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Magnifica Comunità di Fiemme' sawmill: opportunity for an integrated barcode management system.

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“Fa più rumore un albero che cade
piuttosto che una foresta che cresce.”

Lao Tzu

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Abstract

The Magnifica Comunità di Fiemme' (MCF) sawmill represents an Italian leader company in softwood lumber manufacture. There, time saving and high productivity need to be competitive. In this sense, a key role is played by the packages track management system, that has been shown to be not efficient and time consuming. For this reason, a feasibility study on the use of a barcode system to track packages is performed. Nevertheless the knowledge of barcode systems in timber industry is still limited, the research shows that MCF' sawmill would profit from the installation of an integrated management system based on barcodes. It is a relative new system for sawmills, already used in some timber companies that has been revealed convenient in terms of time saving, mistakes transfer reduction and real update. Collected data has also shown that there are few software designer businesses focused on specific barcodes for timber industry. Among them, Projecta is the most suitable solution. It is a software producer for system integration which design also an integrated management system based on barcodes. Overall, the results indicate the way to innovate the management system of a sawmill with comparable characteristics of the MCF' sawmill. This assay is the starting point for more detailed studies on the application of barcode systems in timber industry. For example, the operability of barcodes with old management systems could be tested to identify how they can work simultaneously, avoiding the fully replace of the old systems and containing the innovation costs.

Riassunto

La segheria della Magnifica Comunità di Fiemme (MCF) si colloca tra le aziende italiane considerate leader nella segagione del legno di conifere. Qui, il risparmio di tempo e il mantenimento di un'elevata produttività sono necessari per essere competitivi. A questo scopo, un ruolo chiave è dato dal sistema di gestione dei pacchi di tavole, che si è rilevato inefficiente e dispendioso in termini di tempo. Per questo motivo è stato effettuato uno studio di fattibilità sull'uso del sistema di codici a barre per la gestione dei pacchi. Nonostante la conoscenza e l'applicazione di tali sistemi nel settore del legname sia ancora limitata, la ricerca ha rilevato che la segheria della MCF può beneficiare dall'installazione di un sistema di gestione integrato basato sui codici a barre. Si tratta di un sistema relativamente nuovo nelle segherie, già in uso in alcune aziende del settore, che è stato ritenuto vantaggioso in quanto consente il risparmio di tempo, la riduzione del trasferimento di errori e l'aggiornamento in tempo reale. Dai dati raccolti è emerso che ci sono poche aziende specializzate nella produzione di sistemi di codici a barre specifici per il settore del legname. Tra queste, la soluzione ritenuta più adatta è quella proposta da Projecta. Si tratta di un'azienda specializzata nella produzione e realizzazione di software integrati, che produce anche un sistema di gestione integrato basato sui codici a barre. Nel complesso i risultati descrivono come può essere innovato il sistema di gestione di una segheria con caratteristiche simili a quelle della segheria della Magnifica Comunità di Fiemme. Questa tesi rappresenta la base per lo svolgimento di studi più approfonditi sull'applicazione di sistemi di gestione con codici a barre nel settore del legname. Per esempio, resta da approfondire come i sistemi di codici a barre si integrino con i vecchi sistemi di gestione, evitandone la completa sostituzione e contenendo i costi di installazione dei nuovi.

1. Introduction

In the last 30 years timber demand on global economy has been growing because wood uses multiplied and the number of people using wood increased globally. In this sense a sawmill, i.e. the primary industry of wood processing, plays a key role in transforming logs into boards, making timber available for a variety of applications. The sawmill could be defined also the factory in which logs are cut to make sawn timber. It includes boards, beams (often assembled in panels used for buildings), carpentries and furnitures (Xiloglos). In Italy sawmills are located mainly in the Trentino Alto-Adige region, where the forest area accounts for about 727.152 ha (54% of total area). According to Delpero et al. (2017), Trento province accounts for 52 operating sawmills. Most of them were started after the Second World War. The average number of employees is 8,9 each. About 39% of them have up to 5 employees; only 11% are hiring more than 20 people meaning that there are a lot of family-run businesses. Company's turnover is for almost between 1 and 2.5 Million Euro, with a total annual income of 81.516.712 Euro. The average surface (including buildings and open space) is 8.513 m^2 each. Most of sawmills are included within the Programme for Endorsement Forest Certification (PEFC), and 7 companies adopted PEFC and Forest Steward Council (FSC) (double certification).

In this context the Magnifica Comunità di Fiemme' sawmill (MCF) represents a unique example of business company oriented towards innovation being quite big in terms of employees and area, environmental friendly, and marketing also to neighbouring countries. Moreover, MCF' sawmill was always looking to be a model in innovation and kept its productive systems up to grade. This policy, constantly oriented to the future, is very important because the environment in which the sawmill evolved is changing. In particular, nowadays sawmill costumers look for innovation, quality, just-in-time service and lowest price (Beauregard et al. 1997).

1.1 The Magnifica Comunità di Fiemme' sawmill

The history of MCF is very old: it was born officially in 1111. It is a public authority that safeguards a territory of about 20.000 ha, including grazing and mountain areas. About 60% of this land (11.000 ha) is composed by high forest, dominated of conifers: Norway spruce *Picea abies* (L.) H.Karst., silver fir *Abies alba* Mill., larch *Larix decidua* Mill., Scots pine *Pinus sylvestris* L. and stone pines *Pinus cembra* L. Wood utilizations and reforestation are planned and managed by the MCF.

The sawmill focuses on milling the logs coming from MCF and Fiemme Valley forests. So, there is a short production chain that makes a final product of very high quality.
For this reason, Fiemme Valley represents a model of sustainable development, where human activity is balanced with forest management planes.

The sawmill is located in Ziano di Fiemme in an area of about 50.000 m² and it accounts for 35 employees. In 2016 sawn timber volume amounts to 36.250 m^3, with a turnover between 5 and 10 Million Euro. The value of MCF forests is showed by its certifications: in 1996 the MCF starts the process of eco-certification proposed by the Forest Steward Council and in 1997 it reached the FSC certification. Ten years later another forest certification was established: the Programme for Endorsement of Forest Certification schemes (PEFC). This company represents the first Italian authority with both the certifications.
The sawmill is structured in different areas (see fig. 1.1), where boles coming from the fresh stock are processed to obtain boards and semi-finished products. Different processes are described in the next paragraphs and summarized in the figures 1.1 and 1.4. Its understanding is fundamental to have an overview of the management system.

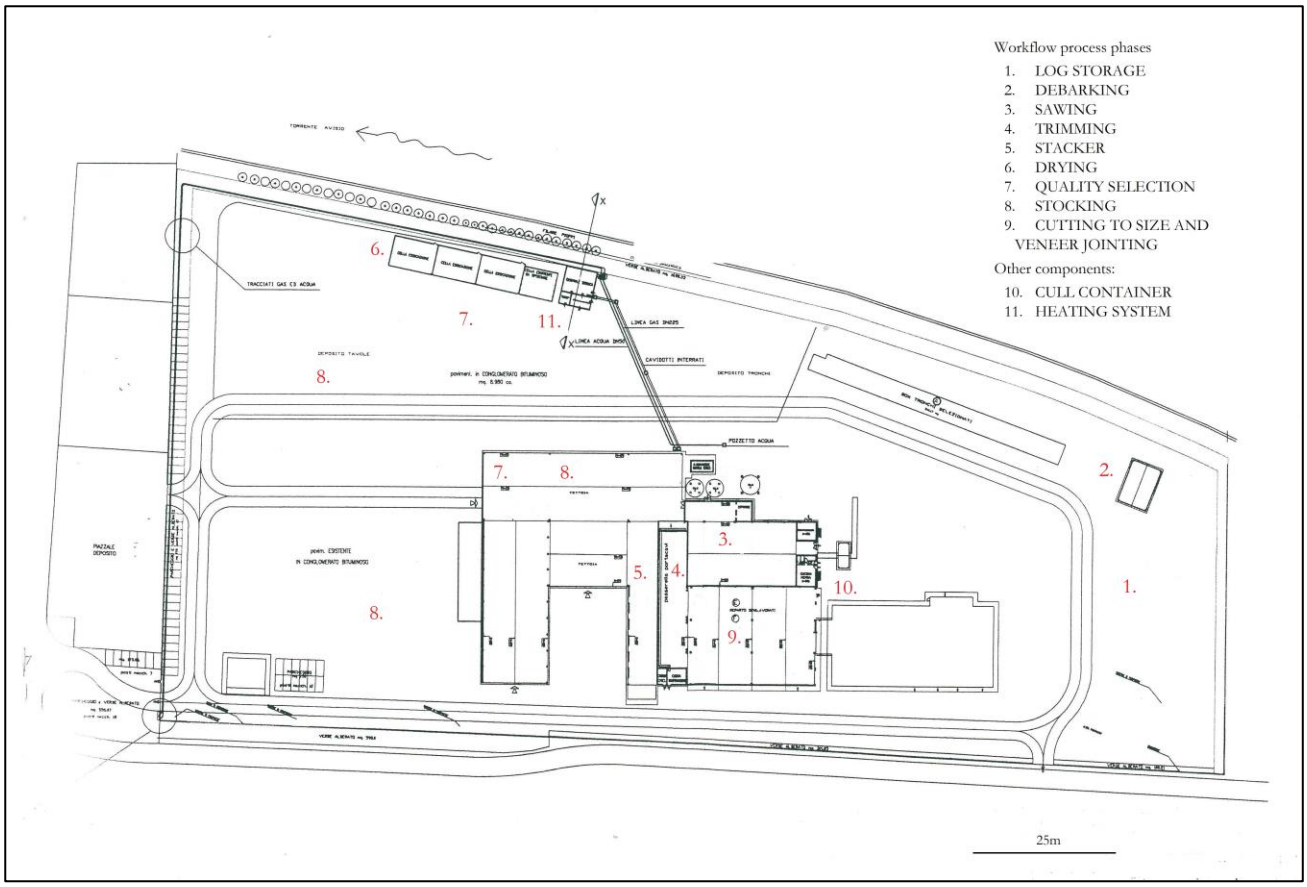

Figure 1.1: Sawmill layout showing the work flow phases (numbers) at Magnifica Comunità di Fiemme' sawmill.

At the MCF' sawmill the workflow to produce sawn timber includes the following steps:

1. log storage, an area of about 8.000 m² in which logs are stored and distinguished by origin to allows the separation between MCF' logs (both PEFC and FSC certified) and logs from other public administration parcels (which are PEFC certified only);
2. debarking and log quality selection, where boles are debarked, measured (see fig. 1.3) and classified in classes by size, quality and species stored in different boxes (see fig. 1.2).

   An expert operator visually classifies log quality in five different visual categories based on the presence and extension of knots, decay, ring shake and other wood defects. The internally categories are defined as:

   - Quality A: logs contain few adhered knots. Rot, ring shake and insect decay are absent. Logs are straight and without cracks.
   - Quality B: logs with few knots, narrow growth rings, ring shake less than 35 cm of diameter, reaction wood less than 10% in cross-sectional area, maximum 2 resin pockets for each end cross section.
   - Quality C: reaction wood less than 30% in area, adhered and no adhered knots, ring shake less than 1/3 of log diameter.
   - Quality IV (saw material): logs rich of knots, discoloration, insect decay, rot less than 20% in cross-sectional area.
   - Quality V or Mill cull: logs with rot, cracks, knot, resin pockets, stain above the threshold for the other qualities.

   Quality "A" is almost never identified. "B" and "C" boles are used for joinery. Saw material is used for packaging or semi-finished products. Cull logs proceed on semi-finished products department.

Figure 1.2: Boxes of way out containing logs of specific size, quality and species.

Figure 1.3: Debarker machinery.

3. Sawing, in which logs are sawn in different assortments. The cut is performed by an informatic log' three dimensions (3D) scan, that identifies an ideal cutting plan in relation to log characteristics and requested lumber order(s). Before cutting, the cutting plan is confirmed or modified by the saw operator, with focus on high production (in terms of quality and quantity) and cull reduction. The whole sawing process is planned according with costumer' requests and available material.
4. Trimming, which makes the boards transversal cut perpendicular to the boards length. It is performed on boards for joinery (quality "A", "B" and "C").
5. Stacking: the stacker packs boards. There are different boxes that collect the boards in relation with their sizes (length, thickness and width). Each new board stack is identified with a numeric code, that is automatically saved by the stacker computer and manually written by the operator on a side of the first sequence of boards. During package formation an automatic system put wood laths between boards row to allow an easier drying.
6. Drying. It consists in reducing the wood moisture content to reach an equilibrium between wood and environment in which it is used. Normally, target moisture content is between 12-15%, which represents the commercial humidity of dry wood. To achieve this aim two methods are used:
    - natural drying or air seasoning: boards packages are exposed to air in external environment under coverage. There, actual wood moisture content varies according of climate conditions. Normally, it is not expensive in terms of cost, but it requires long seasoning times (at least 1-2 months). So, it is used for particular orders or high value species (such as stone pine), or to shorten artificial drying process.
    - artificial drying: boards packages are located inside the drying kiln, where temperature, air relative humidity, atmospheric pressure and ventilation are controlled. Its time span is limited from some hours to 1-2 weeks in relation of species, initial wood moisture content, boards thickness, targeted wood moisture content at the end of the drying process. Despite this, it is quite expensive in terms of energy. For this reason, in 2015 a heating system based on wood chips was installed (see fig.1.1, number 11).
7. Quality selection: dried boards are manually classified by the operators and stacked in new packages. Quality "A", "B" and "C" are sell for joinery. Lower qualities (4 and 5) are processed in the semi-finished products department.

Only rotten boards are recycled by the chipper to feed the heating system. Is important to mention that during the drying process, boards width is reduced by 5-7% and deformations (e.g. cup) occur. As a consequence, board downgrade to lower qualities. Therefore, quality selection is performed after drying.

8. Stocking. Selected joinery packages are stocked and made ready to be sold. At the sawmill two stocks are available: an inside covered stock, where quality "A" and "B" are collected and an outside storage area, mostly used for quality "C". In the second case, packages are covered by nylon cloths, which protect timber to get wetted from rainfall, snow and wind.
9. Cutting to size and finger jointing machine. Selected boards of lower quality (4 and 5) are processed by specialized machines:
   - splicer: it joins rectangular wood pieces cut from different boards and jointed end-to-end via finger joints. It is useful to discard timber portions with defects (like big knots, resin pocket) and creates boards with specific characteristics, as required by the customers.
   - moulder, a machine with a rotating utensil around an axis (fixed or movable) equipped with multiple blades. The car motion is relative: the wood is pushed into the machine or the moulder axis move around the wood. Different cable shapes are available (perpendicular or parallel to the rotation axis) to obtain the predefined profile.
   - press: it produces a mechanic action to strongly adhere wood pieces and boards. It is composed of roller conveyor, vacuum unit and control panel.

   Through these devices, a large variety of the so called semi-finished products is obtained (see fig. 1.4). Two productions are mainly distinguished: a first without view defects used for frames, doors, windows and a second characterized by small knots and discolorations, utilized for furnishing accessories.

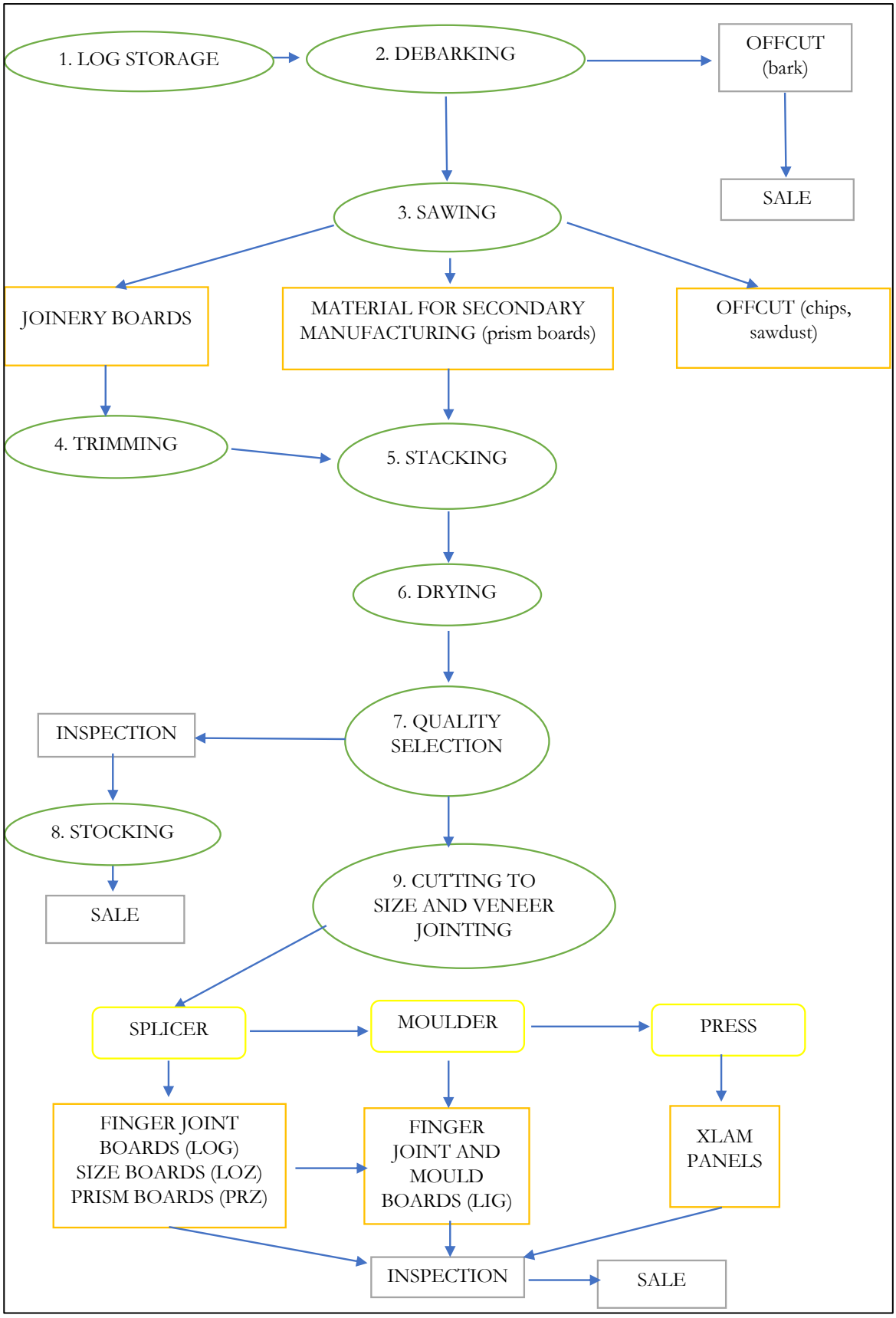

Figure 1.4: Milling layout showing work flow phases (numbers) and relative products at Magnifica Comunità di Fiemme' sawmill.

1.1.1 Stocks organization

Stocks organization is very important because it is strongly connected with the management system. As mentioned above, the sawmill production is divided in steps. Currently, every step is identified by a number and is connected with virtual stocks (see fig. 1.5), in which relative products are collected. The first one is called "Fresh stock" (number 20), where we find the new packages made by the stacker. During drying process, they virtually move to the "Artificial drying stock" (number 30) or to the "Production stock" (number 40). "Rough material semi-finished products" (number 50) correspond to packages for which cutting to size and veneer jointing will be performed. "Tested boards stock" (number 60) collect proved joinery packages. Stock 70 is occupied by the "Semi-finished tested products". Offcut produced in the different steps are collected in the "Offcut stock" (number 80). "Sale stock" (number 90) gather tested packages of stocks 60 and 70.

In this structure a key role is occupied by the management system (Crespell at al. 2006). It is about Winwood and Wingest software, provided by Sidera about 25 years ago. They work manually, in sense that every operation is registered by an operator, starting from log storage. A lot of time is required because in each step employees have to write package' number in entrance and exit in specific lists; then data is copied by the office worker. Moreover, new packages created by the stacker are not real-time visible in the software. Therefore, every day is necessary to save the file provided by the stacker in a pen drive and transfer the data to the mainframe. Without this operation new packages remain unknown and are lost; so, is very important to update the system every day to not miss information during the stacking process. In this way, the first stock (i.e. number 20) is update at the previous day and all the operations are registered.

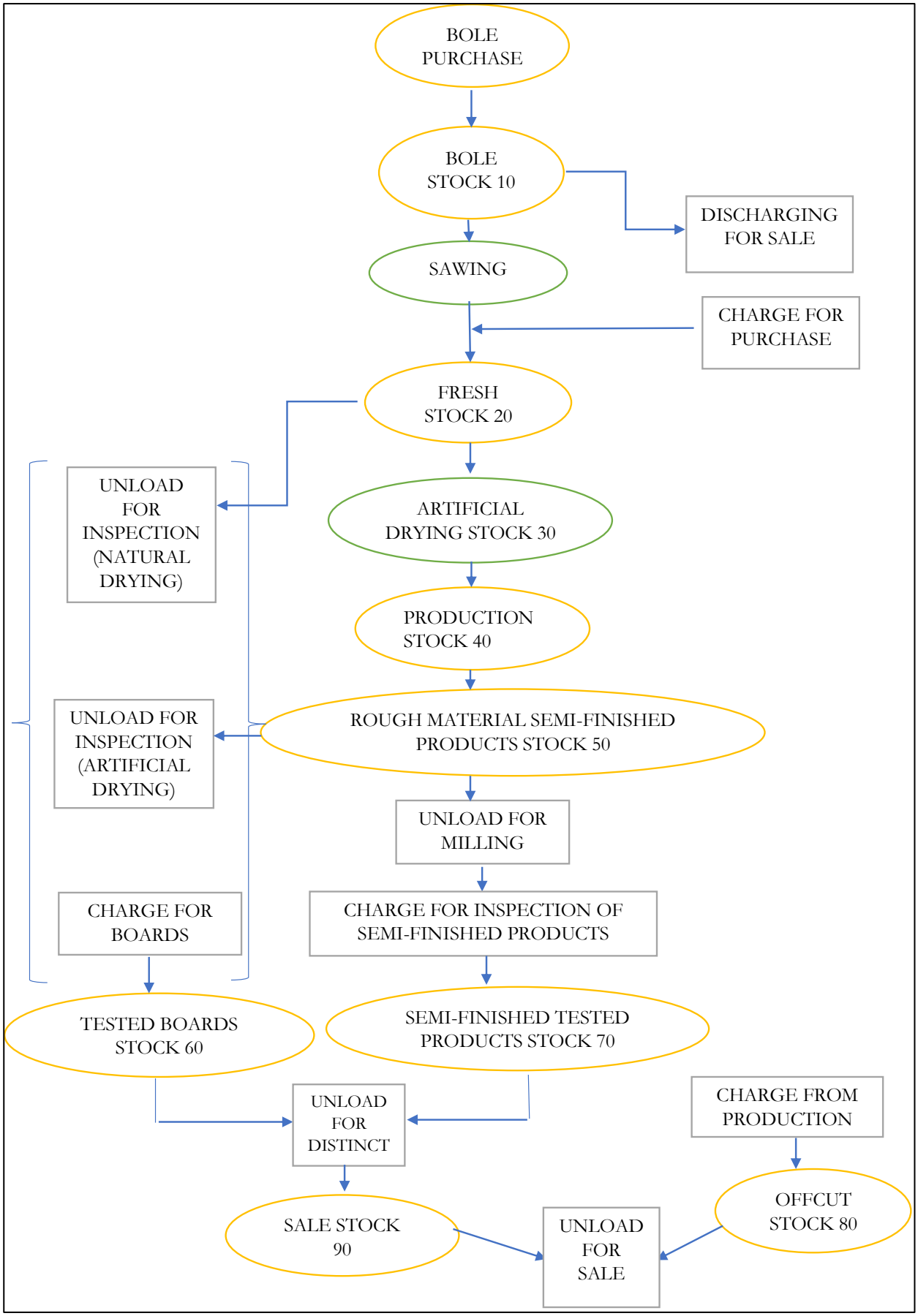

Figure 1.5: Stock layout showing the virtual stocks and related inspections and sale.

In 25 working years, the management system has revealed some gaps that represent the starting point of this research. From March to May 2018 I conducted an internship at MCF' sawmill. During the time I spent there, I had the possibility to analyse and understand in detail the productive process, asking questions to operators of the departments and perform some operations with the management system. Thanks to this practical experience I had got acquainted with workflow and I was able to identify some pitfalls in the workflow organization. Most of the pitfalls are related to the way of manage and store data, operations that are done either manually by different operators, increasing the risk of misinformation, slowing down the process and increasing organization costs.

The main problems I identified can be summarized as follows:

1. the stacker computer (phase 5) is not connected with the management software; so every day the office worker has to get data from the stacker computer (with the list of new packages) and copy it into the software;
2. sometimes operators make mistakes during identification, annotation and coping packages numbers;
3. the software update is not real-time, but there is at least one day of delay;
4. all the operations are time consuming because data about the same packages is produced many times;
5. there is no connection between software and productive units.

Overall the resulting organization system is not efficient, time consuming, and it does not provide an overall up-to-date and reliable source of information. To these pitfalls there is a huge need to remediate for the company in order to increase efficiency and reduce the management costs (Hansen et al. 2011).

An integrated management system and data management seems to be appropriate to fill this gap. For this reason, a feasibility study on the use of a barcode system to track packages would be ideal. According to Jia et al. (2018) the barcode is an automatic identification technology based on computer, designed for the automatic scanning of information. It allows automation and real-time management of material purchase, arrival, storage, custody, warehouse-in and out (Hong-Ying 2009). The whole system includes database server, client software, wireless network and barcode label printer. This technique was firstly used in the late 1970s, and today it is still the most used in designating and identifying products throughout the world (Pihir et al. 2011; Porter et al. 2004). Moreover, it would be good to know the opinion of timber working companies, which already applied such methods, and also to learn from software designer businesses what they can offer.

In fact, learning from previous experiences, even if coming from slightly different contexts, can provide useful information in evaluating the possibility to include such managing system at MCF' sawmill.

1.1.2 Objectives

This thesis seeks to explore the possibility to include a barcode system at MCF' sawmill, by:

1. exploring the market' proposals by interviewing software designer businesses and learn directly from them the pros and possibly the cons of their systems;
2. analysing the factory' implementation by visiting and interviewing timber companies in which the barcode management system was already introduced to learn first-hand comments and possible suggestions;
3. merging the knowledge collected and discuss the possibility to implement a barcode system at MCF' sawmill useful to save time, reduce mistakes and up-to-date of new packages and changes, possibly user-friendly and cheap.

The MCF' sawmill represent a unique case study to illustrate how an integrated management system based on barcodes can possibly contribute to innovate a sawmill with comparable characteristics. The research revealed that there are few market proposals and variable solutions according with sawmill' economy availability, intervention timespan and vastness. Of course, this innovation is not appropriate for family-run businesses because it is not required and sustainable in economic terms, but it would definitely improve MCF' sawmill work flow efficiency.

2. Material and Methods

In order to satisfy the research' objectives, a survey analysis was performed. It is one of the well-known tools to get general and detailed information on a specific issue. A non-probability sample method was applied: the "judgement sampling", in which the example is defined by the researcher opinion or through the consultation of an expert. This choice is strictly connected with the research' aims: it's not required to make a statistic research based on a well-represented sample, but it's well-accepted to know in general how these systems work in timber industry.

Two questionnaires were prepared (see Appendix A and Appendix B), one for software designer businesses and a different one for timber companies equipped with a barcode management system respectively. The questions were defined after internship of 5 weeks at the sawmill. There, I understood how the sawmill production is organized and how the actual management system works, with the aim of identify the sawmill' requirements for a barcode system.

The questionnaires were filled out by face-to-face interviews. This method has some advantages: high response rates, minimize misunderstanding, probe the answer of the respondents and observe their behaviour at the same time. The main disadvantages are high costs, time consuming and intrusive. Overall, in this investigation there were some limiting factors, which drastically reduced the number of companies involved. The most important is the lack of innovation in most of the sawmills, most likely they are family-run business. Another one is represented by the area of interest, which regarded the Italian situation; so, foreign companies weren't involved. Also knowledge and barcode application on this sector is still limited. As a consequence, barcode system bidding companies are restricted. Nevertheless, this approach allowed to get information on barcode systems from its promoters and users. In this way, a general overview was detached.

Market' proposals (objective 1) were firstly analysed by visiting Xylexpo fair on the 8th May, 2018. It is an international show of technologies involved in the production processes of woodworking. Then, some suggestions were carried out by timber companies in which questionnaires were applied. The benefit of this approach is that only software designer businesses focused on timber industry were identified, which proposals were examined through the relative questionnaire.

In the study of factory implementation with a barcode system (objective 2), the identification of timber companies equipped with was the first target. There, a consultation with the sawmill owner provided an initial target population composed of 6 companies, according

with its experience. Starting from May 2018, they were contacted to verify if they use these systems and its availability to take part on the survey. During the analysis the list was enlarged based on information provided by timber companies contacted.
In both the cases, barcode systems were examined by answering at the following points on the questionnaires:

1. installation data;
2. system' adaptability;
3. operating features;
4. wi-fi connection requirement;
5. learning activities;
6. advantages and disadvantages in comparison with the old systems;
7. cost;
8. time required for installation;
9. companies equipped with these systems and software designer businesses of your information.

Moreover, some specific questions were prepared to understand how such systems work in real cases that are frequent at MCF' sawmill. It is about the working features of barcode systems in the following cases:

- two packages are put together (question 1);
- packages change stock (question 2);
- application within companies characterized of different stocks (question 3);
- barcodes removal for semi-finished products making (question 4).

Questions 1 and 2 were asked at timber companies equipped with barcode systems and software designer businesses respectively, while questions 3 and 4 were applied only at the second ones.
To discuss the barcode system implementation at MCF' sawmill (objective 3) I had also an internship of 5 weeks at MCF' sawmill. There, I understood how the actual management system works; then, I identified what are the sawmill requests for a barcode system. Based on sawmill' requests and questionnaires information, barcode system implementation is discussed.

3. Results and Discussion

3.1 Barcode management systems available at the moment

In exploring market proposals (objective 1), a barcode designer company was identified, and interviewed at Xylexpo fair. Three others businesses were contacted after interviewed companies suggested their name. However, two of them didn't answer; another refused to participate in this project. So, a single software designer business was interviewed. It is Projecta, an Italian system integrator company specialized on software design and production to automate industrial processes and improve the efficiency of working phases. It was founded about 10 years ago and today it accounts of 12 employees. It offers three different software about management, production and warehouse. Moreover, it provides four services concerning software, hardware, integration and consulting. These products can be applied in wood manufacture, chemistry and mechanic sector.

Projecta suggested the JE-Warehouse Management System (JE-WMS) and JE-MOBILE software as the barcode management system suitable for the MCF' sawmill. This system works by portable guns (i.e. palmtops) (see fig. 3.1), that are connected with the central computer. Wi-fi connection is required to allow the registration of the working phases directly with the gun. Barcodes are printed through the connection of portable printers at the gun (see fig. 3.1) or by sending a request on the record database.

Figure 3.1: Portable gun and printer showing how they work simultaneously.

Specific knowledge on the system interface of fixed and mobile platforms is required to work in a proper way. So, learning activities on employees need, which duration varies according modules and application area.

In decreasing importance order, system pros are revealed by Projecta in: less transcription mistakes, precise material identification and traceability, stock management and update directly from the office, real stocks update and time saving. Based on the same criteria, the cons are: the organization of trainings, the software requires paid periodic updates, the need of dedicate an employee to manage the system, data lose and limited compatibility with old informatic systems (like Windows 98).

Few companies are specialized in barcode software design for timber industry. A possible explanation for this may be the low demand of barcode management systems by the timber companies. In fact, of 22 timber companies contacted, only 3 revealed the use of barcode systems.

In fact, most of the Italian sawmills are family-run business (Delpero et al. 2017), focused on the satisfaction of the local market. This explains the limited number of timber companies equipped with a barcode system and the low demand of such systems. It means that its use on Italian sawmills is limited because in small companies, innovation is perceived as not required. Timber companies equipped with barcode system are medium-big size with at least 10 employees, like the companies described in the next paragraphs. So, we can affirm that it is convenient in case of leader companies at national and/or international scale, where the time saving and the high productivity need to be competitive.

3.2 Opinion about barcode systems by system users

To analyse the factory' implementation of barcode system (objective 2) timber companies equipped of barcode were searched. From an initial target population of six companies, the sample was enlarged and 22 timber industries were raised, located in Trentino Alto-Adige and Veneto regions. Among them: nine didn't answer, ten declared that barcode system is not present on their reality. Three revealed that they have been using the system and their availability to participate at the survey. The first produces wood-based panels, the second is involved in wood processing and trading. The third is specialized in wood furniture manufacture. So, three surveys were collected, which information are reported below.

3.2.1 Company 1

It represents an Italian leader in producing wood-based panels. It is equipped with a barcode system since it was founded (i.e. 1986). It is from Progen software, provided by Ateikon (Treviso, IT). In 2017 another software was installed: Wingest, given by Sidera (Trento, IT). Software' adaptability allowed the transfer of most of data collected in Progen to Wingest. Both the systems work through pre-printed barcodes and gun. In particular, the software generates the barcodes and the gun reads barcodes and insert stock changes and machine operations on the packages. These devices interact through wi-fi connection, that is required also to print barcodes and allows every working station to see new packages. This connection is made through digital transmitter, located in different areas of the factory. Another important feature of Wingest software is that, in relation with costumer' requests, it identifies how many boards of a certain package (codified by a specific barcode) need. Then, worked boards take another code provided by the computer while the remaining boards maintain the initial number.

Nevertheless, both the old and the newly installed systems work in the same way, this change required learning activities for the employees. The training period was of 2-4 weeks, according with work' needs. Also a continue update of the office workers is revealed appropriate to perform software' operations.

Progen system cons, for which it was switch, are: it doesn't allow dynamic research and 2-3 months are required to make a change in the software. The advantage of both the systems is the time saved during working operations. Moreover, Wingest requires less time to make a change, which accounts for 2-3 hours. Based on a pros list other benefits were found. In decreasing importance order, they are: less mistakes, packages traceability, time saving and real updates of new packages and changes. Based on the same considerations its

disadvantages are: system management, excessive operators responsibility in the barcode application, cost and finding mistakes. Information about system' cost and time required for the installation are not provide because they are unknown.
Overall, the company is more dissatisfied than satisfied about the old system, while it is fully satisfied for the new one.
Three others companies were suggested by company 1 as sawmills who use barcode system. They are located in Austria; so they weren't contacted.

3.2.2 Company 2

It is a sawmill, who was founded in 1960. It is involved in working and sale of sawn timber (especially hardwoods), semi-finished wooden products and pellet. In this reality a barcode system was introduced between 2010 and 2011 by Zucchetti. Only some functions of the old system were adaptable to the new one. Theoretically Zucchetti' software works by pre-printed barcodes and gun. Practically the gun still doesn't operate. So, the system is used only to manage packages movement between the stocks. In this system wi-fi connection is not required to print the barcodes, that are manually registered on the computer. Moreover, the innovation didn't need of learning activities for the employees.
System' pros identified by the owner are: time work saving and higher traceability. Based on a pros list other benefits were found. In decreasing importance order, they are: time saving, real updates of new packages and changes, less mistakes and packages traceability. Based on the same considerations its disadvantages are: high cost and system management.
System' cost and time required for the installation are not provide because they are unknown. In conclusion, even though the gun doesn't work, the owner is fully satisfied of this system. Two others companies were recommended as potentially equipped of barcode systems; the first one wasn't call because it is ubicated in Austria; the second one didn't answer.

3.2.3 Company 3

It works on furniture components since 1964. Plinths, light rails, cornices and accessories represent the company' products. It covers 10.500 m² and accounts for over 40 employees. There, barcode system was installed in 2014 by Projecta. It is about JE-WMS and JE-MOBILE software, who became operative in 2015. Old system catalogues and configurations were transferred to the new one; it means that JE was adaptable with the old management system.

JE works by pre-printed barcodes and gun (that is equipped of JE-MOBILE), connected via wi-fi. This connection is necessary to include new packages, make them visible from working stations and to print barcodes. Full system operability required employees training. It was organized in four days for everybody, spread in two years, with a total amount of 1000 hours for 30 employees (i.e. about 30 hours per employee).

JE advantages defined by the owner are data traceability and semi-automation of the factory' processes. Based on the list, in decreasing importance order other benefits are: real update of new packages and changes, time saving, packages traceability and less mistakes. Its cons are: no user friendly and requirement of specific knowledge for the office worker to perform software' operations and changes. Another important disadvantage carried out by the list is that, if there are mistakes, it's difficult to find out and correct them.

Installation cost accounts for dozens of thousands Euro.

Time required for installation was six months to start and two years to make operative all its functions. Owner revealed that it is fully satisfied of this system; moreover, through JE time saving in stock management is high and it amortises system' cost.

A barcode designer business and a timber company equipped of barcodes were suggested by company 3. The first one declared that in this moment it cannot participate on the study; the second one wasn't call because of its location.

To wrap-up the questionnaires information are briefly summarized. Even though barcode is an old technology (Pihir et al. 2011), in timber industry it was applied mostly recently (only in one case it has been applied more than 30 years ago). However, timber companies applied different barcodes systems: JE, Zucchetti, Wingest software. Despite this, all systems work by pre-printed barcodes and gun. In particular, the software generates the codes and the gun reads its information, update and register other features of the material in relation with the working progress. To do this, pre-defined information should be registered on the software. For this reason, primary attention is focused on the adaptability, i.e. the possibility of transfer and convert data from the old management system to the new one. Moreover, it is fundamental to guarantee the continuity of data collection and make comparison and analysis of many parameters during the time, like cutting volume, productivity and sale. In both the cases, new systems were compatible with the old ones. Dealing of new management systems, employees training activities were necessary. It concerns of learning and continue update of operators, which varies according with worker' needs. Barcode systems advantages and disadvantages are summarized in the figures below (see fig. 3.2 and 3.3).

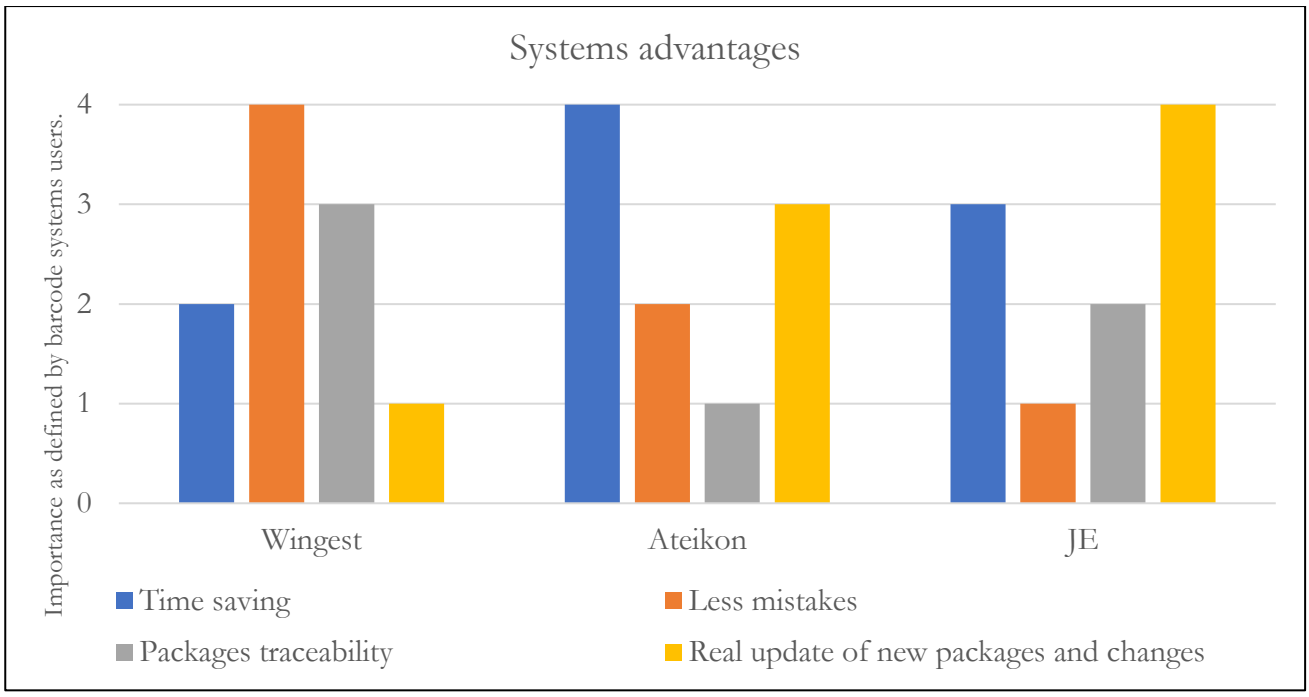

Figure 3.2: Barcode systems pros defined by its users in importance order (4= very important; 3= fairly important; 2= important; 1= slightly important).

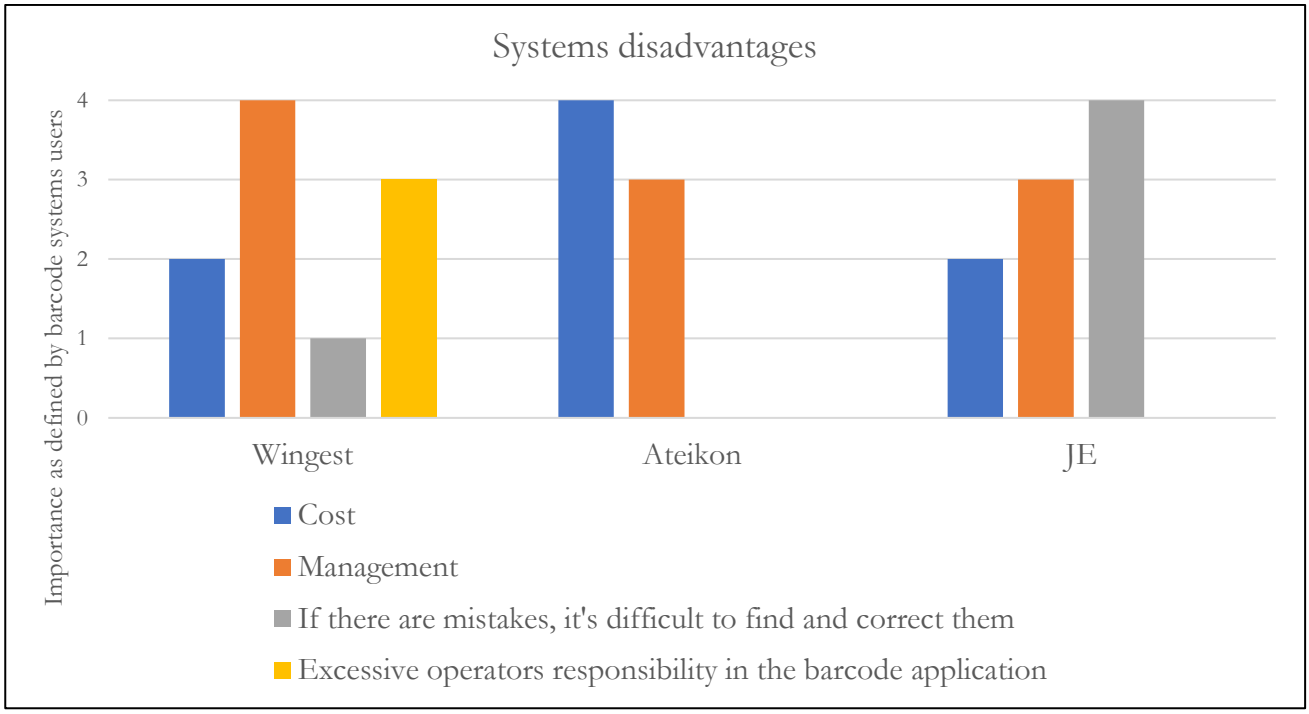

Figure 3.3: Barcode systems cons defined by its users in importance order (4= very important; 3= fairly important; 2= important; 1= slightly important).

In both the figures above (see fig. 3.2 and 3.3) we can see that Wingest, Ateikon and JE have different pros and cons. This result is very important to identify what is the most suitable solution, according with the sawmill' requests for a barcode system.

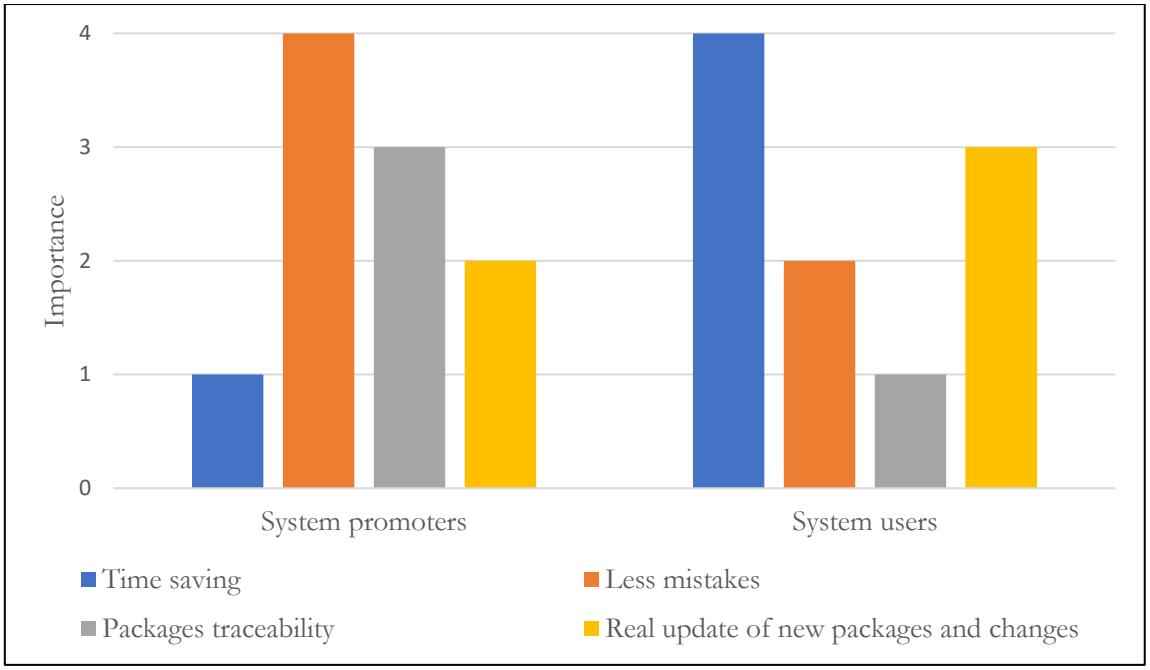

Figure 3.4: Comparison of barcode system pros ordered for importance by system promoters and users (4= very important; 3= fairly important; 2= important; 1= slightly important).

On the figure 3.4 system pros are represented by comparing the answers of barcode system promoters and users, to detach an overview of that system. Projecta, the software producer company interviewed, identifies the mistakes' reduction as the main advantage, followed by packages traceability, real update of new packages and time saving.

According to the system users, time saving is the most important advantage. In fact, handmade operations are performed through informatic technology which is faster and more precise (Jia et al. 2018). However, it allows the real update of new packages and changes (second advantage), which is essential to plan the delivery material date. Through informatic technology, also frequent mistakes of manual input and writing are reduced (third advantage). Packages traceability (fourth advantage) is not so important because, in both the cases, it has been assured by the old management systems.

A possible explanation of these differences may be the different way of thinking of system promoters and users. As reported above, these systems have some disadvantages. Timber companies declared that the software management is the weakest point, followed by its cost. A reliable explanation for these might be the lack of innovation for long time in timber industry.

As a consequence, new systems are completely different from the old ones and a lot of time is required to understand its features. Moreover, a huge investment is required because all

the system should be renewed. Finding mistakes (third disadvantage) in some cases is not immediate.

Dealing with new systems installed recently, makes it unclear of what is the proper way to work in these situations. Operators responsibility is defined excessive only in one case. Most of companies revealed that it is the same of the old systems; what is changing is the way to work.

Projecta, a software designer company, revealed and ordered for its importance other disadvantages, which are:

- sometimes the software requires periodic payment updates (fairly important);
- could be necessary to employ an operator for the software management (important);
- possibility of data loss (slightly important).

In addition, it says that cost and management, which were defined as cons by system users, are the consequences of the innovation, always present when a change and/or innovation is performed. The complexity of find mistakes underlined above is not mentioned, in sense that it could be a problem only if you don't know well how to move within the software; normally, this condition occurs in the firsts months after the installation.

Operators responsibility is revealed as equal as the handmade systems; what is changing is the way to write packages number. So, it doesn't represent a disadvantage, according with most of timber companies.

Also some specific questions were prepared to understand how barcode systems work in specific real cases. The relative answers are summarized in the tables 3.1 and 3.2.

Question: "How do you proceed if two packages are put together?"			
Answer	Wingest	Ateikon	JE
It doesn't happen	X		
Previous numbers are deleted		X	
Re-use of a package barcode			X
Use of a new barcode		X	X

Table 3.1: Barcode systems working features in case of put two packages together.

Question: "How do you work if the packages change stock?"			
Answer	Wingest	Ateikon	JE
A download operation is performed	X	X	
Another code is provided		X	
A transfer or mission is done with the gun			X
Barcode remain the same			X

Table 3.2: Barcode systems working features in case of packages change stock.

What stands out in the tables is that different software provide solutions to work on specific real cases. More precisely, in case of assembling two packages (see table 3.1) both the systems work by using a new barcode. If the packages change stock (see table 3.2) Wingest and Ateikon proceed with a download operation accomplished with the use of a new barcode, while JE works by a transfer or mission with the gun and barcode remain the same. Others information are carried out from the software designer business (Projecta), in which questions about system application on timber companies composed of different stocks and semi-finished products department were asked (see paragraph 2.2). The relative answers are summarized as follow:

- in a company composed by different stocks it proposes to use neutral barcodes, that identify a specific information when they are applied;
- if packages go on the semi-finished products department and barcodes should be removed, a reliable solution consists in send the packages in working progress with the gun; then, barcodes are removed. At the end of the process, new packages take a new barcode.

3.3 Implementation of a barcode system at MCF' sawmill

The analysed systems simplify the management of boards packages because they are time saving, mistakes reducing and real updating in favour of packages traceability. These pros fill its cons (management, high cost) required for its installation and functioning. So, barcode system is appropriate to implement the management system of timber leader companies.
Based on surveys' information, the MCF' sawmill has the preconditions for the installation of a barcode management system. In fact, it is a leader company in softwood lumber where the time saving and the high productivity need to be competitive. According with MCF' sawmill requests for a barcode system (see paragraph 1.2) and barcode systems pros and cons (see fig. 3.2 and 3.3), the study revealed JE, provided by Projecta, as the most useful solution. It is the most convenient in terms of management and cost; moreover, it guarantees the real update of new packages and changes simultaneously with time saving.
This barcode management system is composed of an informatic platform for logistic and stock automation (JE-Warehouse Management System), that check material movement and store by managing simultaneously its removal and restock. This system is accomplished of a complementary platform for portable terminals (JE-MOBILE), that is connected with the fixed one via wi-fi.

JE-WMS is characterized by six main functions:

1. control panel: it makes analysis on productivity and free space in graphs;
2. mapping: management and division of logistical space in different areas, according with stock type, movement, etc;
3. configuration: useful for multi-company and/or multi-plant;
4. integration: implementation with others management software by data import/export;
5. movement: management of removal, restock, inventory, material traceability with lot and quality;
6. data: receiving data from unmovable position, mobile pc and Radio-Frequency IDentification (RFID) gates.

These functionalities are well performed by applying together a mobile platform (JE-MOBILE), that works in connection with the fixed one. It controls the logistic by using the most innovative identification technologies (barcodes and RFID). So, the stock management is performed with palmtops and portable printers (see fig. 3.1).

Its functions are summarized in:

1. inventory: driven procedure for easy inventory management;
2. delivery and shipping: management system of incoming and outgoing logistics;
3. tick packages: check procedure management;
4. stock: stock transactions (removal, restock) control;
5. production: manufacturing progress and declaration;
6. labelling: control of packages label process.

This application is available for Windows CE, Windows Mobile, Windows Phone and Android platforms.

System application process suggested by Projecta use a step-by-step method, which cost depends on factory needs; normally, an annual fee is established that includes base assistance and updates. System implementation could be done also by using "Fondo Impresa", an interprofessional fund promoted by the main trade union associations (CGIL, CISL and WIL).

4. Conclusions

The purpose of the current study was to explore the possibility to include a barcode management system at MCF' sawmill. More precisely, this objective was examined by exploring market proposals (objective 1), analysing factory implementation (objective 2) and discuss system application at MCF' sawmill (objective 3). This research has identified that market proposals are limited at few software designer businesses. It means that MCF' sawmill has to choose between few market proposals. The second major finding is that barcode system is appropriate for timber leader companies at national and/or international scale, like the MCF' sawmill. This study has found that barcode systems work by pre-printed barcodes and gun. The most important advantage of barcode system is the time saving, while the main disadvantage is the hard management. Overall, barcode systems simplify the business management and increase its efficiency. The most important finding to emerge from this study is the possibility to modernise the MCF' sawmill with an integrated management system based on barcodes. Collected data suggested Projecta as the most suitable solution for this purpose.

In general, knowledge on barcode systems for timber companies is still limited. Nevertheless, these findings show a reliable solution to fill the gap in the actual management system of the MCF' sawmill. So, this thesis has provided an innovative tool to modernise the management system of leader sawmills at national or international scale, like the MCF' sawmill.

A limitation of this study is the low participation of timber companies and software designer businesses. This might be explained by considering that the collaboration was asked from a student, clearly not a client. Also the lack of innovation in timber industry reduced the number of companies involved. Notwithstanding these limitations, the study suggests that there are some solutions useful to improve the efficiency and the efficacy of management.

Despite these promising results, remain unclear how barcodes can work simultaneously with old management systems.

Acknowledgment

In this thesis I would like to thanks all people who collaborated. First of all, thanks to the MCF sawmill' owner Stefano Cattoi, who defined the need of a feasibility study on barcode system. Moreover, he provided the initial list of timber companies who were supposed to be equipped of barcode system and he suggested some questions useful to understand how the barcode system works in specific real cases. I want to thank all the sawmill workers, who dedicated some time to explain the productive processes; however, they were always friendly during the internship. Among them, I mention Claudio Corradini, the office worker who provided information on the actual management system. In particular he taught how does it works based on real cases and the relative problems. Another important gratitude goes to Paola Gatto, a professor of rural economy and evaluation of Padua University. She suggested some criteria useful to prepare the questionnaires, like the presence of open questions (i.e. what are system pros or cons) and questions with provided answers that will be ordered for its importance by the respondents. Thankfulness to Giovanna Piccoli, who helped me during the thesis correction. An important thanks goes at the timber companies that adhered to this survey and allowed to visit them and collect information about their management system. Without them, the thesis would not have been done. I would like to express gratitude to Projecta, the software designer business who participated on the study. In this sense, thanks to Massimo Rossi, the responsible of sales and account manager. He organized a visit to see on a timber company how its system works on real cases. In addition it was always friendly and available for clarifications.

I know that in general the supervisor should not be thanked because the thesis is the final result of a collaboration relationship. But, I believe appropriate to mention my supervisor, the professor of wood technology Alan Crivellaro. Before to identify the thesis, he helped me in finding some companies to work with. Moreover, during the study he was always available for suggestions, comments and clarifications with a modest attitude.

Thanks to my girlfriend, who always supported me during the internship and the writing of the thesis also if I was often angry and stressed.

Thanks to my family, who accepted my desire to continue the study in the master course of Forest Science. Moreover, they provided the economic support also during the internship and the visits at the timber companies. Furthermore they supported me in solving the problems occurred during the study.

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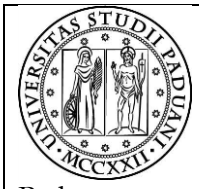
Appendix A: questionnaire for timber companies equipped with barcode systems.

Padua University	**Statistic survey on barcode systems in timber industry**		**Questionnaire for timber companies equipped of barcode system**
Date	Timber company		Products
Question number	Question		Answer
1	Software name		
2	How long did you install the system?		
3	Has it been possible to adapt the old management system to the new one?		
		☐	Yes
		☐	No
		☐	In part
4	How does the system works?		
		☐	Pre-printed barcodes
		☐	Transponder
		☐	Gun
		☐	Other
5	Is the wi-fi necessary for new packages to be visible from the machines?		
		☐	Yes
		☐	No
6	Is the wi-fi necessary to print the codes made by the system?		
		☐	Yes

		☐	No
7	Did you need to organize employees training activities?		
		☐	Yes
		☐	No
7.1	If yes, how long did it takes?		
8	How do you proceed with the barcode if two packages are put together?		
		☐	It doesn't happen
		☐	Previous numbers are deleted
		☐	Use of a new barcode
		☐	Re-use of a package barcode
9	How do you work if the packages change stock (like from fresh to dry stock)?		
		☐	a download operation is performed
		☐	another code is provided
		☐	a transfer or mission is done with the gun
		☐	barcode remain the same
10	What are the advantages of the system rather than the old one?		
			1
			2
			3
			4
			5
10.1	Between these advantages, what are the most important for you?		
		☐	Time saving
		☐	Less mistakes
		☐	Packages traceability
		☐	Real update of new packages and changes
		☐	Other
11	What are the system		

	disadvantages?		
			1
			2
			3
			4
			5
11.1	Between these disadvantages, what are the most important for you?		
		☐	Cost
		☐	Management
		☐	If there are mistakes, it's difficult to find and correct them
		☐	Excessive operators responsibility in the barcode application
		☐	Other
12	Equipment cost		
13	Required time for its installation		
14	Are you satisfied of this management system?		
		☐	Fully satisfied
		☐	More satisfied than dissatisfied
		☐	More dissatisfied than satisfied
		☐	Fully satisfied
15	How much time did you save in the stock management?		
16	Do you know some wood companies that already use this system?		
		☐	Yes, ……
		☐	No, ……
17	Do you know some designer companies of barcode systems?		
		☐	Yes, ……
		☐	No, ……

Appendix B: questionnaire for software designer businesses

 Padua University	**Statistic survey on barcode systems in timber industry**		**Barcode system promoters questionnaire**
Date	Company name		Products
Question number	Question		Answer
1	Software name		
2	Application area		
		☐	Wood manufacture
		☐	Mechanic sector
		☐	Food products
		☐	Other
3	Is the new management system compatible with the old ones (like windows 98) used by the companies?		
		☐	Yes
		☐	No
		☐	In part
		☐	Other
4	How does the system works?		
		☐	Pre-printed barcodes
		☐	Transponder
		☐	Gun
		☐	Other
5	Is a Wi-fi connection necessary to see the new packages for its milling by the machines?		

		☐	Yes
		☐	No
6	Is necessary to have a connection to print the barcodes emitted by the system?		
		☐	Yes
		☐	no
7	How do you proceed with the barcode if two packages are put together?		
		☐	it doesn't happen
		☐	previous numbers are deleted
		☐	re-use of a package barcode
		☐	use of a new barcode
8	How do you work if the package change stock (like from fresh to dry stock)?		
		☐	a download operation is performed
		☐	another code is provided
		☐	a transfer or mission is done with the gun
		☐	barcode remain the same
9	In timber companies composed of different stocks, how do you apply the system?		
		☐	Different barcodes for each stock
		☐	Package takes a number when it is produced, which is update in each consecutive operation
		☐	Other
10	When the packages are put in the semifinished department the barcode should be removed to make other production. How do you proceed?		
11	Does the system requires specific knowledge for its correct use?		

		☐	Yes
		☐	No
11.1	If yes, what?		
12	Did you need to organize employees training activities?		
		☐	Yes
		☐	No
12.1	If yes, how long did it takes?		
13	What are the system advantages?		1 2 3 4 5
13.1	Between these advantages, what are the most important for you?		
		☐	Time saving
		☐	Less mistakes
		☐	Packages traceability
		☐	Real update of new packages and changes
		☐	Other
14	What are the system disadvantages?		1 2 3 4 5
14.1	Between these disadvantages, what are the most important for you?		
		☐	Cost
		☐	Management
		☐	If there are mistakes, it's difficult to find and correct them
		☐	Excessive operators responsibility in the barcode application
		☐	Possibility of malfunctions
		☐	The software requires periodic payment updates

		☐	In case of problem it's necessary to call the bidding company
		☐	Other
15.	Do you know some wood companies that already use this system?		
		☐	Yes, ……
		☐	No, ……
16.	Do you know some designer companies of barcode systems?		
		☐	Yes, ……
		☐	No, ……