart sensors, is mainly concentrated to the FSCN.

The project in this report will be continued in cooperation with SCA Forest. Timpe will continue his research into the results of his study at greater depth here in Sundsvall, in collaboration with the RFID group and the group for System Analysis at the FSCN.

The FSCN has previously published analyses and more general studies of RFID in relation to logistics. The focus has mainly been on packaging and the Swedish food industry, with its highly centralised logistic chains. Examples of these reports include: “RFID, -Framtiden för den svenska livsmedelsindustrin (RFID - the future solution for the Swedish food industry)” FSCN R-04-56. For a more general discussion of RFID and logistics see: “Viktiga frågor vid införandet av RFID (Important issues concerning the implementation of RFID)”, FSCN-R-02-30.

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BARCODE AND RFID TECHNOLOGIES: ALTERNATIVES TO LOG STAMPING FOR WOOD IDENTIFICATION IN FORESTRY?

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SUMMARY

This investigation was undertaken for SCA Skog AB, a large Swedish forestry enterprise, to determine whether it is possible to substitute the procedure of stamping logs for identification with an application of Radio Frequency Identification (RFID) technology or barcodes.

There are two categories of requirements that future barcode or RFID systems would have to meet if implemented in this context, which are requirements regarding technical feasibility and requirements regarding cost effectiveness. An examination of the characteristics of possible barcode and RFID systems reveals that their capability to meet these requirements varies greatly, depending on the specific properties of the system in question.

To analyse the present procedure of stamping and examine possible new systems, certain concepts of business economics are applied. Namely, these are the A-R-A Model, information network mapping, and the concept of value-adding time vs. non-value-adding time. Applying these concepts on the current situation reveals that stamping the logs is the single longest non-value-adding activity along the supply chain from logging sites to mills.

In trying to find better marking technologies for the identification of logs it is taken into account that SCA is interested in finding a system that is upgradeable in such a way that it allows for more information on incoming wood to be stored and retrieved through the marking of logs. If such a system was found, SCA would be willing to tolerate a maximum increase in marking-related operational costs of 100 percent, which is the major cost effectiveness requirement that suggestions for such a system need to meet.

An evaluation of the feasibility of barcodes in the log handling environment reveals that because barcodes require clear line-of-sight and are easily influenced by optical covering, they are not to be recommended in this context.

Regarding RFID technologies it can be concluded that they are much more suitable for the working environment and application context that this investigation focuses on. For implementation in a log marking system, the application of simple, passive Read-Only (RO) RFID tags in combination with a more centralized information administration system is to be recommended. While feasibility problems can be solved by utilizing a removable plastic plate, cork pens or wooden nails as tag housing, the
question of whether the system should be open or closed and will eventually meet all cost effectiveness requirements cannot be determined at this point.

Some more in-depth research and tests would be required to solve all feasibility issues and analyse all the cost drivers of the preliminary designs presented in this report. As no serious obstacle to implementing the proposed solutions have yet been encountered, it is sensible to continue the investigation of this subject to reach a final conclusion of the applicability of RFID technology in this context.

LETTER OF THANKS

I would like to thank SCA Skog AB for providing me with such an interesting assignment for my thesis work. Working on a subject that had hardly been studied and investigated before was a very exciting and memorable experience that helped me learn a lot about how to approach such kind of work. It made me get a better understanding of what matters when possible changes in logistics processes are considered. I owe special thanks to Mr. Kjell Wilhelmsson (SCA Graphic Research) and Mr. Per-Anders Hedström (SCA Skog) who took the time and patience to provide me with the information I needed to get from SCA to understand the nature of the problem.

At Mittuniversitetet I was assisted in my work by Mr. Leif Olsson, Mr. Johan Sidén and Mr. Hans-Erik Nilsson whom I thank for taking continuous interest in the process of my work and for providing me with valuable input on the technological aspects of this thesis. Without their guidance I would not have managed to understand RFID and barcode technologies and I would not have known whom to contact to learn more about how these technologies may be applicable in the context that is the focus of this investigation.

Meanwhile, my tutor Mr. Mats Klint, lecturer of business economics at Mittuniversitet, checked my thoughts on the theoretical framework I needed to develop for this analysis and helped me choose the applicable models from business economics literature. I would like to thank him for the essential feedback he provided me with and for taking such an active role in assisting me in every possible way.

Last but not least, I owe thanks to my father and all my fellow students who took interest in my work and had numerous suggestions concerning possible solutions of the problem. I appreciated getting a different perspective on the whole subject by listening to the spontaneous ideas and valuable fresh thoughts of people who were not restricted in their thinking by prior knowledge of the subject and could thus help me brainstorm the problem.
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1. INTRODUCTION

In today’s world of globalising markets and industries companies are required to continuously explore each and every possibility to improve their operations’ design. Competitive advantage in a market were competition is global is often the result of a more efficient way of resource utilization and work process design. In manufacturing industries, logistics is a function of business that is crucial to the process of providing customer value, which is why one needs to make sure it is performed in the most efficient way. Forestry, which involves may steps and processes needed to turn a tree that grows in a forest into paper or some other customer product is no exception to that rule.

Nowadays, high-tech applications are crucial in most business areas. Information is processed using computer networks and automated systems that can process data in the blink of an eye and eliminate the possibility of human error. The performance of a business partly depends on the extent and quality of the internal information flow and the reliability of the information systems. High-tech has also conquered the world of forestry business but there are some information-related processes along the material flow from logging sites to factories that have not yet been reengineered to better fit today’s computerized and automated information networks. When trees are cut, the logs need to carry identification numbers, which are manually stamped on the logs. The question of how this process could be reengineered using modern technologies to make it more efficient and possibly enhance the information that is gathered through the marking is an exciting subject.

If it was possible to substitute the stamping with barcode or RFID technology and partly automate the tagging and tag reading procedures while enhancing the information provided by the tags, the whole function of logistics in forestry would be improved. In turn, more efficient logistics procedures and better information flow would support possible competitive advantages. The aim of this investigation is therefore to explore and evaluate possibilities to substitute the stamping of logs with applications of barcode or RFID technologies.

2. PROBLEM DEFINITION

The purpose of this research, is to determine whether it is feasible and economical to substitute the process of stamping wood logs with applications of barcode or RFID technologies. Special attention is given to the question of whether RFID or barcodes can be used to improve the efficiency of the logistics procedures involved in cutting trees and shipping logs to mills by serving the related information and identification needs better than currently used technologies.

Those needs result in two problems that are linked, but need to be addressed separately, namely the problem of identification and the problem of time control. The identification problem arises when a forest is harvested and logs need to be marked so that they can be identified later. This identification is necessary as it enables handlers along the supply chain to know which area logs come from, who owns that forest and who was in charge of logging. Moreover, the identification of logs is important because payment issues are linked to the unique number connected with the logging site.

Nowadays, these numbers are stamped on the logs, which is a time-consuming, messy procedure that includes no or only partial time information and has to be carried out manually by forwarder pilots. The subject of interest in this investigation is whether RFID technology or barcodes would be a better, workable alternative to present procedures.
The time control problem refers to the fact that due to a complicated wood supply chain it is very difficult to control the time gap between the cutting of a tree and the moment it arrives at the mill for processing. As there is a lack of time information in today’s identification procedure, harvesters, forwarders, and truck drivers throughout the chain can hardly be coordinated in such a way that each log is forwarded to the mills in the right time. That causes economic losses as wood that remains unprocessed for too long can no longer be used in production due to deteriorating quality.

Thus, the question arises whether an implementation of RFID technology or barcodes may enhance the control over the above-mentioned time gap. However, this can be seen as a secondary problem to the subject of identification as it is impossible to solve the time control problem without implementing better identification technologies.

Therefore this project is restricted to investigating the opportunities RFID or barcodes may offer to solve the identification problem better than the current procedures and technologies. Consequently, it focuses on what effects the implementation of new technologies may have on the job description of harvesters and forwarder pilots and whether or not is may make their tasks that are related to information processing easier and more efficient.

3. **OBJECTIVES**

The underlying objective of the investigation is to determine what effects an implementation of barcode or RFID tagging technology would have on the material and information flow regarding the different stages involved in harvesting trees and taking the logs from the forests to the mills.

Interesting factors that special attention is given to are effects on economic efficiency and effects on work processes and handling procedures. The ultimate goal in implementing such information and identification technologies in wood flow systems is to make those systems more efficient, by avoiding costs and losses that occur otherwise.

Effects on handling procedures are interesting to investigate as tagging a log with an RFID device or a barcode for identification differs greatly from today’s process of stamping the wood, which is a time-consuming, messy procedure that has to be carried out manually by the forwarder.

The research will therefore be partly based on the forwarders’ and harvesters’ perspectives as they are the parties that are most concerned by the workability of identification techniques. Once the problems they incur with current procedures have been identified, RFID and barcode systems will be examined and evaluated regarding their capability to solve these problems and at the same time be economical in the overall context of supply chain efficiency.

4. **DESIGN AND APPROACH**

The problem that is dealt with in this report requires the analysis of possible applications of barcode and RFID technology in the system to cover two different areas. Firstly, the application in question needs to be examined in terms of whether it is technically doable and the related practical issues need to be discussed. Requirements concerning feasibility may concern the label material used, the handling and ergonomics involved, etc. Secondly, it must be investigated what requirements a new system would have to meet in terms of cost effectiveness, in other words, it must be evaluated what would make a new system an economical solution. Figure 4.1 shows the relationship between
the two different kinds of requirements that possible solutions need to meet.

![Feasibility Requirements](image1) ![Cost & Efficiency Requirements](image2) ![Possible Solutions](image3)

**Figure 4.1:** influences of requirements

Economic efficiency and feasibility are thus the two areas of requirements that need to be considered when possible solutions are analysed. Ignoring one of them would result in the failure of the research. It does not make sense to investigate the costs and operating efficiency of a system that is technically not possible or that cannot be implemented because of practical restrictions. At the same time, it is meaningless to explore technical solutions to the problem in great depth if it is clear that they would never meet the requirements regarding costs and efficiency.

The investigation necessary to find possible solutions that meet both types of requirements is largely exploratory and empirical. Nevertheless, in order to be able to analyse supply chain efficiency and possible changes along the chain through the implementation of RFID or barcode technologies, a certain theoretical framework needs to be developed and applied.

The first step in the investigation is an examination of SCA’s current wood flow system to get a better understanding of the feasibility requirements that need to be considered. Once the wood flow system is understood a suitable theoretical framework for the upcoming analysis is chosen through the adaptation of popular models used in different fields of business economics. In addition to that, an understanding of RFID and barcode technologies is developed through the review of relevant literature to get a first impression of how these technologies could be implemented in forestry.

Then RFID and barcode systems are explored in greater depth in cooperation with experts in the field of these technologies to determine the workability of those systems in the wood supply chain from a technical point of view. Meanwhile, the cost and efficiency requirements are investigated and discussed. Finally, solutions that match both areas of requirements are designed and explained and the theoretical framework is applied.

**5. INTRODUCING THE WOOD FLOW SYSTEM**

In order to be able to explore possible improvements through the implementation of new technology, an understanding of current procedures in the material flow is required. The following description of the material flow process is based on explanations and clarifications given by Mr. Per-Anders Hedström, Head of Development and Innovation at SCA Skog AB. Figure 5.1 illustrates the different processes involved in harvesting trees and shipping the logs to the corresponding mill.
The starting point of the whole process is a forest area that has been chosen for logging. A harvester is the first handler to work on the site, cutting the trees and leaving a logged area behind. A forwarder then collects all the logs from the ground and transports them to the roadside, building up a pile of logs there. This pile of logs is then fetched and shipped to the corresponding mill by a truck.

All those operations must usually be finished within three to five weeks as wood may not be too old when it arrives at mills for further processing. Only during winter months when the wood quality deteriorates less quickly, wood may lie piled but unprocessed at a logging site for up to 15 weeks. Making sure that wood does not arrive at mills too late is crucial as the quality of finished products cannot be guaranteed if the deterioration of wood fibre has had too much effect on the quality of incoming raw material.

Areas chosen for logging can be quite large so that it may take the harvester several days to complete the logging. Although forwarder and harvester always work in a team, it may be that they do not arrive at the logging site on the same day. Coordinating the work of harvesters, forwarders and truck drivers in such a way that all logs are always picked up and shipped to mills in time is a challenging task. The most common problem in this coordination is that the truck drivers arrive too late to pick up the logs from the piles next to the road.

**Identification and Stamping**

When the logs have been collected from the forest area and brought to the road, it is the forwarder’s task to stamp the wood in the pile. The number stamped on the logs acts as a code that provides information necessary for the further handling of the wood. It identifies the area the logs come from, the corresponding forest owner, and who was in charge of logging the site. Furthermore, the identification number tells how the related payment issues need to be handled.

Once a shipment of logs arrives at the mill, they have to pass through a measuring station where the number that has been stamped on the logs by the forwarder is checked in order to make sure that the truck driver picked up the right wood when he carried out the order that was given to him. This is done by entering the number on the wood into a computerized database that links each identification number to the relevant information concerning logging site and ownership- and payment issues.
Time control information cannot be contained in form of these identification numbers. Time is managed by keeping track of the starting and finishing point of the harvesters’ and forwarders’ work.

Judging the process of stamping the wood regarding practicality issues reveals poor workability. The identification numbers have to be stamped in red paint by hand, which makes the procedure time consuming and messy. As a rule, at least 20 percent of all logs in a pile need to be stamped by the forwarder but in practise it is hard to choose those 20 percent of logs in such a way that they are evenly distributed in the pile.

An even distribution is of importance because one pile of logs does not necessarily equal one truck load of logs. Sometimes several truck loads are needed to process one pile of logs, so that in the first shipment only the top part of a log pile may be taken to the mills. However, the problem is that the forwarder pilot may find it hard to reach out to the top of the wood pile to stamp some of the top logs because the pile may simply be too high. Thus, more logs will be stamped in the lower part of the pile than in the upper one, so that only few logs that arrive at the mill early will carry identification numbers.

Today, there hardly exists any better alternative to the procedure of stamping the wood. Sometimes paper tags are used to mark woodpiles but there are several problems related to that practise. First of all, paper tags are less weather resistant than numbers stamped directly on the wood. They are easily destroyed or carried away by rain, snow, wind, etc.

Secondly, it is much easier to sabotage the identification of the wood. If somebody wanted to steal wood from a pile where paper tags have been used, all that person would have to do is to rip off the paper and take the unmarked wood away. Stamped numbers do not offer complete protection against theft but to remove the marking on the log one would have to saw off the part of the log that has been stamped, which involves a little more effort than in the case of paper tags.

During the analysis of this supply chain it is important to keep in mind that not all stages are carried out by SCA directly. There are multiple parties involved in this process as the workers on the logging sites and the truck drivers are usually employees of companies that are contractors to SCA. If possible changes along the supply chain are considered the question of how the related costs should be split amongst the different parties will automatically arise and must be dealt with.

6. INTRODUCING RFID AND BARCODE TECHNOLOGIES

6.1 RFID

RFID is a special form of automatic identification that is defined as follows:

Radio frequency identification, or RFID, is a generic term for technologies that use radio waves to automatically identify people or objects. There are several methods of identification, but the most common is to store a serial number that identifies a person or object, and perhaps other information, on a microchip that is attached to an antenna (the chip and the antenna together are called an RFID transponder or an RFID tag). The antenna enables the chip to transmit the identification information to a reader. The reader converts the radio waves reflected back from the RFID tag into digital information that can then be passed on to computers that can make use of it. (www.rfidjournal.com)
RFID systems can vary greatly from each other in terms of the specific technology utilized, the transmission frequency used, and their range.

**Types of tags:**

Tags may be active or passive, depending on whether or not they carry a battery. So-called passive tags do not carry one and are only activated once they receive a signal from the radio magnetic field created by the reader. Active tags do carry a battery and thus have an energy source of their own that enables them to send stronger signals and have longer ranges than passive tags. The drawback of active tags is that the battery attached to them shortens their life time significantly. Whereas passive tags have no set boundary to their life time and simply operate as long as they remain undamaged, active tags are restricted to a life time of 5 – 10 years, depending on the capacity of their battery. (Engberg, Forsman, Johansson in Öhman, Zetterlund 2004, p. 17)

In addition to the differentiation based on whether or not they carry batteries, tags may be characterized as being of an RO (read-only) or an RW (read-write) kind. There also exist tags that can be described as having a “write once – read many” feature. (ibidem)

RO tags already carry a serial number and are pre-programmed by the manufacturer. When they are to be utilized, a central database is required where the information that corresponds to the different item numbers on the tags is stored. “Write once – read many” tags are blank when they are delivered so that they may be programmed and customized according to the requirements of their purpose in an organisation. Data may be stored on these tags once and read an unlimited number of times thereafter. As data can be stored directly on the tags, a central database is not necessarily required and the information infrastructure can be decentralized. A typical storage capacity for such kind of tags is 2 KB. (ibidem)

RW tags are re-writable, meaning that the data stored on the tag may be modified at all times. As those tags are the most sophisticated, they are also the most expensive of the three varieties. (ibidem)

**Tag housing:**

RFID tags can be put into different housings depending on the requirements of the environment in which they are supposed to operate. One of the most common design formats of tags is the so-called coin or disk, which is a round housing with a hole for a fastening screw in the middle. Coins can be as small as a few mm and do usually not exceed 10 cm in diameter. (Finkenzeller 2003, p.13)

For animal tagging glass housings have been developed that can be injected under the skin of the animal. The microchip they contain is embedded in a soft adhesive to ensure that the needed mechanical stability is achieved (Finkenzeller 2003, p. 14). Plastic housings are utilized when great tolerance to mechanical vibrations and temperature fluctuations is required. The can easily be integrated into other products and have a greater functional range than glass housings (ibidem).

Another possible carrier for an RFID chip is a paper or plastic foil, which is utilized for so-called smart labels. Those smart labels are paper thin and supplied as self-adhesive stickers on rolls. Their great flexibility makes them ideal for luggage tagging and identification in air transportation (Finkenzeller 2003, p. 19).

Other formats of RFID tag housings include key rings for access control systems and plastic cards in credit card format often used for customer identification and automatic fare collection in public transportation.
Frequencies:

In order to make the transmission of data possible, both RFID tag and reader must be tuned to the same wave frequency. Most RFID systems operate on low frequency (around 125 KHz), high frequency (13.56 MHz) and ultra-high frequency UHF (860-960 MHz). Microwave (2.45 GHz) is less common. (www.rfidjournal.com)

The frequency chosen for an RFID system is of importance because it influences a number of other features that determine the performance of the tag as the following paragraph indicates.

Different frequencies have different characteristics that make them more useful for different applications. For instance, low-frequency tags use less power and are better able to penetrate non-metallic substances. They are ideal for scanning objects with high-water content, such as fruit, but their read range is limited to less than a foot (0.33 metre). High-frequency tags work better on objects made of metal and they can work around goods with high water content. They have a maximum read range of about three feet (1 metre). UHF frequencies typically offer better range and can transfer data faster than low- and high-frequencies. But they use more power and are less likely to pass through materials. And because they tend to be more “directed,” they require a clear path between the tag and reader. UHF tags might be better for scanning boxes of goods as they pass through a dock door into a warehouse. (www.rfidjournal.com)

Applications:

Today, the most common applications of RFID technology include payment systems (e.g. toll collection systems), access control and object tracking (ibidem). Companies have also begun to implement RFID systems in their supply chain and work-in-process mechanisms. Most of these systems remain closed systems today, due to the fact that RFID tags are still quite expensive. Therefore, an open system where tags would be disposed instead of reused is hardly affordable in most cases.

It is difficult to state the per-unit cost of RFID tags because prices not only depends on the specific type of tag in question but also on the volume ordered. Roughly, prices usually vary between US-$0.20 and US-$0.40 for simple RO tags, whereas RW tags may cost as much as US-$100. Prices are expected to continue dropping significantly in coming years. Common expectations are that in a few years RO tags will cost no more than US-$0.05 (www.rfidjournal.com).

Apart from the price factor there is one other feature of RFID tags that has limited and restricted their applications in the business world, which is their sensitivity to metal. Depending on the frequency used, metal objects can influence and disturb the electromagnetic field needed to transmit information from the tag to the reader. As many of today’s manufacturing processes still take place in a very metalliferous environment, some RFID systems have proven to be unreliable and unfit to perform under these circumstances.

In addition to that, standards for RFID technology are still being developed and have not yet been properly established so that an organisation that implements RFID today risks to not comply with future standards anymore once they are agreed upon, which would inevitably result in adaptation costs.
**General Selection Criteria:**

Finkenzeller, p. 26 (2003) lists four criteria that can be used to select an RFID system that best fits the requirements of the organization that implements it. Firstly, one has to decide which operating frequency to apply. This feature is important because it determines how sensitive the system will be to the influence of metal objects in its electromagnetic field. Systems operating on microwaves are the least sensitive and have successfully been utilized in production lines and painting systems of the automotive industry.

In addition to that, one needs to determine the best range for the system that is to be implemented. The needed range depends on the positional accuracy of the tag and if read-only tags are used, it also determines the minimum required distance between a tagged object that enters the interrogation zone and the following object. If RO tags, which usually operate on high frequency are utilized, it must be assured that only one object at a time enters the interrogation zone of the reader as multiple simultaneous signals by more than one tag would interfere with each other and could no longer be processed by the reader.

Microwave systems differ from other frequencies regarding this issue as their signal is directional while the signal of the other possible frequencies spreads in all directions. Consequently, the interrogation zone of the reader can be narrowed but needs to be designed with more precision in the case of a microwave system.

The third criteria that needs to be investigated when deciding what sort of RFID technology to implement is the degree and importance of security requirements. They determine how much security logic and authentication procedures should be incorporated in the system.

The last criteria for the selection of an adequate RFID system is the requirement regarding memory capacity. Depending on the application and purpose of the system that can vary greatly and as the memory capacity of the tag is a major factor influencing the price level, it is important to precisely determine the needed memory capacity and not overestimate it, which would result in unnecessary costs.

**6.2 Barcode**

Barcodes are a very common technology that has been widely implemented across various industries for item identification. Barcode systems consist of a paper tag with black, vertical stripes of different width (the actual bar code) and a scanning device, which needs to be connected to a computer system. The transmission of data is initiated by a light signal send from the scanner to the tag. The stripes of the barcode reflect the light in a unique way, which enables the scanner to translate the reflected signal into a specific binary code that can be interpreted by the computer. (Lumsden in Öhman, Zetterlund 2004, p.15)

To scan a barcode different types of light can be used. Some systems use simple red light, others operate with infra-red or laser light. In all cases, barcode technology requires free sight between the tag and the scanner. Furthermore, the barcode needs to be clearly visible and undamaged. If the stripes on the tag are covered with too much dirt or dust, the light signal cannot be reflected properly anymore and the barcode cannot be read.

There are numerous different barcode formats that differ in the number of stripes, the way the data is coded by the stripes, whether they only represent digits or also letters, and their areas of
application. The EAN (European Numbering Association) code is the most common of them. It was created specifically for the grocery industry and is made up of 13 digits. They identify the country of origin of the product, the corresponding company and feature the manufacturer’s item number and a check digit.

Code Codabar is a barcode format that consists of numbers and letters. It was designed to suit medical and clinical applications with high safety requirements. Code 2/5 interleaved is a format implemented in the automotive industry, goods storage, pallets, shipping containers and heavy industry. The processing industry, universities and libraries usually use a different format, which is called Code 39. (Finkenzeller 2003)

6.3 Comparison

Finkenzeller, p. 8 (2003) shows a table that compares the features of different identification systems, among them RFID and barcode. An adapted version of the table is presented below.

<table>
<thead>
<tr>
<th>System parameters</th>
<th>Barcode</th>
<th>RFID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical data quantity (bytes)</td>
<td>1-100</td>
<td>16-64k</td>
</tr>
<tr>
<td>Data density</td>
<td>Low</td>
<td>Very high</td>
</tr>
<tr>
<td>Machine readability</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Readability by people</td>
<td>Limited</td>
<td>Impossible</td>
</tr>
<tr>
<td>Influence of dirt/damp</td>
<td>Very high</td>
<td>No influence</td>
</tr>
<tr>
<td>Influence of (opt.) covering</td>
<td>Total failure</td>
<td>No influence</td>
</tr>
<tr>
<td>Influence of direction and position</td>
<td>Low</td>
<td>No influence</td>
</tr>
<tr>
<td>Degradation/wear</td>
<td>Limited</td>
<td>No influence</td>
</tr>
<tr>
<td>Purchase cost/reading electronics</td>
<td>Very low</td>
<td>Medium</td>
</tr>
<tr>
<td>Operating costs (e.g. printer)</td>
<td>Low</td>
<td>None</td>
</tr>
<tr>
<td>Unauthorised copying/modification</td>
<td>Slight</td>
<td>Impossible</td>
</tr>
<tr>
<td>Reading speed (including handling of data carrier)</td>
<td>Low ~4s</td>
<td>Very fast ~0.5s</td>
</tr>
<tr>
<td>Maximum distance between data carrier and reader</td>
<td>0-50 cm</td>
<td>0-5 m</td>
</tr>
</tbody>
</table>

Relating the listed features to the requirements of the forestry industry, one can identify several differences that are important to keep in mind. The fact that RFID systems are capable of storing much more data than barcodes is one of them. If RFID technology was implemented, one could enhance the knowledge about the tagged log by storing more data on the attached microchip than a simple identification number.

Another difference that is of significance is the fact that RFID systems cannot be read by people, while barcodes always feature actual numbers that are visual and can be read. Consequently, in case there is a system failure of the reading device, a barcode can be processed manually but an RFID tag cannot. An RFID-tagged item cannot be identified by people and the system failure of the reading device would therefore have more severe consequences in the case of RFID technology than in case of barcodes.
A disadvantage of barcodes in comparison with RFID systems is their sensitivity to dirt and optical covering. While optical covering and exposure to dirt has no influence on the readability of RFID tags, it has severe consequences for barcodes. As indicated earlier, once free sight between the reader and the code is no longer given or the stripes of the code are covered with too much dirt, barcodes can no longer be read. This disadvantage may have a grave impact on the decision what technology to implement in forestry where harsh environments (exposure to weather and heavy machinery) are unavoidable.

Costs are another factor that inevitably has an influence on such a decision. While the purchasing costs of RFID systems are much higher than those of barcodes, the latter have the drawback of having certain operating costs, once the system is implemented. Barcodes need to be newly printed whereas in a closed system, a certain number of RFID tags may be used an unlimited number of times.

Furthermore, RFID systems have clear advantages regarding reading speed and reach. They can be read in a split-second, which offers great potential to speed up the measuring process at the mill if it could be automated. The fact that depending on the frequency of the RFID systems, their reach can be up to 10 times longer than that of barcodes may facilitate the reading process as less precision is required by the reader.

7. THEORETICAL FRAMEWORK

7.1. The A-R-A Model

To better understand and analyse the different dimensions of the problem investigated, the so-called A-R-A Model is utilized. This model is usually applied in the context of industrial networks but also helps in this case to capture the different aspects of the subject of this investigation separately.

The model, developed by Håkansson/Johanson in Ford, p. 145 (2002) argues that in each network there are interrelated actors, resources and activities. Actors are defined as those parties who have control over resources and have the capacity to undertake activities. They may be individuals, groups of individuals, firms, groups of firms, cooperations, etc.

Five characteristics are pointed out that define an actor. Actors always have control over and undertake activities (1). Consequently, they have relationships with each other based on the related exchange processes (2). Their activities result from a control over certain resources, which may be direct or indirect (3). Direct control is based on ownership whereas indirect control is obtained through relationships with other actors. In addition to that, actors are goal-oriented (4) and have different knowledge about the activities, actors, and resources in their network (5).

An activity is defined as the combination, development, exchange or creation of resources through the utilization of other resources. The model acknowledges two different kinds of such activities, namely transformation activities and transfer activities. Transformation activities occur when resources are changed and processed. They are always carried out under the direct control of one actor. Transfer activities take place when control over a resource changes from one actor to the other.

Resources cannot be narrowly defined or specified as they exist in unlimited kinds and variations. The ultimate goal in a network is to achieve added value through the processing and the combination of the resources controlled by the different actors. Resources may thus be characterised by their
corresponding actor controlling them and the way they are utilized in activities. The degree to which they are standardized or unique is another characteristic used to describe resources.

Applying this framework to the wood supply chain already described, one can identify four different kinds of actors in the process, namely harvesters, forwarders, truck drivers and the operators of the measuring stations at the mill. The resource they are primarily dealing with is the wood they are handling. It is important to notice that none of the parties mentioned obtains direct control over the resources they process as ownership is never transferred to any of them.

Five separate activities can be identified in the wood flow as described in chapter 4. Namely they are the cutting of the trees (1), the collection and piling of the logs (2), the stamping of the wood (3), the shipment to the mill (4), and the measuring and controlling at the mill (5). Two of these activities (2 & 3) need to be carried out by the same actor, the forwarder pilot. For further characterisation of the activities involved, one needs to notice that they are all transformation activities. At no point in the supply chain is direct control (i.e. ownership) of the resource in question (i.e. the wood) transferred from one actor to the other.

The information that is stored in form of the identification number stamped on the logs may be regarded as an additional resource necessary to complement the primary one. A complete list of variables in this A-R-A Model would look as follows:

- **Actors:** harvesters, forwarders, truck drivers, measuring station operators
- **Resources:** wood, information
- **Activities:** cutting the trees, forwarding & piling of logs, stamping of logs, shipment, measurement and control

If the related technology was changed and one would switch from the utilization of stamps to barcode or RFID technology that would have effects on all three variables of the A-R-A Model.

It would affect the activities carried out at least partly because the procedure of stamping the wood would be substituted with a different activity. Consequently, it would affect the actors as the division of labour amongst them may have to be restructured or new specialized workforce may need to be employed. The resources would be affected through more sophisticated information storage and transmission capacity related to the new technology implemented.

Because the focus of this research is to explore possibilities for changing the identification-related procedures, it makes sense to adapt the A-R-A Model in such a way that it only focuses on the transmission and transfer of information along the chain. Such an adapted model would have the following variables:

- **Actors:** harvesters, forwarders, truck drivers, measuring station operators
- **Resources:** information
- **Activities:** stamping, checking of numbers, accounting for incoming wood

Excluding everything related to the core purpose of the chain, which is the transfer of the wood, allows the analysis to concentrate on the information network that exists to facilitate and assist the core purpose of the procedure. Understanding this information network and related requirements is necessary to be able to judge possible changes and improvements through the implementation of RFID or barcode technology.
However, it must be kept in mind at all times that the sole purpose of this information network is to serve and facilitate the wood flow. Each possible change in the information network must be evaluated regarding its potential to meet that purpose.

The basic benefit of applying the A-R-A Model on this case is that it facilitates the analysis and makes it possible to study the effects of the introduction of new technology on actors, resources and activities separately.

7.2 Information Network Mapping

There are two dimensions to understanding the information network that exists along the wood supply chain. The first dimension consists of comprehending the basic information needs that each party involved in the supply chain has. Those needs may differ along the chain as the tasks of harvesters, forwarders, etc. also differ from each other and the needed information is closely linked to the task carried out by the operator in question. Figure 7.1 illustrates the information need (IN) situation along the wood supply chain.

![Figure 7.1: Information needs](image)

Once the information needs of all actors have been clarified, one can move on to the next dimension of understanding the network, which deals with the question of how the identified needs are actually served. Naturally, the information required by each party along the chain can only be obtained through some sort of exchange of information amongst the actors involved. Thus, each actor can be assigned a certain information inflow (II) and a certain information outflow (IO). To coordinate these information flows, a central database is utilized and needs to be added to the picture. A complete sketch of a possible information flow system is shown in figure 7.2.

![Figure 7.2: Information inflow and outflow](image)

Understanding the information flow that takes place amongst the different parties (i.e. all the operators and the database) is essential for exploring possible improvements in the information network through the implementation of better identification technology.
7.3 Value-Adding Time vs. Non-Value-Adding Time

A key concept to evaluating the economic efficiency in a supply chain is the differentiation between value-adding time and non-value-adding time, introduced by Christopher, p. 110 (1998). In this model value-adding time is defined as time that is spent on an activity that adds directly to the customer value of the product. Manufacturing is clearly one of those activities, but value-adding time also includes the shipment of material and other “means of creating the exchange” (Christopher, p. 110). Non-value-adding time is “time spent on an activity whose elimination would lead to no reduction of benefit to the customer. Some non-value-adding activities are necessary because of the current design of our process but they still represent a cost and should be minimized.” (ibidem)

According to Christopher, p. 113, efficiency in a supply chain can therefore be expressed through the following function:

\[
\text{Efficiency} = \left( \frac{\text{Value added time}}{\text{End-to-end pipeline time}} \right) \times 100
\]

Once the whole supply chain has been examined in terms of value-adding and non-value-adding time, specific changes may be undertaken to reengineer the processes in such a way that non-value-adding time is minimized. A graph that shows the addition of value and the addition of costs through the different stages of the chain helps identify how much time is spent on value-adding activities and how much time is taken by non-value-adding activities.

Figure 7.3 shows such a sketch for the wood supply chain until the point at which actual processing at the mill sets in. Numbers in the sketch are used to label activities while letters mark the different stages between those activities when no process takes place. Because of the time value of money, cost is added even during those stages when material lies idle.

![Cost and value allocation along the chain](image-url)
Legend:
1: trees are cut by harvester
A: logs lie on the site
2: logs are collected and piled by forwarder
3: logs are stamped by forwarder
B: logs lie piled next to the road
4: logs are collected by truck
5: logs are checked and measured at the mill

The graph reveals that stamping the logs once they have been collected by the forwarder (activity 3) and the measurement at the mill (activity 5) are the only activities in the chain that do not add to the customer value of the product. However, the identification of logs is absolutely necessary so that these activities cannot be eliminated completely. The identification of logs as such naturally does not add any value to the product, but its purpose is to improve the coordination of the value-adding activities.

Therefore the focus in reengineering these processes of identification should not only be on how to minimize the costs associated to them but needs to include the question of how to maximize the benefit that proper identification and tracking technology can bring regarding the other processes in the chain. If through the implementation of better identification technology the coordination of the harvesters’, forwarders’ and truck drivers’ operations could be optimized, fewer wood would be lost, time control would be facilitated and the ratio between cost-adding and value-adding time could be improved as the chain becomes more efficient.

8. RESEARCH METHOD

The main method of information gathering and field research in this investigation was interviewing. There are two major areas of knowledge that need to be covered in this research and interviewing proved to be the most suitable method to explore them. Namely, these areas are knowledge about working processes and information flows at SCA and knowledge about how RFID or barcode technologies may be used to fit them.

In order to achieve an understanding of the current procedures along SCA’s supply chain and get to know different perspectives on SCA’s problem, several meetings were held with representatives of both SCA Skog and SCA Graphic Research. Notes were taken during and after these meetings to capture the results of these discussions. Furthermore, a field trip was undertaken to learn more about the perspectives of the handlers involved in processing the wood and to examine the whole supply chain from logging sites to measuring stations. Semi-structured interviews were conducted with harvesters, forwarders, truck drivers and measuring station operators. The open questions posed were designed to understand their point of view regarding the subject of this study and identify the most problematic stages in the current wood handling and information processing procedures. The answers given to the questions were noted down during or after the conversations that took place directly in the working environment of the interviewee.

In addition to the interviews, the handlers’ work process was visually observed during that trip to get a first-hand impression of the handlers’ tasks and their working environment, which was necessary to understand the practical requirements that RFID and barcode technologies would have to meet if they were to be implemented.
In interviews and discussions with experts on barcode and RFID technology the capability of barcodes and RFID to meet these specific requirements was then determined. As there is little prior study on possible implementations of the above-mentioned technologies in this specific context, interviewing people with relevant knowledge was the only way to find out how RFID or barcode systems could be tailored to fit SCA’s current process design.

In two cases, discussions were held directly with experts at Mittuniversititet to explore this area of the investigation and the results of both conversations were noted down. Representatives of the Technical Department of Mittuniversititet also provided further contacts and suggested other interviewees who were then contacted by telephone. These interviewees mostly represented companies and organisations in the barcode or RFID business who were contacted to learn more about prices and technical specifications of different systems. Structured interviews were prepared for these telephone conversations and notes were taken during the course of the interviews.

In addition to interviewing contacts suggested by experts at Mittuniversititetet, an internet research was undertaken to find RFID and barcode companies and contacts worldwide. Standardized emails were sent to several people at companies from many different countries (e.g. Italy, USA, India) to ask them specific questions on system prices and properties. The underlying motive for asking many different people about the same subject instead of being satisfied with just one answer was the desire to achieve maximum validity and reliability of the provided information.

9. ANALYSIS OF THE CURRENT INFORMATION NETWORK

9.1 Mapping the Information Network

The following description of SCA’s information network is based on the semi-structured interviews that were conducted with different actors along the chain during the trip undertaken with Mr. Per-Anders Hedström to observe the handling procedures and get a better, first-hand understanding of the practical issues related to the subject of this report. Special attention during the interviews and observations was given to the following questions:

- What are the actors information needs?
- How much time do they need to dedicate to the transmission of information (which always is a non-value adding activity) and what means of transmission do they use?
- How reliable are the current procedures?
- What are problems the interviewee may incur with these procedures?

An examination of information needs revealed that they do not vary greatly between the actors involved. In order to be able to perform their task harvesters and forwarders simply need to know the location of the site that they are assigned and when they are supposed to start the logging procedure. In addition to that, they need to know whether that site is chosen for a complete logging or for thinning. The truck drivers need to know the location of the site at which log piles are ready for being picked up and they need to know what mill these logs are supposed to be shipped to. The operators of the measuring station also need to be able to identify the area the wood on the truck they are examining comes from.

Figure 9.1 shows a map of the information network in SCA’s wood supply chain as it exists today. The links between the different actors represent the transmission of information while the arrows indicate the direction in which the information travels.
The 1st stage in the process (1) is a dialogue between SCA’s different industries and the organisation’s forest management and transport division. This dialogue’s purpose is to determine how the industries’ demand can be matched with possible supply. Once a decision is reached, the production manager, who is in charge of coordinating different logging teams, sends orders (traktdirektiv) to the harvesters and forwarders (2) who always operate in teams.

These orders feature, amongst other specifications, a number by which the site that has been chosen for logging can be identified. All forest areas carry such a number which is shown on the maps the harvesters and forwarders use to allocate the site they have been assigned. Once they have arrived at the area, they begin processing the trees. Mistakes are very rare at this stage. Only two or three times a year the wrong site is logged because identification numbers have not been read carefully enough or maps have been interpreted incorrectly. If this happens, it is mostly a site next to the correct one that is logged by mistake.

While the harvester is operating, a processing file is developed in a computer system linked to the harvesting machinery. Data entered into this processing file includes the quality category of each tree that is cut, its type (e.g. fir, pine), its diameter, the time when it was harvested and the length of the logs that were cut from it. The procedure of entering these data into the processing file of the computer system is semi-automatic as some of the measurements are done by the machine itself while other parameters like the tree type must be determined manually. However, this does not slow down the process of logging as the operator of the harvesting machine simply needs to press a button on his handling stick to choose a new tree type or quality category while he approaches the next tree he intends to cut. Thus, no non-value-adding time is spent on this activity of creating the processing file.

The stamping of the wood (3) is done by the forwarder once he has collected and piled the logs. Each forwarder carries a box, containing an ink-pad and a core to which different number plates can be attached. The forwarder looks up the site identification number and copies it to the core by attaching the number plates accordingly. Then he uses the core and ink-pad to stamp the logs he has piled. There are two rules that he has to comply with in doing so. Firstly, 20 percent of all the logs in

**Figure 9.1:** The actual information network
the pile need to be stamped. Secondly, the distribution of stamps must be done in such a way that there is one stamp per square metre of the pile’s cross section. The second rule is relevant because one pile of logs does scarcely equal one truck load of logs. An equal distribution across the pile ensures that no matter how many times the truck needs to be loaded again to process the whole pile, each truck load will carry some of the marked logs.

The process of stamping the wood is the most time consuming one in the information network. Depending on the conditions of the working environment (weather, lightness, etc) and the size of the pile that needs to be stamped it takes the forwarder about 10 to 20 minutes to complete the task. The most significant problem with the stamping procedure is the paint it involves. Having to attach the right numbers to the core and then use the ink pad to stamp the paint on the wood always leaves the forwarder’s hands and clothes stained. This is particularly agonizing because the red paint used for the wood stamping is very sticky and difficult to get rid of, once it has touched skin or fibre.

Once a day harvesters and forwarders send reports on the progress of their work to the production manager and transport manager (4). The harvester’s report contains the processing file that has been developed during his work, which is then used to update the computer systems of the above-mentioned managers. Filing these reports only takes a couple of minutes as the procedure is almost fully computerized.

The transport manager relies on the topicality of the information provided by his computer system as he is in charge of coordinating the transportation of logs from logging sites to mills. When harvesters and forwarders have worked on a site, the transport manager issues orders to the truck drivers, instructing them to pick up the wood (5). The order files handed out to the truck drivers feature, amongst other specifications, the site identification number that has been used by harvesters and forwarders to allocate the area and that the forwarder has stamped on the log piles. In fact, the instruction file given to truck drivers shows this identification number in visible digits and in barcode format but the barcode is not utilized in the current process design. Once the truck driver arrives at the log pile, he checks whether the number on his order matches the number on the logs and starts shipping the logs to the mill.

When the truck arrives at the measuring station it is investigated by the measuring station operators (6). The measuring station mainly consists of a ramp that acts like a weighing machine. It determines the weight of the truck that is positioned on the ramp, which is important because the truck drivers payment is linked to the total weight of the freight he has processed. Thus, empty trucks are weighed when they leave the mill and weighed again once they return with their freight.

In addition to the weighing of trucks there are several other procedures that take place at the measuring station. Once the truck has arrived, the measuring station operator takes a brief look at the freight and stamp on the wood. Because of his experience a quick glance at the freight already tells him whether the log size is right and the quality of the wood is good enough. The truck driver then hands his order file to the measuring station operator who manually enters the logging site identification number into his computer system to record the arrival of the wood from that site and gives the order file back to the driver. Normally, it takes the measuring station operator less than 5 minutes to process an incoming truck. False recording is rare but sometimes the procedure is prolonged because the truck driver first hands the wrong order file to the operator, so that the numbers on the logs and the number on the order do not match. He then has to go back to his truck and find the right order file among his papers. When the entry has been made into the measuring
station’s computer system, the entered data is used to update the production manager’s and transport
manager’s systems and to account for the incoming wood (7).

In regular intervals samples from the incoming wood are taken at the measuring station for further
examination. These intervals differ between saw mills and pulp mills. At saw mills, the measuring
station operator takes a foot rule and measures the length and diameter of a log on every 18th truck.
Out of this sample every 20th stack of logs is selected for a sub-sample that is set aside for more closer
investigations regarding age and quality of wood. The sampling and examination of wood is an
important way for the independent measurement and forestry control authority to check whether or
not the forestry companies comply with the set rules specifying what wood can be cut and utilized.

At paper mills, the procedures as such do not differ from those at the saw mills, but the required
intervals for the sampling are different. At paper mills, a log on every 50th truck is measured by the
operator and out of this sample every 5th stack is taken for the sub-sample. Either way, only stamped
wood can be selected for the samples because investigating the logs without being able to trace back
where they came from and when they were logged makes little sense.

All in all the conclusions from the field trip through the wood supply chain are that the current
information flow system is quite efficient with little possibilities for errors or mistakes to occur. As the
computer systems utilized are regularly updated by incoming reports and information from other
actors, it is ensured that all parties along the chain have the information they need to perform their
tasks. The single most time consuming non-value-adding activity along the information chain is the
process of stamping the wood. It is also the most problematic of the activities because of the dirtiness
involved. Thus it definitely makes sense to explore possibilities to reengineer this assignment to make
it less messy and more efficient, while other procedures along the chain have a lesser need of
improvement.

In order to examine possible changes in the network that could occur if the stamping was
substituted, it is useful to apply the A-R-A Model again at this point and make it represent the whole
picture of the information network map. Doing so results in the following list:

**Actors:**
- SCA Industries, Production Manager, Transport Manager, Harvesters, Forwarders,
  Truck Drivers, Measuring Station Operators

**Resources:**
- Information

**Activities:**
- steps 1 through 7

### 9.2 Interest in Additional Information

As was indicated previously, the actors along the information network have little need for
enhanced information. They are provided with all they need to know to perform their tasks relating to
the material flow from logging sites to mills. However, at SCA’s industries, there is a general interest
to expand the knowledge about incoming wood from the forests.

The reason is that the processing of wood fibre for the manufacturing of paper and paper-
resembling products involves a variety of chemicals that are a major cost driver in production. The
amount of chemicals that needs to be used to achieve the desired effect depends on parameters like
the age, assortment and type, quality category and other properties of the incoming wood. If it was
possible to adjust the amount of chemicals needed to the specific characteristics of the next batch
awaiting processing, one would be able to make more efficient and economical use of these chemicals,
which would result in actual cost savings. Therefore, it would generally be appreciated if the marking of logs not only consisted of an identification number but if it was possible to store and retrieve additional information on the stack that is marked.

The problem with analysing this aspect in depth is the difficulty to precisely express the possible incremental economic benefit that could be achieved through obtaining additional information on incoming wood. Possibly, the additional economic benefit that could be realized would justify the implementation of a log marking system that is much more costly than stamping but as long as no exact projection of expected cost savings exists, this is hard to judge.

In addition to that, the desire to know more about the incoming wood does not match the actual capabilities of the process design at the mills as it exists today. Even if one could collect much additional data by substituting the stamping with another technology, one could not yet turn that into any economic benefit because the processes at saw and pulp mills are currently unfit to make use of this additional information. They are not designed to have a more precise treatment of incoming material that is fine-tuned to the specific properties of the next batch.

Reengineering the processes at mills to allow for additional information to be of any benefit would require huge investments in new machinery. Consequently, when thinking about possible economic benefits from more sophisticated identification and marking technology, one has to take into account that they will not occur in the short term but possibly in 5 to 20 years, when processes at the mills have been reengineered and modernized accordingly.

10. COST AND EFFICIENCY REQUIREMENTS

10.1 The current Costs of Stamping

In order to be able to understand the cost-related requirements of alternatives to the stamping procedure one must first know what the costs of marking the logs are as it is done today. From this knowledge conclusions can be drawn regarding whether or not possible alternatives would or would not be more cost effective.

The material needed for the stamping of wood logs (core, stamps and paint) is very cheap. Consequently, the cost of stamping the wood consists almost entirely of personnel costs. The forwarders who are in charge of the stamping have a wage level of about SEK 250 per hour. (With the current exchange rate of about SEK 7.3 per US-$ that equals costs of US-$ 34.) The stamping procedure usually takes about 3 percent of the total working time of a forwarder, so when calculated on an hourly basis, the stamping costs about SEK 7.50 (250*0.03) or US-$ 1.03. If seen as a single event that takes 10 – 20 minutes, the costs of one stamping procedure may be expressed as being between SEK 42 and SEK 84 (250*1/6, 250*2/6), which equals US-$ 5.75 to US-$ 11.50.

Harvester and forwarder operators work in two shifts a day and in an ideal situation, the stamping of logs is done when the forwarder machine’s operators switch. The one who gets off the machine stamps the pile that has been collected while his colleague keeps the forwarder machine operating and goes on with collecting the logs. But this smooth and efficient division of labour is not always possible. In 40 percent of all cases, the forwarder operator currently working on his shift has to take care of the stamping of logs. While he is busy stamping the wood, the operator machine has to be stopped and lies idle. Because of the time value of money this idle time needs to be taken into consideration, too, when discussing the costs associated to log stamping.
When evaluating the costs of a log identification system it must be kept in mind that the actual marking procedure is not the only cost-adding activity that is linked to the identification. Reading and administrating the information are other cost drivers that should not be ignored. However, the marking procedure is the most cost-adding of all identification-related activities. When trucks have carried logs to the mills and incoming log loads are registered at the measuring station, the measuring station operators’ task, which usually only takes five minutes to complete does not only consist of checking the identification numbers on the logs. They also visually check the truck load of logs for any nuisances regarding quality and log size.

The visual checking of truck loads is a procedure that cannot be substituted by a newly implemented identification system. Thus, little would change regarding the costs of the processes at the measuring station, even if a new marking system was in operation, given that reading the marking would not take longer than it does today.

### 10.2 Cost Restrictions for future Systems

In the evaluation of cost differences between present procedures and possible future systems, the incremental operational costs are the most decisive parameter. The initial investment needed to implement a new system is a once-only outlay and a return on this investment will sooner or later be realized when the system has been implemented, given that it is economical regarding day-to-day operations.

It is reasonable to assume that the utilization of more sophisticated identification technology will inevitably result in somewhat higher costs. Therefore, it is crucial to know how much additional costs SCA would be willing to tolerate for a better identification system. The company has stated that if a feasible system was found that could be upgraded to allow more information on incoming wood to be retrieved from the identification tags or labels once the company can make use of it, the system’s operating costs may be doubled. If an alternative to stamping proves to be feasible but does not include the possibility of enhancing the retrieved information by upgrading the system, future system costs should not be significantly higher than the current ones.

Any possible solutions to the problem must thus be examined in terms of whether they will be able to meet these restrictions once they are in operation.

### 10.3 Relationship between Costs and Reliability of Systems

One of the key issues in determining efficiency requirements for future systems is the question of how much reading failure and loss of markings the system can tolerate while remaining operational and economical. Regardless of the type of technology utilized, a certain percentage of markings will always be lost. Because this concerns both barcode and RFID technologies, the term “identification unit” will be used in the following section to refer to tags or labels that may be in barcode format or utilize RFID technology.

In an open system where each new marking is done with a new identification unit, this simply results in the costs linked to one marking being unreadable. If the percentage of lost markings remains very low, these costs do not need to be considered because 20 percent of all logs arriving at factories and mills carry markings. Thus, even if 5 to 10 percent of them are damaged it will not be difficult or time consuming for the one reading the identification unit at the measuring station to find a marking in the stack that is readable.
However, in a closed system where a limited number of identification units circulates, the percentage of lost markings determines the amount of replacement costs that are incurred as new labels or tags are bought to replace the damaged ones. The yearly replacement costs in a closed system are influenced by several factors. One of them is the scale of implementation as the total number of identification units in the system has an influence on the absolute number of lost markings. That absolute number of lost markings per year can be found by multiplying the amount of units in the system with a certain failure ratio that expresses lost markings per year as a percentage of total markings. Finally, the price of one individual identification unit needs to be taken into account as it influences total replacement costs directly.

The following formula shows the above-explained relationship between these different parameters.

\[
\text{Total yearly replacement costs} = \text{no. of identification units in the system} \times \text{yearly failure ratio} \times \text{identification unit price}
\]

In a simple example that includes a system with one million identification units, a yearly failure ratio of 10 percent and a tag/label price of US-$0.25, the calculation of total yearly replacement costs yields the following:

\[
1,000,000 \times 0.1 \times 0.25 = 25,000
\]

Total yearly replacement costs would thus be US-$25,000.

It must be understood that there is a non-proportional relationship between the price of one individual identification unit and the failure ratio. The more reliable the identification unit is required to be, the more expensive it is. A key issue in optimizing a closed system and keeping it as economical as possible will thus be to find the optimum combination of tolerable failure rate and related identification unit price that best fits the desired scale of implementation.

11. FEASIBILITY REQUIREMENTS

For the analysis of alternatives to the stamping of logs it is important to know what practical and technical requirements these alternatives would need to meet to fit SCA’s current process design. Some feasibility requirements concern the handling as such and thus relate to ergonomics, while others concern the restrictions on wood contamination set by the mills and requirements regarding weather resistance and durability.

Handling:

The way the task of marking the logs is currently designed requires that the marking or tagging be done manually, using a hand-held device. There is no automated system or machinery in the process design at the moment that could carry out that task without any human guidance and it is reasonable to assume that integrating such an additional machinery into the current system would be difficult and not cost effective. Instead, the new system should allow for the forwarder to continue making the markings by hand, using a wireless, hand-held marking or tagging device.

The reading of the tags or identification labels should also allow for a portable wireless device to be used. To read the RFID tag or scan the barcode on a label and visually check the incoming truck load, the measuring station operators would have to leave their office, go out to the truck on the ramp and
choose a tagged or labelled log to be read. Therefore the reading or scanning technology he utilizes should be portable and wireless, too.

Wood Contamination:

Processing wood fibre at the mills is a very sensitive procedure that can easily be harmed if the fibre contains too much contamination. Therefore labels and tags used on the wood logs should carry as little objectionable material into the processing as possible. Plastics can not at all be tolerated in the fibre processing procedure, so no plastics should be utilized in the labelling or tagging, unless they can be removed before the wood is processed. Metal is another problematic material that should be avoided but may be approved if only tiny amounts are utilized. In contrast to that, paper is tolerable as a tagging or labelling material as it cannot stand the high temperatures involved in processing the fibre and thus simply vanishes.

Durability and Weather Resistance:

The handling and shipping of logs involves a lot of heavy machinery, which requires the label or tag in question to be very robust and rugged. It would make no sense to use a material on the wood that could not stand the rough handling environment and would easily be damaged by the machinery handling the logs. The label or tag would be required to remain unharmed when logs collide while they are loaded, fall to the ground or cause other sorts of agitation and clashes.

Moreover, the tags or labels would have to be weather resistant enough to remain unharmed if left outdoors, stuck to a log in the forest for up to 15 weeks, which is the time logs may remain unprocessed in winter. During the course of one year, outdoor temperatures the tags or labels would have to stand may vary roughly between −30 and +30°C while weather phenomena include blazing sun, rain, hail, snow, and wind. The label or tag material itself and the material used to attach it to the log would thus have to be fit to stand such hard weather conditions and must be insensitive to the influences of temperature, aridity, humidity and dirt.

12. CURRENT UTILIZATION OF RFID AND BARCODES AT SCA

To learn more about how RFID and barcode technologies have already been implemented in other divisions of SCA and to explore possibilities of drawing valuable conclusions from these previous experiences, an interview with Mr. Peter Eriksson, Logistics Manager at SCA Transforest, was conducted. The questions posed in this telephone interview related to the context of current RFID and barcode utilizations, the characteristics of the RFID system used, the working environment of the tags, the expected benefits from the implementation of these systems as compared to the prior situation, the format used for the barcodes, and the major cost drivers involved.

When asked about the context of RFID utilization in logistics, Mr. Eriksson explained that RFID tags are currently used for the identification of good carriers that are shipped between Sweden, London and Rotterdam. It is a closed system of 1300 tags that were fitted into the outer layer of the carriers in form of small plastic boxes.

The plastic housing of the tags was chosen because the tags need to be protected from possible influences of weather while the good carriers are stored outdoors and await shipment.

As the tags are used in a closed system and only carry the specific identification number of the carrier they are attached to, they are never removed from it but stay on that specific carrier all the
time. Despite the fact that the tags are of the RW type with a data storage capacity of 8kb, they are never reprogrammed once the carrier identification number has been stored on the chip. The operating frequency for this system is 2.45GHz, and thus belongs to the range of microwaves. Although the above-described RFID tags were quite expensive and cost € 80 a piece, the fact that the system is closed and includes only a very limited number of tags makes the utilization of RFID in this context economical.

The expected benefits from the implementation of RFID technology were a reduction in error frequency and a reduction of paper work involved as less printed identification-related files are needed. In principle, these benefits were met and the system proved to be very reliable but other problems arose once the system was in operation. Handling personnel seemed to be reluctant to make use of the new technology and often relapsed to old procedures and routines.

According to Mr. Eriksson, the implementation of the system was rather smooth. The major difficulty was ensuring that the right number was stored on each of the tags that were needed. Shortly after the implementation when the system was in operation, there were a few problems related to two or more tags entering the reader’s interrogation zone at the same time, resulting in a fuzzy signal. After the process design had slightly been changed to solve this issue, reading problems did no longer occur. The major cost drivers of this RFID system were the individual tags that needed to be acquired and the software that was needed in order for the tags to be read and interpreted.

Barcodes are also used in the shipment of finished products at SCA. They are directly printed on the paper reeds and are thus used to identify individual objects rather than goods carriers. The barcode format that is used is code 128 C, which is defined by ISO 15417 and especially designed for forestry. The identification of objects with barcodes is just as reliable as the RFID tagging but it is used in a different working environment, where there is no possible influence of weather. Paper reeds need to be stored indoors as they would be severely damaged if exposed to weather. The main cost drivers of the barcode technology are the needed software and the reading hardware that is required.

Consequently, one must conclude that there is hardly anything to be learnt from prior utilization of RFID and barcodes at SCA that would be valuable for this research. In both cases, the working environment and feasibility requirements differ too much from the ones that are linked to the context, which is investigated in this report. The only aspect that was of significance when the RFID system for the good carriers was introduced and that might reoccur if RFID was implemented for log tagging is the reluctance of handling personnel to make use of newly introduced technology. This is a widely known phenomenon that can be observed everywhere in the business world across various industries but that should be taken into account when a modification of current work processes is considered.

13. DECIDING ON SYSTEM SET-UP

There are a fast variety of issues that need to be taken into account when searching for a barcode or RFID system that would be suitable to replace the stamping of logs for identification purposes. The following analysis presents them in a structured, sensible way and discusses them separately. Through the process of elimination of unsuitable options the best possible system is eventually developed.
13.1 Feasibility of barcodes

There is a major difference between barcodes and RFID technologies that needs to be considered in this context, which is the fact that barcodes always require clear line-of-sight to be readable while RFID tags use radio waves for data transmission. The consequence of that is that a barcode must always be visible on the surface of some sort of tag or label while RFID tags can be placed inside a housing.

This difference is significant because of the characteristics of the working environment a new marking system would have to function in. As was indicated earlier, that environment is very hostile, rough and messy. The barcode marking on the wood would have to stand blazing sun without bleaching and rain and snow without blurring. Moreover, it would have to be durable enough to stand agitation and collisions caused by the handling of logs without suffering too much damage in form of scratches, small holes, cracks, etc. In addition to that, the label would always have to remain clean enough to ensure readability. But in an environment where the influences of dirt, mud, resin and sawdust are always present, optical covering of labels is very likely to occur.

After an evaluation of the wood handling environment, it is obvious that regardless of the specific tag housing or label material used, tags or labels will often be bedaubed to some extent and suffer some damage in the form of scratches, cracks and small holes. The difference between RFID technology and barcodes regarding this aspect is that these damages and optical covering are capable of making a barcode label unreadable but they do not affect the readability of RFID tags placed inside some sort of durable tag housing.

Consequently, one must conclude that barcode are not to be advised for utilization in the context of marking logs for identification purposes.

13.2 Active RFID Tags vs. Passive RFID Tags

After having ruled out barcodes as a feasible option, the specific properties of RFID technologies need to be examined to determine how suitable RFID is for this type of application.

One of the first things to decide upon is whether active or passive tags should be utilized in this context of application. The main advantage that active tags have over passive ones is their enforced signal that allows for a reading range of several metres instead of several decimetres. But with prices varying between US-$ 10 and US-$ 100 active tags are considerably more expensive than passive tags and are therefore not advisable in any system that involves a large number of tags. Even if utilized only in small amounts in a closed system, active tags would not be able to meet the cost effectiveness requirements set by SCA for their future log identification system.

However, in this context of application it is possible to design systems that can sufficiently operate with reading ranges of up to one metre so that there is no need to consider the use of highly expensive active tags.

13.3 RW RFID tags vs. RO RFID tags

The next thing to determine is whether RO RFID tags are sufficient for the application in question or whether RW tags are needed. The major technological difference between these two types of tags is that RO tags carry a random serial number, which can be read but not modified, so that no additional information can be stored on the tag. In contrast to that, RW tags are re-programmable so that the data they carry can be modified whenever necessary.
The question of which type to use is of importance because it has a significant impact on the costs of the whole system, regardless of whether it will be a closed or an open one. Today, simple RO RFID tags with good reliability cost about $0.25 per piece while RW tags cost between US-$0.70 and US-$1.00. Although prices for both types of tags are expected to drop significantly in the next few years with RO tags probably hitting a final low of US-$0.05 in price, a major cost difference between RW and RO tags will always remain.

As a main desire regarding a future system is to include technology that is upgradeable to allow for an enhancement of the information retrieved through the tagging of logs, the question is whether such a system can be built around simple RO tags or whether RW tags need to be utilized. As the following explanations show, RO tags are in fact sufficient for setting up the desired upgradeable system.

As was previously mentioned, RO RFID tags are generally pre-programmed and carry a unique serial number when they are delivered. Consequently, it would not be possible to store the logging site identification number directly on the RFID tag that would be placed on wood logs. Instead, a link would need to be created between the serial numbers of the tags that are placed on the wood and the corresponding identification number. That link could then be stored in a central database that is accessible for all actors along the chain who have to handle identification numbers.

In detail, the necessary procedures would be the following: The forwarder places the tags on the logs and reads them with a reading device linked to his computer system. The order in which these two activities should be carried out to achieve maximum efficiency depends on how feasibility-related issues are solved and remains to be investigated. To ensure that radio wave signals do not interfere with each other, tags need a certain geographic distance between each other when they are read. That distance depends on the frequency that is utilized but generally several centimetres are enough to ensure that signals do not become fuzzy. It may therefore make sense to construct a system where tags are placed first and read individually immediately after their placement.

Once the forwarder has placed the tags and his computer system has accounted for all the related serial numbers, the forwarder creates a link between these serial numbers and the identification number of the logging site he is working on. That link is then sent to the computer system at the measuring station and to the database of the transport leader to which truck drivers have access to. When trucks arrive at log piles the truck drivers read one of the tags with a simple, portable reading device and the link that has previously been created makes the connection between the serial number on the tag the truck driver has just read and the corresponding logging site identification number.

When the wood arrives at the mill, the measuring station operator also reads one of the tags with a simple, portable reading device and the serial number on the tag will again lead to the correct corresponding logging site identification number. This way the incoming wood can be sufficiently identified and accounted for. In case a closed system is implemented, the link between serial numbers and logging site identification number can then be erased so that the link-free tag can be taken off the wood and re-used on new logs from whatever possible logging site.

When the system is to be upgraded, all the modification that needs to be undertaken concerns the way information is entered, administered and presented in the databases. Regarding the tag as such, it does not make any difference whether the link of its serial number leads to an identification number only or to a whole list of parameters that describe characteristics of the wood the tag is placed on.
Consequently, a less costly RO tag is sufficient to design a system that accounts for the desire to upgrade it in the future to enhance the information gathered on incoming wood. The advantage of centralizing the information storage in the proposed way is that one not only eliminates the need for expensive RW tags but one also becomes independent of possible restrictions regarding the data storage capacity of tags. As a consequence of that, upgrading the system is easier and the parameters that are of interest in a more sophisticated information system can be chosen and presented without having to keep data storage limitations of tags in mind.

However, the key issue in making such a centralized data administration feasible is to make sure that all actors along the chain who need to have access to logging site identification numbers are connected to databases that include the current links between serial numbers of tags and identification numbers. Creating reliable back-up systems is compulsory to ensure that one is sufficiently protected against possible system breakdowns.

13.4 Open Systems vs. Closed Systems

Another feature that need to be decided upon when possible new marking systems are investigated is whether the RFID system should be closed or open. In a closed system, the tags used to mark logs would be circulating and re-utilized, while an open system would include tags that remain on the log they were put on and vanish once that log is processed at the mill or factory.

As figure 13.1 shows, the cost structures of open and closed systems vary considerably, which needs to be taken into account in the analysis.

As part of the initial investment, both options include the cost of new, possibly customized hardware and software that is needed to set up the new system. In operating costs, both alternatives have operational software costs and hardware maintenance costs in common. However, there is a decisive difference between the two designs, namely the fact that in a closed system, the costs for the limited number tags that are needed can be regarded as part of the initial investment, while an open
system includes continuous operational costs for an unlimited number of tags that need to be acquired.

Furthermore, in a closed system, one cost category needs to be added, which consists of the costs incurred when the tags are removed again from the wood, once it has arrived at or passed the measuring station. This task of removing tags would require an additional, non-value-adding job step to be included in the process and would therefore add considerably to the costs of the whole identification system.

13.5 Cost Calculations regarding Open and Closed RFID Systems

After this general discussion, the specific cost characteristics of open and closed RO RFID systems need to be considered to determine whether a closed or open system should be recommended. The related advantages and disadvantages then need to be evaluated. It must be understood that the numbers presented in this section are based on rough estimates rather than exact calculations. They are designed to give the reader

a first impression of the extent of costs rather than to show exact true figures, which would need to be obtained in an in-depth, time-consuming study of the scale of SCA’s operations and the related cost structures.

Open RFID systems:

The most important issue regarding feasibility of open systems is to find a non-contaminating tag material that is durable and stable enough to fulfil its purposes without harming processes at the mills. However, as line of sight is not necessary, it is possible to take into account the possibility of putting tags in a less weather resistant material (e.g. paper, wood) and protect them by inserting them in the log rather than attaching them to its surface.

Even though feasibility is not an unsolvable problem that rules out all open RFID systems, there are cost-related issues, that refer to the general difference in cost structure between open and closed systems and need to be evaluated.

The advantage of an open RFID system is that it does not add another costly non-value-adding work step to the process. But it inevitably includes the utilization of an unlimited number of RFID tags, which would be the major cost driver of such a system. SCA handles roughly 80 million logs per year out of which 20 percent need to carry markings. Thus, 16 million tags would have to be spent during the course of one year.

Consequently, yearly tag costs for an open system involving simple RO tags with a price of US-$ 0.25 per piece would be US-$ 4 million (0.25*16,000,000) if it was to be implemented today. Even though prices for RFID technologies are expected to drop further in coming years and generally depend on order quantity, it is not reasonable to assume that tag prices will ever fall below US-$ 0.05 for the simplest of tags, which would lead to yearly tag costs of US-$ 800,000 (0.05*16,000,000).

Closed RFID systems:

One major benefit of a closed RFID system is the fact that one does not have to take into account any restrictions regarding tag housing material as the tag would be removed before the wood fibre is processed at the mills. Thus, one can concentrate entirely on satisfying the feasibility requirements that relate to handling, durability and weather resistance in the best possible way.
But this freedom of choosing the tag material that would best satisfy durability and weather resistance issues comes at a certain price related to the cost structure, which is the extra work step that any closed system requires for the retrieval of tags. However, a re-utilization of a limited number of tags adds no tag-related costs to the operating costs of the system.

To serve all the marking needs of SCA in a system where tags are circulating roughly 800,000 tags would be needed. Thus, total tag costs would be US-$ 200,000 (800,000*0.25). The calculation of total tags needed is based on a cycle time of 15 weeks, which is the maximum amount of time wood may spent unprocessed after logging. As RFID tags have no predetermined limit to their lifetime, unless they carry a battery, the acquisition of this number of tags can be regarded as a once-only investment, given that the tags are durable and robust enough to have a relatively low yearly failure rate.

Conclusion:

The crucial issue in deciding whether a closed or an open system is preferable is cost effectiveness. The question is whether a closed system that involves a very limited number of tags but adds an additional work step to the process would be more economical than the utilization of an unlimited number of tags in a process that would not require the addition of this extra non-value-adding work step.

This general evaluation cannot be concluded at this point because there are certain cost drivers that depend on the solution of feasibility-related issues and carry the potential to have a large impact on the costs of the system. Such cost drivers can be divided into two categories, which are costs for tag housings (1) and the complexity and duration of possible tagging, tag removal and data administration activities (2). If further research reveals that a closed system is feasible but the related tag removal procedure is very complicated, time consuming and costly, it may be advisable to tolerate the operational costs of continuous tag acquisition instead. On the other hand, if it can be proven that tag removal would be easy and add little costs to the system, a closed system may be recommended.

14. POSSIBLE TAG DESIGNS

The main concern in designing tags and finding the right tag housing is meeting the feasibility related requirements on durability, weather resistance and handling. While wood contamination requirements can be ignored in a closed system, great care must be given in an open system to avoid the utilization of harmful material. In a closed system, it must also be taken into account that the retrieval of tags should be easy, fast and cheap so that the process remains economical.

The fact that the possible capability of RFID tags to fit this type of application context has previously been given only little attention means that the tag housings that are common today cannot be used for this working environment without a certain degree of customization. In the following section a number of customized solutions are presented and discussed.

14.1 The Plastic Plate

This solution is designed to meet the requirements of closed systems and is based on the utilization of a flat plate of roughly 10*10 cm in size as tag housing. The plate is made out of hard, durable plastic that offers the necessary protection to the RFID chip and antenna it carries inside. The plate features one tongue on either side which are made out of flexible synthetic material, so that they can curve backwards. To attach these tongues to the cross section of wood logs two metal staples are used. Figure 14.1 shows the designed plastic plate as it would look on the cross section of a log.
Attachment:

The tag plate is attached with a customized, portable stapler gun that features a compartment capable of storing several plates and of automatically forwarding them one by one for stapling. The staples are placed simultaneously and automatically, so that the operator of the stapler gun does not have to make sure that he manually places the staples at the right place. In an ideal situation, stapler gun and tag reading system are incorporated into the same device. This way, a tag can first be attached to the log and read immediately after that to retrieve its serial number. Having attachment and tag-reading capabilities included in the same device enables the handler to perform both tasks without having to add another work step to the procedure. This way it is ensured that the procedure of tagging the logs does not consume more time than the present-day process of stamping them.

As the above-described customized stapling gun with incorporated tag reading system does not yet exist, it will take a certain investment in engineering and further research to create it. At this point, it is impossible to judge with absolute certainty whether or not the suggested device will eventually be operational. But as no major technical obstacles that would make this design impossible to manufacture could be identified so far, it does make sense to conduct further investigations regarding the possible engineering of such a customized device.

Tag Retrieval:

Tags can be retrieved as soon as logs arrive at the measuring station. As the retrieval adds a new work step to the processing of logs, it remains to be investigated whether a new job place should be created for that task or whether it can be incorporated into some other handler’s job description. The size of the plastic plate (roughly 10*10 cm) makes the plate fit into a person’s hand easily. The upper and lower edge of the plate slightly curve away from the log so that it is easy to put one’s thumb and fingers behind the plate. Once the plate is grabbed, it can be pulled off the log without difficulty as the flexible plastic tongues that held the plate on the wood will start to curve backwards and will slip underneath the staples once the plate is pulled away. Thus, the tag plate can be retrieved and the only contamination that is left on the wood are the metal staples used to hold the plate’s tongues.

It may be considered to use a flat, metal spatula to facilitate the pulling away of plates from the logs by pushing it between the plate and the log it is attached to. Another tool that may be helpful to
remove tag plates from logs is a simple, large gripper that can grab the top and bottom edge of the plates more easily than a person’s hand.

Although no practical tests with prototypes of plates have yet been conducted, it is reasonable to assume at this point that retrieving the tags in the above-described manner will be neither more time consuming nor more costly than the procedure of tagging the logs.

It is obvious that the tongues of the plates will be worn out after being used a certain number of times, which is why plates and tongues are not fixed together. Tongues carry two plastic knots that fit into two corresponding holes on either side of the plate, so that tongues can be attached and removed from plates at discretion.

**Optimizing Durability and Stability:**

Designing a plastic plate that offers enough protection from outer influences to the tag it carries is not a problem. However, a key issue in making this solution operational is to make sure that plates stick to the logs and do not fall off. This largely depends on the degree of flexibility of the tongues that hold the log on the wood. If the material is too flexible and soft, it might slip from the metal staples when the logs are handled and make the plate come off. On the other hand, if the material chosen for the tongues of the plates is too stiff, it will be too difficult to remove the plates from the logs again.

Consequently, one must give great care to finding the optimum degree of flexibility of the plastic tongues that are to be utilized. In addition to that, tests may reveal that one tongue on either side is not enough to ensure that tags stay in place. But it is reasonable to assume that adding another pair of tongues to the system would then improve stability to a sufficient level without having a great influence on the feasibility or cost issues involved.

Other variables that have an influence on the stability and durability of the proposed tag design and that should be examined to find the optimum solution are:

- the length and width of tongues
- the thickness of plates
- the distance between plastic plate and staple
- the size of staples
- the shape of staples
- the question whether the plate should be squared or its edges should be rounded

**Applying the A-R-A Model:**

To understand how the implementation of the suggested solution would affect actors, resources and activities along the information chain the A-R-A Model is applied at this point. The question of what changes in each of these dimensions is discussed in the following section.

Actors: Changes on the actors level depend on who is in charge of the removal of tags from logs. Another job that needs to be taken into account is the storage and administration of tags that are not utilized at the moment. It remains to be closely investigated whether measuring station operators should remove, store and re-distribute the tags or a totally new actor should be added to the process to take over that task. At this point, it is reasonable to assume that this job is not occupying enough to justify the addition of a complete new entity but the number of personnel at the measuring stations may need to be raised to account for the additional tasks that need to be performed at this point of the supply chain.
Resources: The greatest change regarding the resources that are passed on along the chain (which only includes the information that is handled as the focus is on the information flow and not the wood flow along the chain) is that the new system opens possibilities for upgrading and enhancing the information that is gathered. Unlike the stamping procedure, RFID tagging as it is suggested in this solution would not restrict the information provided by the marking to only consist of an identification number.

Furthermore, the characteristics of the information network change if the suggested system is implemented. It becomes more centralized as all the information that is significant for user interface is stored in the databases instead of on the logs. Logs do no longer carry their specific identification numbers directly but have a random serial number that has no relevance as such. Only when put together with the right link that matches the serial number with the corresponding identification number stored in the computer systems of the actors involved can logs be identified properly.

Activities: On the activities level, the stamping of logs and all related tasks like the attachment of the right number plates to the core are substituted by tagging activities. These consist of attaching tags to logs and reading them to reveal their serial number. Thereafter, the link between serial numbers and identification number needs to be made and forwarded to the computer systems of the relevant actors.

The truck drivers who arrive at the logging site to pick up the wood then need to read the tags again with portable reading devices so that they can check whether they are at the right logging site.

At the measuring station, tags are read using a portable reading device that the measuring station operator carries. As no identification number is shown on the logs, the wood can no longer be identified by checking the number visually. The checking of numbers and accounting for incoming wood is thus more automated than it is today.

A totally new area of activity that needs to be added is the removal, storage, management and redistribution of tags once they are taken off the logs. As all of those activities are non-value adding, organising them in the smoothest and most efficient way will be crucial to ensure that the system as a whole is economical.

System Variations:

Instead of putting the RFID tag into a hard plastic plate, one can also consider the option of putting it in a gel pack. A gel pack can be described as a plastic bag that contains viscous material. Today, gel packs are often used as a substitute for ice packs that one puts on injured parts of the human body to cool them. Gel packs can be stored in the freezer where the gel they contain becomes hard and cold and in case of an accident, they can be taken out and used to treat the injury.

In this case, gel packs may be advisable as tag housing because of the agitation that is caused by the handling of logs. A hard plastic plate does not offer any possibility to absorb shocks and physical pressure and would start moving or passing the pressure on in some way when hit with something else (e.g. another log). There is a risk that the method of attaching the plastic plate with two flexible tongues held by metal staples will eventually not be able to stand that pressure and movement and will cause the tag to come off.

In contrast to that, physical pressure can be absorbed if a gel pack is utilized as the gel will simply deform to a certain extent instead of putting pressure on the mounting of the tag. However, for a
stable attachment of tongues and to ensure it stays in place the way it was attached, a plate would always need to have a hard, stable frame even if it mainly consists of a soft gel pack.

14.2 Cork Pens

This solution involves the usage of pen-shaped corks as tag housings. These cork pens have the advantage that they can be put in a log instead of having to be attached to the outer surface. Thus, the danger of loosing tags because of some damage that can occur on the outside layer of a log is eliminated. The fact that cork is used as housing material makes this solution fit for usage in an open system where wood contamination requirements need to be considered. Figure 14.2 shows such a cork pen inserted into a log. Unlike figure 14.1, it shows the longitudinal section of the log.

Attachment:

The injection of pens into logs is divided into two steps. First a hole in the wood needs to be drilled or stamped. Then the pen needs to be injected into that hole, possibly with a gun-resembling tool that uses air pressure for the injection. At some point before or after the injection of pens, tags also need to be read for revealing their serial number. The key issue in making the attachment procedure economical is ensuring that the above-described tasks can be carried out as smoothly as possible. It remains to be investigated whether there is a possibility to engineer a single, portable device capable of storing a certain amount of pens, stamping or drilling holes, injecting the pens and reading tag serial numbers at the same time. Designing that device would guarantee that all these tasks can be carried out in one go so that as little time as possible is spent on this non-value-adding activity.

Tag Retrieval:

As was previously mentioned, this design is fitted to the requirements of an open system. However, it is reasonable to assume that it would be possible to retrieve tags if a closed system was preferred over an open one. Therefore figure 14.2 shows a wire, which is an optional feature of the design that is not needed when the system is open. In a closed system, a hook could be used to grab the wire and pull the pen out of its hole. Another option is to use machinery that operates with vacuum to suck the cork out of the hole again. As no tests with prototypes of this kind of cork pens have yet been undertaken, it cannot be stated at this point whether it will be possible in practise to remove pens from their holes again, once they have been stuck in them for several weeks. The degree
of difficulty in pulling out the pens largely depends on how loosely or tightly they were fitted into their holes.

However, if it is possible in practise to pull out the pens again, one can be certain that they will be damaged in such a way that their immediate re-utilization is impossible. The RFID tags inserted in the cork would have to be retrieved and then fitted into new cork pens before they would be ready for re-utilization.

Optimizing Durability and Stability:

The main variables that have an influence on the durability and stability of the above-described system are shape and size of cork pens. It must be kept in mind that the frequency that is utilized has a certain influence on the space the antenna of the chip requires. The antenna may be coil-shaped or straight and making sure that the cork is large enough to house the antenna of the chip is crucial. The shape of the pen is important because it determines how well the pens will stick in the wood.

Another important aspect in optimizing durability and stability is fine-tuning the size of holes to the size of corks. The more precisely corks can be fitted into holes, the more stable the system will be. There is a danger that corks may be damaged or come off if too much moisture enters into small chinks between wood and cork and then freezes. The expanding water may then push the cork out of the hole or loosen it enough for handling to cause it to fall off.

Applying the A-R-A Model:

**Actors:** Possible changes on the actors level would only need to be considered if this tag design is used in a closed system where tags have to be retrieved and re-utilized. In an open system there is no job task added to the system that would require any changes regarding the actors involved.

**Resources:** The changes between this proposed system and the current one regarding the information level are just the same as the differences between the current procedure and the proposition involving plastic plates. The identification technology both suggestions are based on is the same, so that the question of whether cork or plastic plates are used as tag housing material has no influence on the capabilities that concern information gathering and retrieval.

**Activities:** The tagging-related activities that would need to be performed by the forwarder in this scenario are the stamping or drilling of holes in the logs, the injection of pens and, at some point before or after the placement of pens, the reading of tags.

Truck drivers and measuring station operators would need to perform activities similar to the ones described in section 14.1 to read the tags and process the information. If the system is implemented as an open one, the chain of tagging-related activities along the material flow ends at this point, but if this scenario is applied as a closed system, one needs to add the activities of removing pens, retrieving the tags they carry and fitting these into new pens.

It may be considered to outsource all activities that are related to fitting tags into new pens because it is highly doubtful that SCA has the capability in the form of resources and expertise to perform that task efficiently.
System Variations:

A variation of this system that would make it unsuitable for being implemented in a closed system is the utilization of wooden nails that contain the tags. Those nails could be injected into the cross section of logs using an air gun-like device. Attachment of tags would become easier in this case as no holes would need to be drilled or stamped before the tag can be inserted.

However, shooting nails into the wood fibre would make the retrieval of tags hardly feasible and surely not cost effective. It is highly doubtful that wooden nails can be removed from wood logs again without breaking them. Even if it was technically possible, it is reasonable to assume that the procedure needed would be too complicated and time-consuming to meet the requirements regarding economic efficiency in a closed system.

15. CONCLUSION AND RECOMMENDATIONS

After the analysis of the capabilities of both barcode and RFID technologies to determine whether it is feasible and economical to substitute the procedure of stamping logs with possible applications of the above-mentioned technologies several conclusions can be drawn.

Regarding barcodes their need for clear line-of-sight to guarantee readability eliminates them as a feasible option in this context of application. For the utilization of RFID technologies no obstacles that makes RFID generally unsuitable could be identified. It is reasonable to assume at this point that a suitable, customized RFID solution for this specific purpose can be created that is both feasible and upgradeable while meeting the requirements regarding cost and efficiency. This solution should be based on simple, passive RO RFID tags and a more centralized data administration and processing system.

The designs that are presented in this report certainly need some adjustments and modifications to become workable but as no major problem in making them operational could yet be discovered, it is sensible to conduct further research regarding the suggested solutions.

The proposed designs should be discussed further with engineers, tag manufacturers and SCA’s departments in charge of technical development, research and innovation to explore in detail whether or not they can be created and then produced at the right price. In order to be able to judge whether or not the above-described systems would eventually be economical, further study on the incremental costs involved in changing the current procedure needs to be done. Tests with prototypes of the suggested tags could show how they behave when exposed to the real working environment and whether or not they meet all the cost-related and feasibility requirements.

Thus, in order to determine whether or not any of the suggested systems can be implemented in the future, further in-depth study relating to feasibility and cost issues is needed. As no serious obstacles have yet been encountered that rule out the possibility of creating the suggested systems, they deserve to be further investigated.
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