Lappeenranta University of Technology

School of Business and Management

Industrial Engineering and Management

Global Management of Innovation and Technology

4 October 2015

Master’s Thesis

SUITABILITY OF LIDAR TECHNOLOGY FOR FOREST INVENTORY IN RUSSIA

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ABSTRACT

Author: Mikhail Smirnov Title: Suitability of LiDAR technology for forest inventory in Russia Year: 2015 Place: Lappeenranta

Master's Thesis, Lappeenranta University of Technology, LUT School of Business and Management, Degree Programme in Industrial Engineering and Management

128 pages, 15 figures, 19 tables, 2 appendices

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LiDAR is an advanced remote sensing technology with many applications, including forest inventory. The most common type is ALS (airborne laser scanning). The method is successfully utilized in many developed markets, where it is replacing traditional forest inventory methods. However, it is innovative for Russian market, where traditional field inventory dominates. ArboLiDAR is a forest inventory solution that engages LiDAR, color infrared imagery, GPS ground control plots and field sample plots, developed by Arbonaut Ltd. This study is an industrial market research for LiDAR technology in Russia focused on customer needs.

Russian forestry market is very attractive, because of large growing stock volumes. It underwent drastic changes in 2006, but it is still in transitional stage. There are several types of forest inventory, both with public and private funding. Private forestry enterprises basically need forest inventory in two cases – while making coupe demarcation before timber harvesting and as a part of forest management planning, that is supposed to be done every ten years on the whole leased territory.

The study covered 14 companies in total that include private forestry companies with timber harvesting activities, private forest inventory providers, state subordinate companies and forestry software developer. The research strategy is multiple case studies with semi-structured interviews as the main data collection technique. The study focuses on North-West Russia, as it is the most developed Russian region in forestry.

The research applies the Voice of the Customer (VOC) concept to elicit customer needs of Russian forestry actors and discovers how these needs are met. It studies forest inventory methods currently applied in Russia and proposes the model of method comparison, based on Multi-criteria decision making (MCDM) approach, mainly on Analytical Hierarchy Process (AHP). Required product attributes are classified in accordance with Kano model. The answer about suitability of LiDAR technology is ambiguous, since many details should be taken into account.

Keywords: customer needs, forest inventory, LiDAR, North-West Russia

ACKNOWLEDGEMENTS

This thesis was initiated by Arbonaut OY. I would like to thank its CEO Tuomo Kauranne for giving me this opportunity and financial support. I am also grateful to Alain Minguet for his significant support and sharing experience and prompts for this research. Hopefully, this work will be useful for you somehow, I paid much efforts to make it complete.

My warmest thanks to Anu Honkannen, previously project manager of NORDI research unit and the coordinator of Finnish-Russian Forest Academy project. You were so supportive and helpful with academic and life developments. Thanks for your advices and patience. I would also like to thank all NORDI staff for amiable milieu and Finnish-Russian Forest Academy for funding of this research. It was my pleasure to be a part of you. Many thanks to my partner Veronika Höök for her assistance in this research.

I want to thank Professor Juha Väätänen for his support and guidance in conducting this thesis and also for informing about this thesis opportunity. Special thanks to Riitta Salminen, your help for GMIT students is invaluable.

I would like to thank my dearest family, my loving mom and dad and my sister. Thanks for all your love and support in all my affairs, in all successes and failures.

Many thanks to my friends I met in Finland, especially to Russian Community. Guys, you made that year awesome. We shared many amazing moments that make this time unforgettable and enshrined it as my best student time. Hope to see you all again!

Mikhail

27 August 2015

TABLE OF CONTENTS

LIST OF ABBREVIATIONS AND TERMS

AAC – Annual Allowable Cut (raschetnaya lesoseka)

ALS – Airborne laser scanning

Coupe – tree felling area, harvesting site (lesoseka)

GIS – geographic information system

GPS – Global Positioning System

Enumeration – on-site inventory method that entails counting a number of trees on a fenced area with measuring of their stem diameter and specific description (perechyot)

Forest land – the whole land allocated for growing forests

Forest management plan – main obligatory document for a forest leaser that determines practical use of forests and includes inventory data on the leased territory.

Forest management planning – set of forestry activities including forest inventory

Forest stand – forest unit, a complexity of forest vegetation (lesonasozhdeniye)

Forest type – parameter, determining dominating tree species and idiosyncratic vegetation

Measuring inventory – on-site inventory method that is based on taking distant tree measurements (by angle gauge) on a circular sample plots (izmeritelnaya taksatsiya)

Merchantability class – wood quality in terms of output production from growing stock (klass tovarnosti)

NFI – National Forest Inventory (gosudarstvennaya inventarizatsiya lesov)

Ocular inventory – on-site inventory method, done by ocular estimations (glazomernaya)

Plot – a partition of a harvesting site (delyanka)

Site class – evaluation parameter of forest stand productivity, based on growth conditions (klass boniteta)

Stumpage appraisal – growing stock assessment of a felling area with separation on size and quality categories and its monetary value calculation

Sample, sample plot – representative site on a forest stand, where field inventory is done (probnaya plosh’ad)

SFR – State Forest Register (gosudarstvennyi lesnoy reestr)

Underwood – young forest that will constitute a forest stand in the future (podrost); bushes or other vegetation that cannot form a main stand, a lower layer of forest stand (podlesok)

VOC – Voice of the Customer

Wood assortment – timber of defined use with size and quality meeting established requirements (sortiment)

1 INTRODUCTION

LiDAR is a promising innovative technology applied for various tasks in different fields, including forest inventory. Its utilization is widely spread in developed countries. Russian forestry is a big-scale yet underdeveloped industry with tremendous volumes of forest resources available. Extensive and commonly exhaustive forest utilization is not acceptable in XXI century, leading to big problems in future. Sustainable forest use must be a cornerstone of up-to-date forestry and it requires forest inventory information available for business planning. Forest inventory in Russia is mainly conducted with traditional field inventory methods, introduced 40-50 years ago. Though, in order to overcome current problems of Russian forestry, considering large sizes of forest area, objective and precise forest inventory methods with high productivity should be used, such as LiDAR. This research is aimed at determining customer needs in inventory information of forest users in Russia and perspective of LiDAR deployment in Russian forestry.

The concept of forest inventory should be ascertained for Russian context. The traditional corresponding notion is “taksatsiya” that is a set of technical practices to define, record and assess current and future qualitative and quantitative forest resource attributes. (Anuchin 1991) The term “inventorizatsiya” is also currently applied, but it is mainly used in connection with National Forest Inventory (NFI). Forest management planning (“lesoustroystvo”) is also related to forest inventory and stands for specialized forest activity aimed at fulfillment of forest conditions assessment, detecting forest resources and activities planning for sustainable forest use (Nevolin et al. 2003). Therefore, forest management planning includes forest inventory. In this thesis, the Russian term “taksatsiya” is used as a synonym of “forest inventory”, though it is only a technical aspect of inventory. Translation of Russian realities into English was mainly done with the use of forestry and wood dictionary (Linnard and Darrah-Morgan 1999).

1.1 Background of the study

This study is conducted within the CONIFER platform and as a part of the second phase of the project Finnish-Russian Forest Academy (2012-2014), coordinated by Lappeenranta University of Technology. The project is funded by the South-East Finland – Russia ENPI CBC Programme and aimed at building a Finnish-Russian network and promotion of cooperation in the forest sector between Finland and Russia. The project targets educational institutions, research institutes, companies, enterprises, and authorities of the forest sector. The activities of the Academy include conducting joint education and research cooperation concerning the forest sector. They are intended to promote business and creation of innovations, to bring in investments, and to contribute to the modernization of the Russian forest sector.

The project of Finnish-Russian Forest Academy established the cooperation and networking platform CONIFER. CONIFER is an open-format information platform and coordinating entity in Finnish-Russian events, education, training, and R&D projects in the forest sector. It was founded to support cross-border cooperation in the forest sector of two countries with member organizations from both Russia and Finland. The project and platform are especially focused on fostering cooperation between South-East Finland and North-West Russia.

Inside Lappeenranta University of Technology, the project is supported by NORDI (The Northern Dimension Research Centre). This unit was designed to support and develop Russia-associated research and cooperation and served as Russia-related network actor.

This research is done in collaboration with Veronika Höök. She mainly studied customer value and competitive advantage of LiDAR inventory. This thesis is oriented at customer needs on forest inventory information in Russia, their technical attributes and potential demand on innovative technology of LiDAR on Russian market.

1.2 Arbonaut Ltd.

Arbonaut is the concerned party and initiator of this research as a member of CONIFER network. It is a Finnish company, based in Joensuu, and specialized in forest inventory and natural resource management and the world leader in developing information gathering and GIS solutions. Its customer-centric solutions are aimed at collection, analysis and web-based distribution of forests of any climate zone and allow coherent combining of different forestry activities. They are based on innovations implementation and continuous technology development. Arbonaut provides complete turn-key solutions as well as independent data gathering and analysis services.

The company has rich experience in developing versatile GIS software solutions applied in wide range of fields from forestry to education. It contributes to development of geo information systems both on open source basis and open standards and commercial platforms. Arbonaut has global reach and partners with leading forestry and technology companies, like Oracle, UPM and IBM. (Arbonaut 2015)

Arbonaut offers a comprehensive solution for laser scanning forest inventory called ArboLiDAR. It provides forest users with high quality inventory data for a various applications, including harvesting, road and drainage planning. The solution has unique automatic stand delineation method. In comparison to conventional manual methods with the use of aerial or satellite imagery, that are time-consuming and subject to bias, ArboLiDAR produces fast, effective and objective stand delineation process. The method implies also leveraging of satellite or aerial imagery and field inventory for sample plots.

ArboLiDAR accommodates the manager with information concerning forest areas requiring an appropriate type of forest activities – harvesting, thinning or tending. Stand delineation is done on the homogeneity criterion of crucial parameters and digital maps with forest clusters enable efficient forest management. It is announced that customers achieve sufficient cost savings in harvest planning with ArboLiDAR covering the costs of LiDAR inventory fulfillment with much less time expenditures. (Arbonaut 2011)

Concerning LiDAR inventory process stages, Arbonaut deals with remote sensing data processing, geospatial modeling and calculation of results. It also facilitates project management. The flights and data acquisitions are typically done by customers. Field works can be done either by supplier or a customer in Finland, while Arbonaut only outsource this type of work and/or provide training in other countries.

The company is trying to penetrate Russian inventory market. It has participated in a number of conferences and industrial fairs. In the matter of precision provided by LiDAR-based inventory, it is claimed to be higher than in traditional field inventory, applied in Russia, but it is rather complicated issue affected by many parameters. While the pricing of ArboLiDAR is several times less on domestic market than that of other inventory methods owing to high human resource costs, it is expected to be at the same level with traditional field inventory on Russian market. Inherent to LiDAR economies of scale should be also taken into account – the information costs decrease significantly with area size increase.

1.3 Research objectives and research questions

The main goal of the study is finding out the possibilities for implementation of LiDAR technology in the Russian forest inventory market. The research is also carried out to discover what forest inventory methods are applied in Russian forestry and to define the “voice of the customer”, requirements stated by inventory information users. These tasks entail several objectives:

- detecting suppliers and users of forest inventory information in Russia and other possible concerned parties;
- formulating customer needs in forest inventory services;
- identifying how these needs are met – what methods are used, how satisfied are customers with them, what selection criteria are crucial for them and other relevant information;
- looking for desirable attributes of a forest inventory method and comparison of applied methods based on customer needs and perceptions.

In order to reach objectives, research questions should be duly formulated. This study deals mostly with technical and informational aspects of forest inventory from customer’s perspective. The main research question is stated as: *Is LiDAR technology viable for forest inventory in Russia?*

The following auxiliary research questions are used to answer the main question:

- What are the customer needs in forest inventory information in Russia?
- How are these needs met?
- What is the customer perception of forest inventory methods?

1.4 Research methodology

This research has a mixed nature of both exploratory and descriptive study (Saunders et al. 2009). Generally, main research question implies exploratory research. Though, understanding customer needs and studying forest inventory in the context of Russia require perusal of secondary sources of information and detailed description of routines and practices related to Russian forestry. Research questions presuppose collecting mainly qualitative data.

1.4.1 Research strategy

Any research strategy can be applied for descriptive and exploratory (and explanatory) study (Yin 2003). In order to answer all set of research questions, case study and partly survey strategies are used. Surveys are common for exploratory and descriptive studies, and it mainly involve questionnaire as data collection technique. However, structured interviews and some other techniques can be also applied. Case studies are common for explanatory and exploratory studies and can be done with various data collection techniques, usually used in combination (Saunders et al. 2009). According to Yin's classification of case studies, multiple and holistic case study strategies are applied (Yin 2003), since the research targets a number of companies that are studied as whole organizations with one unit of analysis (in most companies, depending on their portfolio, forest planning departments are engaged).

Semi-structured interviews are the main data collection technique of this research, while questionnaire is used for the companies interviewing which is not accessible. The same question list applies for both techniques (Appendix 1).

1.4.2 Sampling and data collection

The research focuses on North-West Russia. Its regions are generally more developed (and have forest clusters formed long time ago) and have better financial capacities compared to many other Russian regions, and North-West Russia is close to Finland with established Finnish-Russian networks. In order to limit the amount of companies targeted by this paper, the following regions were chosen for sampling: Leningrad, Vologda and Arkhangelsk oblasts. The republic of Komi was also considered, and companies from this region were mailed out, but it was not visited and companies from this region were not interviewed. Leningrad, Vologda and Arkhangelsk oblasts were more convenient for sampling due to their proximity to Finland and project budget constraints.

This selection was made owing to several parameters. First of all, these regions has big portion of forest coverage (can be seen on Figure 1, where boundaries of North Western Federal District are delineated by thick black line), thus possess big timber amount. Secondly, the leaders in logging volumes among other North-Western regions are Vologda oblast (14 487 ths m^2 in 2014), Arkhangelsk oblast (11 263), the republic of Komi (8 516) and Leningrad oblast (6 291) (United cross-institution statistical information system 2015). In other words, intensive forestry operations take place in there. Finally, these regions have sufficient number of big forestry companies. The issue of company's size was quite essential for sampling as selecting medium- and big-sized enterprises (with big utilized forest area), solvent companies (with high investment expenditures) was a desirable prerequisite. Finish forestry companies with operations in Russia were also approached. Their location was not of much concern.

For the purpose of exploring both needs and practices in forest inventory methods, different stakeholders must be approached – forest leasers (forest users that basically have logging activities), providers of forest inventory and forestry software companies (forest information processing and GIS software), and the state-subordinate institutions (supervising organizations). In order to define customer needs, companies of different profiles were targeted – pulp and paper mills, sawmills, wood-processing and logging industry enterprises. Companies providing forest inventory services and geo information systems were contacted. The companies were approached and questioned by personal visits, phone and skype calls – at company's convenience.

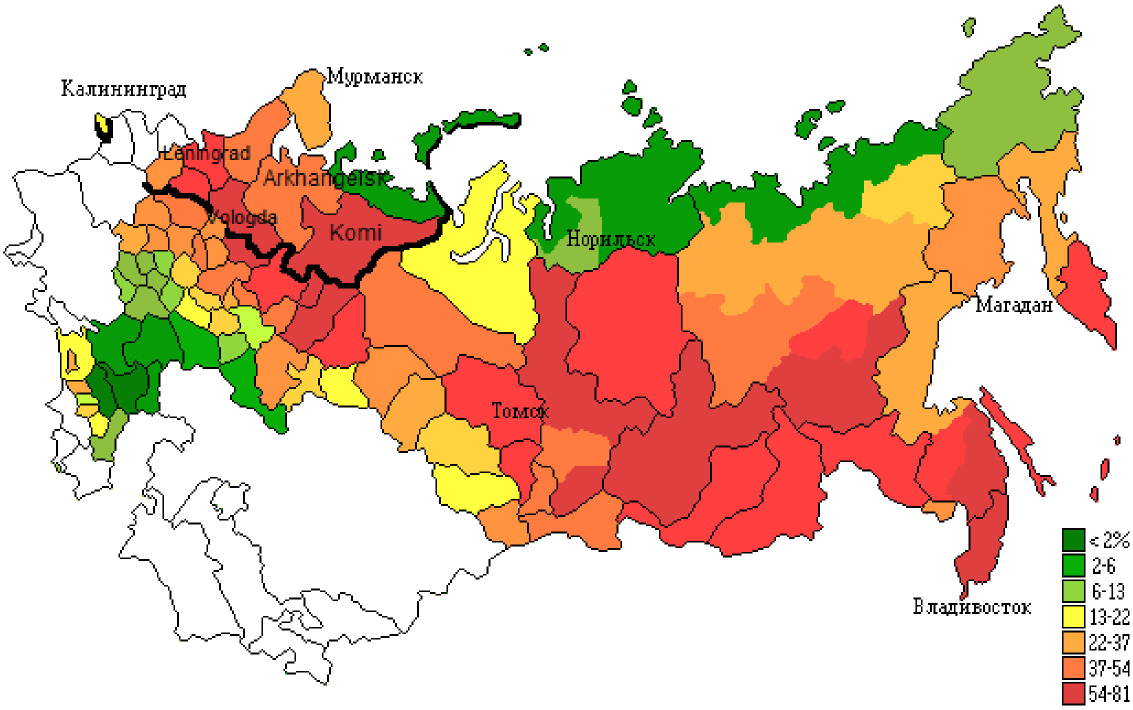

Figure 1 – Forest amount as percentage of total land square (Rus' les 2015)

Company list was compiled with the use of lists and maps with depicted forestry enterprises (ranging in size), separated by industries (Gerasimov et al. 2009), and tables with companies with operation indicators and the list of Priority Investment projects in the Russian forest sector (as of 1.12.2011) (Karvinen et al. 2011). Contact information was found in the Internet, in telephone dictionaries (lesregion.ru) and Russian forestry network Lesprom (lesprom.com), and by referencing.

Data collection includes primary and secondary sources. Semi-structured interviews technique was chosen to obtain empirical data for the work. All contacting with industry's representatives and interviews were conducted in Russian. Some companies felt reluctant partaking in interviews, but agreed to answer questions in written form by e-mail. Data collection is conducted together with Veronika Höök. List of companies was compiled together, and it included 112 companies. The mailout with invitation was done twice by emails, but only one reply was received. The official invitation letter contained information on the project, form of contribution, confidentiality guarantee and other details.

A joint question list includes 27 questions, but for some companies few questions were omitted because of their profiles. All questions are divided into three parts: introductory questions (to outline a company's profile), forest inventory questions (main part) and forest management questions (for the purposes of another research). The question list is presented in appendix 1.

1.4.3 Data analysis

All interviews were recorded on a dictaphone and transcribed afterwards together with Veronika Höök. The length of interviews varies from 40 to 140 minutes. Total time devoted to interviews reaches 10 hours. The interview length depended generally on respondent's wiliness to share information, depth and quality of answers differs significantly between the respondents. Transcribed text was checked and the use of language and grammar was corrected in a thorough way.

In the course of this research totally 14 companies were questioned. Ten companies were interviewed, other four companies answered in written form by e-mail. The answers in written form are short, without much detail. The companies participated in the research mainly represent commercial companies (12) and two governmental organizations. Concerning a type of business, most of those companies are woodworking and logging companies (eight), two of them are Russian operations of biggest Finnish forest companies, three respondents represent the biggest group of companies in corresponding regions. Two other companies are forest service providers with inventory service in their portfolio, one company is a forest GIS systems developer and the last, but not least, company is a house producer made of glued laminated beem. Two governmental companies taken into research are a division of Federal Forestry Agency and a branch of Roslesinforg, the governmental monopoly in the sphere of national forest inventory and the leader in forest management. Although the research is focused on Leningrad, Vologda and Arkhangelsk regions, also two companies from Moscow and one company from Karelia contributed to the research.

Interviewees' opinions are widely present in analysis chapter. Therefore, owing to confidentiality considerations, companies' names are omitted and Latin letters are used instead. Company's brief profiles are presented in Appendix 2.

1.4.4 Limitations

This research targets forest users of North-West Russia, therefore the research questions are answered only in relation to this region. It is the main limitation of this study. The distribution of three respondent types (forest information users, suppliers and software companies, and supervising authorities and state-subordinate companies) was uneven, due to relatively low amount of forest inventory providers (its field tended to be monopolized not long ago), and emerged challenges while contacting governmental institutions. The geographic distribution is uneven as well, owing to low amount of companies agreed on taking part in the research. The research has qualitative nature, and it is based on personal perception of forest inventory needs by forestry companies. Therefore, the discussion of results, for example, comparison of forest inventory methods is rather subjective and cannot be generalized on a broad scale. In addition, only one person in each company was interviewed, opinions and perceptions of other employees can vary.

1.5 Theoretical background and structure of the thesis

This research starts with the literature review. In order to answer the research questions versatile theoretical frameworks are applied.

Owing to the focus of this research on customer needs understanding, the theoretical framework is based on the study of the ”voice of the customer” (VOC) originated from Griffin and Hauser (1993). Stages of the VOC are described, introducing customer needs concept, needs hierarchy and prioritization. In order to classify inventory solutions' attributes, the notion of customer satisfaction is described next in Kano's model of product attribute classifications (Kano et al. 1984). The further development of Kano model, A-Kano model is also introduced (Xu et al. 2009).

In order to formulate recommendations for promotion of LiDAR technology on new market, customer reference marketing is also described. Araising uncertainties for new product launch should be accounted and overcome with customer reference marketing practices.

The big part of theoretical background of this study is devoted to peculiarities of Russian forestry system needed to understand Russian market specifics. It describes established forest classifications, forest administrative institutions, forest use principles and reporting requirements. The geographical focus of this study – North-West Russia is briefly characterized. Russian forestry section is followed by characteristics of Russian forest inventory. Forest inventory in Russia depicted in terms of its types, imperative documents and forest inventory methods applied in Russia. Inventory method description includes conventional methods commonly utilized for decades and few innovative methods for Russian market. LiDAR method is compared with other methods on the basis of these descriptions and interview findings in Discussion section. Forest management and inventory problems are also brought that contribute to understanding of customer satisfactions and possible obstacles for market penetration.

The next chapter of theoretical framework is dedicated to decision-making process in forestry with reference to multi-criteria decision making (MCDM) approaches, especially analytical hierarchy process – AHP (Saaty 1977, 1980). AHP is a simple and effective tool for technology assesment by a number of criteria.

The following chapter is Analysis of Results. It starts with the description of the sample and introduction of case studies. Data collection is classified here. Each case study has an established structure and contains brief company profile, answers to questions of interest, findings and other relevant information. The answers are also presented in the tables for convenience's sake.

The narration is continued by Discussion part, where participants' answers are systemized and research subquestions are answered. The comparison model for forest inventory methods is introduced, it is done with the use of AHP and MCDM approaches. The thesis ends with conclusions, where the main research question is answered based on findings obtained from primary and secondary data. Recommendations for Arbonaut are brought. The thesis structure is presented in the form of chart on Figure 2.

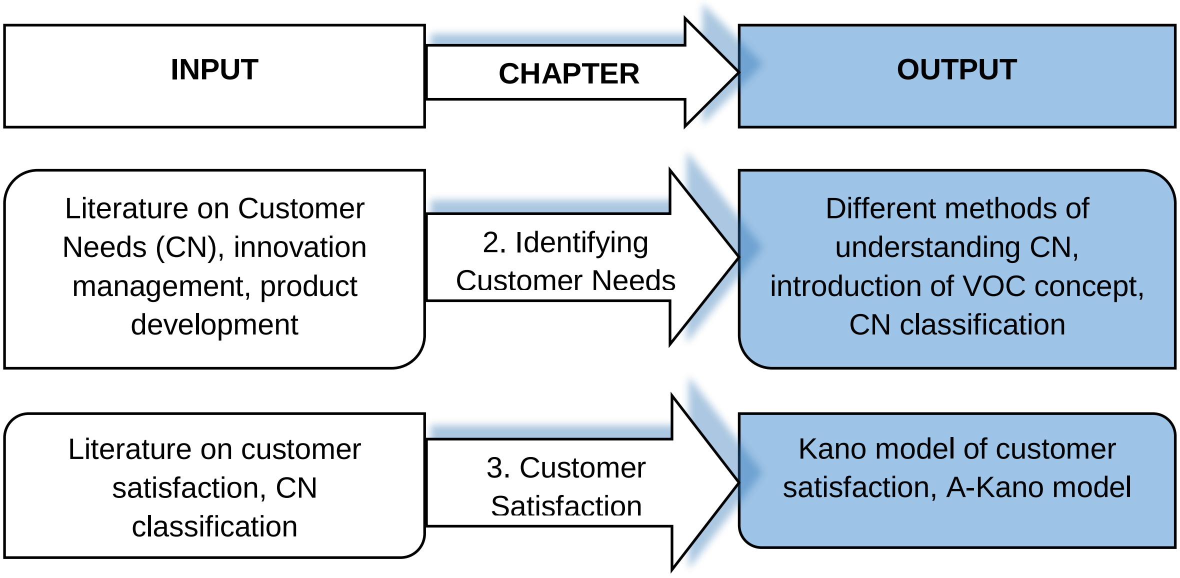

Figure 2 – Structure of the thesis (beginning)

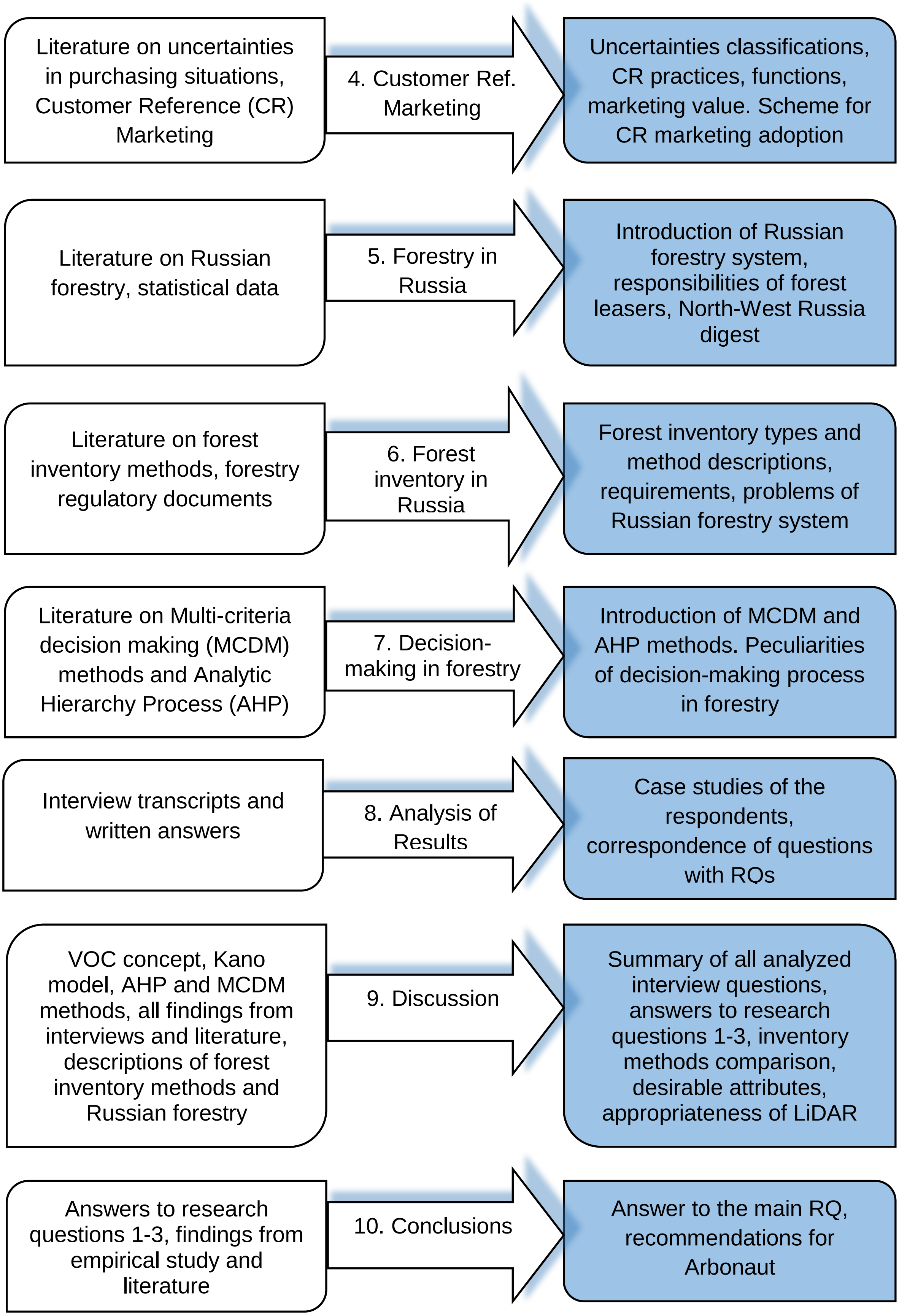

Figure 2 – Structure of the thesis

2 IDENTIFYING CUSTOMER NEEDS

This study aims at conducting a market research of forest inventory in Russia to find opportunities for innovation's implementation and diffusion. It implies identifying and analyzing the market need, market size and existing competition (in terms of products and providers). The market aspects are mainly studied from customer's perspective, and customer needs are in the focus of this research.

Identifying customer needs is possibly the most important stage in the product development process. In order to design a salable product, the company has to understand target customers' needs. The steps of understanding the customer needs are illustrated by Figure 3 in accordance with Ulrich and Eppinger (Ulrich and Eppinger 2011).

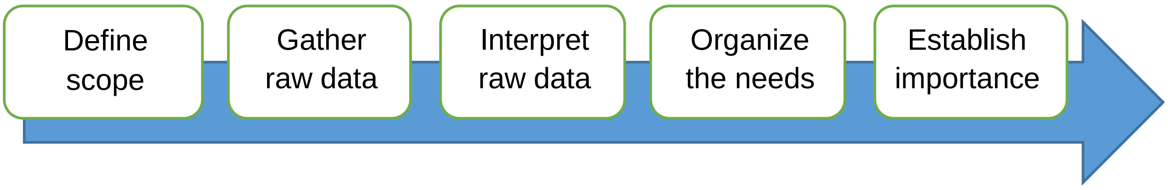

Figure 3 – Generic process for identifying customer needs (Ulrich and Eppinger 2011)

The first step in identifying the needs is to define the scope of the project, which requires formulation of the development project mission. The following aspects are considered in the scope: product description, key business goals, primary and secondary markets, assumptions and stakeholders.

In the second step, data about the market and customers is gathered. According to Lehmann and Winer (Lehmann and Winer 2006), the following questions should be answered to understand the customers: *who buys and uses the product* (understanding the roles of different actors in the purchasing process – initiator, influencer, decider, purchaser, and user. Also includes market segmentation); *what customers buy and how they use it* (customer purchase benefits, not features, also includes understanding purchase frequency, customer lifetime value, and the "share of wallet" assigned to the product), *where and when do customers buy* (preferred channels of distribution of customers, seasonality of demand); and *how customer choose* (different models of customer purchasing behavior). The main methods to collect these data are focus groups and interviews. Another method to gather customer information is observations. (Lehmann and Winer 2006)

In the raw data interpretation phase, the needs stated by customers are "translated" into a language understandable for product development teams. The need statements should express benefits and not the product features or solutions; they must be formulated in a positive rather than negative way; and lastly, the usage of words such as “must” and “should” should be avoided (Ulrich and Eppinger 2011).

Then, identified needs must be organized. The organization process consists of grouping similar needs, eliminating redundant statements, and creating groups of two to five subgroups. In the last step of the needs identification process, some technique should be utilized to establish the relative importance of the needs. This is usually done by consensus among product development team members or with a survey of potential customers, where they are asked to rank or rate a list of a few need statements. (Ulrich and Eppinger 2011)

2.1 Different approaches

According to Squires (2002), there are three research platforms: 1) discovery research (an open-ended exploratory effort to learn about customer culture in order to develop the foundation for new products and services); 2) definition research (there is already a product concept, and the product definition is done by identifying the customer opinions concerning with specific designs, products, and marketing strategies); and 3) evaluation research (there is already a working prototype, and thus the research helps to refine and validate prototypes, design usability, market segments, consumer preferences). (Squires 2002)

Practicing designers, along with the sociology and anthropology literatures, emphasize methods for understanding the complete variety of customer needs. Many articles discuss such ways to uncover customer needs, as empathic design methods, user-centered design and contextual inquiry, as well as ethnography and nontraditional market research approaches. Kansei engineering has also been proposed as a way to expand customer needs information by including customer feelings and other hedonic benefits. Other researchers have suggested ways to embed aesthetics, emotions and experiential aspects into the identification of customer needs. Some researchers also addressed determining priorities, including the use of direct rating scales, the analytic hierarchy process, conjoint analysis, Borda counts and fuzzy/entropy methods. (Bayus 2008)

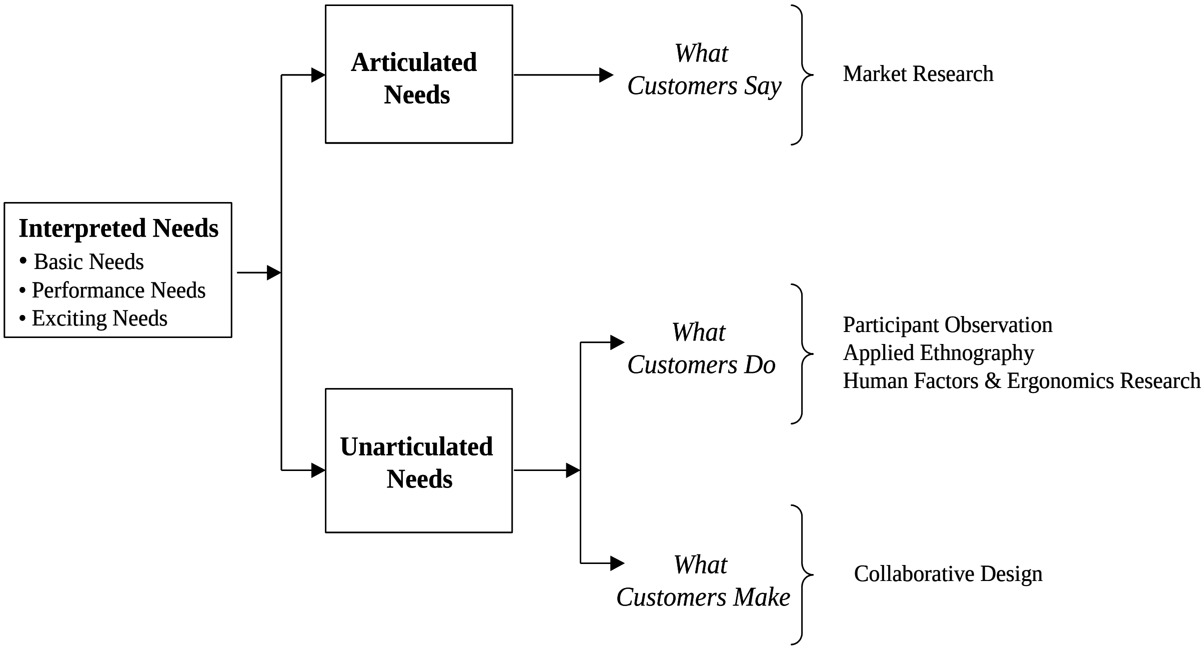

Figure 4 – Approaches for Understanding Customer Needs (Bayus 2008)

Figure 4 systemizes the current theory and practice for understanding customer needs. Interpreted needs consist of articulated (the needs that a customer can readily verbalize) and unarticulated needs (those that customers cannot easily verbalize). There are many reasons why customers say some things (for instance, they believe it is what the researchers want to hear) and many reasons why they do not say other things (they do not remember, do not want to tell, do not know how to tell) (Bayus 2008).

Articulated needs generally involve information dealing with "what customers say." Traditional market research methods such as focus groups, personal depth interviews, surveys, email questionnaires, and product clinics can be used to collect data on articulated needs (Urban and Hauser 1993; McDonagh-Philp and Bruseberg 2000, cited by Bayus 2008). Well-known market research methods include conjoint analysis, perceptual mapping, segmentation, preference modeling, and simulated test markets (Green and Krieger 1989; Urban and Hauser 1993; Kaul and Rao 1995; Urban et al. 1997; Green et al. 2001, cited by Bayus 2008). Other techniques on articulated needs comprise category problem analysis (Tauber 1975; Swaddling and Zobel 1996, cited by Bayus 2008), repertory grids (Kelly 1955, cited by Bayus 2008), Echo procedures (Barthol 1976, cited by Bayus 2008), verbal protocols (Ericsson and Simon 1984, cited by Bayus 2008), laddering and means-ends analysis (Reynolds and Gutman 1988, cited by Bayus 2008). There are also projective techniques, such as product personality profiling, having customers draw their ideal product, hypnosis, and archetype analysis (Shalit 1999 cited by Bayus 2008).

Unarticulated needs generally involve information dealing with “what customers do” and “what customers make”. As suggested by Sanders and Dandanate (1999, cited by Bayus 2008), memories as well as current and ideal experiences of the customers should be considered in order to deeply understand customer needs. A research group can listen to what customers say, it can interpret what customers express and make inferences about what they think to achieve it. Participant observation, applied (rapid) ethnography, and contextual inquiry are the primary methods to discover what customers do. These methods have the common things: they take place in the customer’s natural surroundings and that they are open-ended in nature. In such a way, for example, listening to what customers say can be accompanied by taking notes of conversations and audio taping interviews. (Bayus 2008)

In addition to traditional ethnographic methods, customers can be engaged in self-reporting (studies involving diaries, beepers, daily logs, disposable cameras, self-videotaping, web cameras; Sanders 2002, cited by Bayus 2008), the development team “be the customer” may be organized (collect currently available advertising and point-of-purchase displays, analyze service and pricing options, visit retailers, talk to a salesperson, visit company web sites, call customer support and other actions; Griffin 1996; Otto and Wood 2001, cited by Bayus 2008). Other approaches to better understand what customers do include human factors and ergonomics research (Salvendy 1997, cited by Bayus 2008).

The main method for discovering what customers make is participatory and collaborative design between the development team and the customer. It leads to understanding of what customers know, feel and dream. Techniques include lead user analysis (von Hippel et al. 1999, cited by Bayus 2008), the use of customer toolkits (Thomke 2003; von Hippel 2001; Franke and Piller 2004; Urban and Hauser 2004, cited by Bayus 2008), metaphor elicitation (Zaltman 1997; Christensen and Olson 2002, cited by Bayus 2008), “serious play” using LEGOs (Roos et al. 2004, cited by Bayus 2008), along with making collages, cognitive image mapping, and Velcro modeling (Sanders 2000; SonicRim 2004, cited by Bayus 2008).

2.2 Voice of the customer

The notion of the Voice of the Customer (VOC) refers to the process of capturing customers’ requirements. (Gaskin et al. 2010) As a result of this process, the VOC is a “hierarchical set of ‘customer needs’ where each need (or set of needs) has assigned to it a priority which indicates its importance to the customer” (Griffin and Hauser 1993). This notion has its origin as a component of the Quality Function Deployment (QFD), where the VOC is applied for developing customer needs in relation to design attributes (performance indicators) and basically refers to customer feedback in any form. Collected information is essential for a development of a new product that customers want to purchase, articulating compelling selling points for advertising and promotion, and formulating appropriate pricing strategy to make customers feel that they receive adequate value for the price paid. (Hauser 2008) Underpinning of product development with the voice of the customer is commonly a key criterion in total quality management (Griffin and Hauser 1993).

According to Cooper and Dreher (2010), the VOC methods as sources of ideas include commonly used focus groups, lead-user analysis and customer visit teams. Newer methods such as ethnography, community of enthusiasts, customer (user) design, customer brainstorming, customer advisory board/panel are not so popular. The VOC techniques are opposed to Open Inovation methods (for example, ideas from partners and vendors, ideas from the external scientific community and ideas from start-up businesses) and strategic methods (disruptive technologies and peripheral vision). Three VOC methods – focus groups, lead-user analysis and customer visit teams – seem to be both effective and popular (Cooper and Dreher 2010).

According to Carlson and Wilmot, companies that focus on customers with the use of common language and tools for understanding customer value and has a systematic process of customer value creation, are the most successful (Carlson and Wilmot 2006). Customer value is also a very important concept for manufacturing and product development. *Customer value* can be defined as the benefits that a customer gains explicitly or implicitly from a product, relative to its price (Browning 2003). Therefore, the next equation takes place:

$$\text{Customer Value} \propto \frac{\text{Benefits}}{\text{Price}} = \frac{\text{Benefits}}{\text{Cost} + \text{Margin}} . \qquad (1)$$

There are four aspects of the Voice of the Customer – customer needs, a hierarchical structure, priorities, and customer perceptions of performance. (Hauser 2008)

The first aspects, *customer needs,* relate to descriptions of benefits that a product or service should possess, in the customer’s own words. Understanding customer needs is vital for both product development and marketing. A customer need should be distinguished from a solution or a physical measurement, since it is rather a detailed description (Griffin and Hauser 1993). This distinction is essential in terms of marketing and can be illustrated by the “lens” model of a customer’s choice that is present on Figure 5. The model suggests that customers view the world through the lens of their perceptions or their needs (Brunswick 1952). Thus, customers choose a particular product if they prefer it among others and it is available to them in the market.

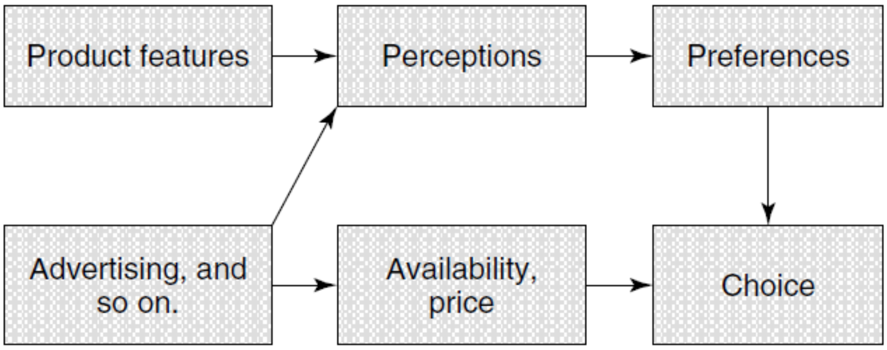

Figure 5 – Lens model of a customer’s choice (Brunswick 1952)

Customer needs consist of basic needs (what a customer presumes a product should do), articulated needs (what a customer want a product to do), and exciting needs (potential performance issues that may delight and surprise the customer). Determining customer needs is mainly a qualitative research question. Typically, from ten to 30 customers are interviewed for approximately one hour in one-on-one interviews. However, focus groups or mini-groups with two or three customers can be organized. (Griffin and Hauser 1993) These interviews are called ‘‘experiential’’, because they are aimed at “experiencing” the customers’ experiences. An interviewee may be asked to articulate the needs related to a number of real or hypothetical experiences (Hauser 2008).

The next aspect is *hierarchical structure*. The amount of needs detected in the first step can be too high that working directly with them is not convenient. In order to get a hierarchy in the VOC, needs must be classified into primary, secondary, and tertiary needs. (Griffin and Hauser 1993) Primary needs are top-level strategic needs (typically 2–10), that define the strategic direction for marketing. Each primary need includes 3–10 secondary, tactical needs, which ascertain aspects that a company should fulfill to satisfy the corresponding primary need. Tertiary needs (operational or detailed needs) give more details for company’s units in question to compose a detailed list of product characteristics or selling points that suffice related primary and secondary needs. Many methods can be implemented for making out a hierarchical structure, but grouping the needs by customers themselves (not by supplier's personnel) is preferable. Focus groups can be applied for this purpose. (Gaskin et al. 2010)

The third aspect is *priorities (importances* by Griffin and Hauser 1993*)*. Some needs are more important for customers than others. Priorities are essential while making decisions what customer needs should be met by a supplier. The balance of cost to fulfill a customer need and its desirability from customer's point of view is taken into account for this. The priorities belong more to the notion of perceived customer needs than to product features or engineering solutions. (Hauser 2008)

Customer's perceptions of performance are a formal market research measurement of how customers perceive the performance of products in comparison with their alternatives in the market. (Griffin and Hauser 1993) If a product does not exist on market so far, the perceptions reveal how customers meet their needs at the moment. Understanding of what products suit which needs most accurately, to what extent these needs are met, and how company's product compete with its rivals is highly valuable in terms of marketing. Customers' perceptions can be shown as a "snake plot" (each product's performance view resembles a snake), while data are usually collected with the use of a questionnaire, where respondents are asked to rate each product on each of the secondary customer needs. (Gaskin et al. 2010)

One more aspect that can be present in VOC is *segmentation.* Customer needs, their hierarchies or their priorities can differ sometimes. If the difference is significant, the segments should be delineated and a complete VOC should be done for each of them. (Griffin and Hauser 1993) Typically, basic descriptions of the customer needs along with hierarchy are common for all the segments. In this case, the segmentation is carried out by identifying priority clusters, and it is called *benefit segmentation* (Hauser 2008).

While concerning the amount of customers that will be interviewed, several issues should be taken into consideration. The first aspect is monetary costs, they are moderate for taking interviews, but costly for analyzing the data. Time expenditures also increase with enhancing a number of interviews. Product development teams tend to avoid unnecessary time delays in the VOC process. On the other hand, there are peculiar benefits of having higher amount of interviews. Firms want to ascertain what number of interviews is enough for unveiling most of the exciting needs. Once exciting needs are met, the supplier gains solid competitive advantages. Companies try to find a balance between identifying a broader set of needs and incurred costs. Griffin and Hauser found out in their study that interviews with 20-30 customers should define 90% and more customer needs, if the companies are quite homogeneous. (Griffin and Hauser 1993)

The implementation of the process steps of VOC has slightly evolved with years of practice after it had been introduced. Initially, most product-development and marketing teams demanded information along the customer-need hierarchy as detailed as possible. Currently the researchers focus on narrower set of needs and work mostly with primary and secondary needs rather than all three layers. Teams tend to delve into tertiary needs for the highest one or two secondary needs only. It helps to decrease amount of measurements on respondents and reduce financial and time expenditures of a marketing research, therefore the researchers may achieve a tradeoff between feasibility and completeness. (Hauser 2008)

3 CUSTOMER SATISFACTION

Customer satisfaction is a very important measure. It is seen as an indicator of product's or service's performance as well as company's future. It reduces price elasticity and even leads to customer's willing to buy more frequently and in bigger volumes (Reichheld and Sasser 1990). Customer retention (defensive) strategies seem to be essential, especially in the saturated market, while new customer acquisition cost is much higher, than costs on keeping the existing client base. For these strategies market share has a qualitative nature. (Matzler and Hinterhuber 1998)

Customer satisfaction is seen as a goal in QFD, since in a long-run, satisfied customers can be viewed as a company's asset. Short-run strategies for the future must be adapted to enhance this asset. High retention rate will lead to higher market share (Matzler and Hinterhuber 1998). Though, customer satisfaction is not linearly correlated with market share. For example, a niche brand can have higher customer satisfaction, than the market leader (Griffin and Hauser 1993). However, high levels of customer satisfaction and perceived quality have additional impact on market share in the future in the form of positive quality image and word-of-mouth. (Matzler and Hinterhuber 1998)

High level of customer satisfaction is claimed to incur high level of customer's loyalty.However, moderate satisfaction does not give much loyalty, therefore producers have to exceed customer requirements and delight them. (Matzler and Hinterhuber 1998) Not only fulfilment of customer needs, but also the type of expectations met determines perceived quality and customer satisfaction (Matzler et al. 1996).

3.1 Kano model

Determining and meeting customer needs have been well understood as one of the basic success factors for product design and development (McKay et al. 2001). Customer need analysis focuses on “hearing” of the voice of customers and following articulation of requirements for marketing and engineering (Jiao and Chen 2006).

Among many methods of customer need analysis, the Kano model is a commonly used effective practice to understand customer preferences. It is a convenient tool in classifying customer needs based on the collected data. The model classifies and prioritizes needs based on how they correlate with customer satisfaction. The relation between customer satisfaction and product performance is nonlinear. The Kano model distinguishes four types of attributes that a product may have: *must-be attributes* do not give much value to the customer, but strong customer dissatisfaction take place if they are absent of poorly sufficed; *one-dimensional attributes* possess linear relationship between their fulfillment and customer satisfaction; *attractive attributes* are usually unexpected for customers and their presence can lead to great customer satisfaction; and *indifferent attributes* that do not interest the customer in the product (Kano et al. 1984).

Sometimes other names for these categories are used: for example, *one-dimensional attributes* may be called as *primary satisfiers* or *performance attributes, attractive attributes* as *delighters* or *excitement attributes, must-be attributes* can be called as *threshold attributes.* The category of indifferent attributes is not of much interest for many researchers, since they do not belong to customer needs. Therefore, it is often not present on the model scheme. Kano diagram is shown on Figure 6.

The must-be requirements are basic requirements for a product. If these requirements are not met, the customer will be highly dissatisfied, although their fulfillment does not increase customer satisfaction. They are prerequisites, the customer takes them for granted and does not explicitly voice them. In any case, must-be attributes are a crucial competitive factor, because if the product misses them, the customer does not consider purchasing of this product at all. (Matzler and Hinterhuber 1998)

In the case of one-dimensional requirements, customer satisfaction is proportional to the extent that they are met. The better value these attributes have, the more satisfied the customer is. They are typically explicitly articulated by the customer. (Matzler and Hinterhuber 1998)

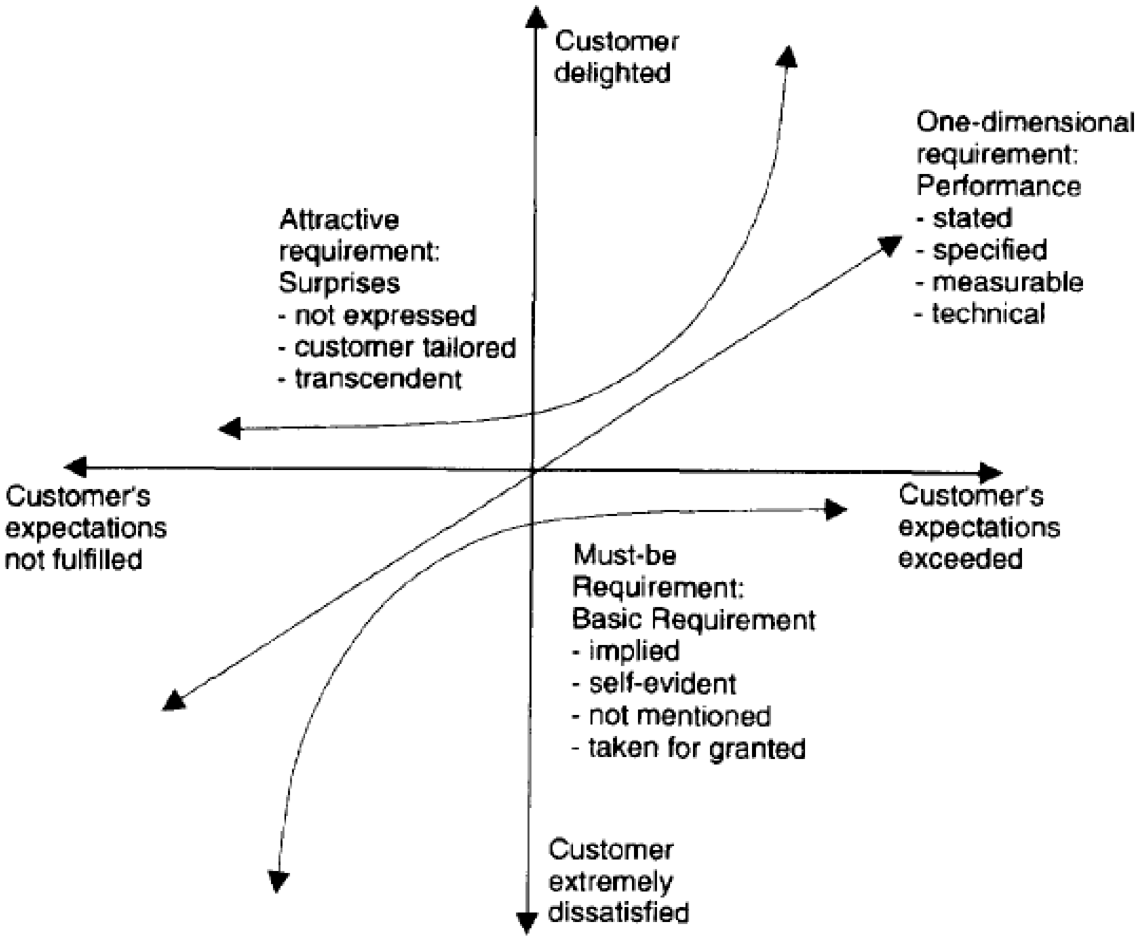

Figure 6 – Kano's model of customer satisfaction (Berger et al. 1993)

Attractive requirements are the most important in customer satisfaction. They are not expressed and unexpected by the customer. The relation between meeting them and customer satisfaction is more than proportional. On the other hand, if they are missing, the customer is not dissatisfied. Attractive attributes that a product has, increase customer perceived value. (Matzler and Hinterhuber 1998)

Kano method possesses clear advantages in classification of customer needs: product requirements are better understood, their classification gives understanding for the supplier about which ones to invest; it is valuable for tradeoff occasions in product development process; specific customer-oriented solutions can be developed for different customer segments with optimal level of satisfaction; the method discovers differentiation opportunities, creating products with different sets of attributes; and applicability in Quality Function Deployment (QFD). (Hinterhuber et al. 1997, cited by Matzler and Hinterhuber 1998)

The Kano model is usually based on questionnaires with a set of question, in which a question pair is assigned to every product attribute. This pair consists of a functional form question, which seizes a customer's response if a particular attribute belongs to the product, and a dysfunctional form question, which seizes a customer's response if the product does not possess that attribute. The questionnaire is distributed to a customer set, and Kano evaluation table has values for each pair (Berger et al. 1993), defining a corresponding customer's perception of a product attribute. (Xu et al. 2009)

The Kano diagram demonstrates customer's satisfaction of the corresponding product performance level. In this way, the model represents only a qualitative method for product attributes assessment. (Xu et al. 2009) A simple way to assign some quantitative values is embedding a scale of customer satisfaction/dissatisfaction (Matzler and Hinterhuber 1998). Though, the results will remain being qualitative in nature and cannot reflect the exact degree of customer satisfaction (Berger et al. 1993).

Customer needs can be sorted by different criteria – empirical observation, mode statistics, and customer satisfaction coefficient. Two-dimentional metrics of attribute categories based on the customer satisfaction coefficients can be used. In this case, a positive number applies the relative value of fulfillment the customer need, and a negative number stands for relative costs of not fulfilling this customer requirement. Another way is a graphical Kano diagram with predefined scales of customer satisfaction/dissatisfaction. Two values (coordinates) are assigned to each requirement and they define the nature of a product attribute based on the quadrant on the graph where this point belongs to. (Berger et al. 1993)

However, the Kano model has some shortcomings. It seems to be inadequate for decision making which attribute should be applied to a product and which not. The proposed methods for giving numeric values stay subjective, the attributes within the same category cannot be distinguished by common practices, and the model represents a qualitative routine. The model is customer-driven and the producer's capacity is not evaluated by the model. Cost constraints are commonly defined by the expertize of a product development team, so that only available (for producer) features will be included in the product (Matzler and Hinterhuber 1998). Some researchers proposed cost functions, but they are inadequate to consider complex product development costs (Xu et al. 2009).

3.2 A-Kano model

Xu et al. proposed an analytical Kano (A-Kano) model. It extends the original Kano model (Kano et al. 1984; Berger et al. 1993) by bringing in new quantitative indicators and statistical calculations. New features of the model include: *Kano indices*, quantitative values that measure customer satisfaction based on Kano questionnaires and surveys; *Kano classifiers*, which comprise a set of criteria for customer needs classification based on the Kano indices; *Configuration index*, which facilitate functional requirements choice by decision factor; and *Kano evaluator*, a performance indicator considering both the customer's satisfaction and the producer's capacity to meet customer requirements. (Xu et al. 2009)

A-Kano model considers interaction between customers and suppliers. Customer needs seems to be imprecise and ambiguous owing to their linguistic nature (Jiao and Chen 2006). Therefore, analytical tools can be hardly utilized for the analysis of customer needs, and the concept of *functional requirements* (FR) is introduced, meaning objective and explicit specifications obtained from customer needs (CN). The producer calls on them while searching for economy of scale after retrieving diversified customer needs. The process of analytical Kano model deployment is illustrated on Figure 7. (Xu et al. 2009)

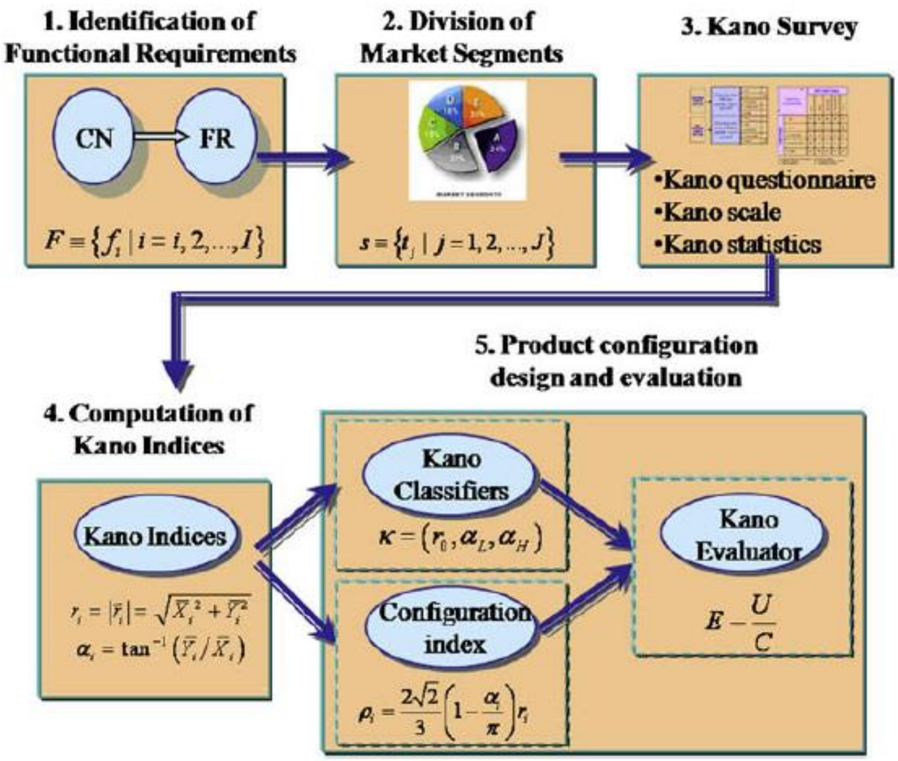

Figure 7 – Steps of analytical Kano's model (Xu et al. 2009)

Xu et al. study showed that A-Kano model has better performance than traditional model in some aspects. It provides customer need analysis with quantitative measure of customer satisfaction, decision support, considering producer's capacity. It gives an opportunity for logical prioritization of customer needs and advantages assessment of the designed product with the Kano evaluator. The routine of product configuration design is among the main difference of these two methods – in traditional Kano's model functional requirements are selected manually, based on the attribute categories. In comparison with other quantitative methods (conjoint analysis, stated choice methods, and discrete choice analysis), the A-Kano method determines customer preference based on customer's satisfaction/dissatisfaction. (Xu et al. 2009)

4 CUSTOMER REFERENCE MARKETING

4.1 Arising uncertainties

While making purchasing decision, industrial customers face some uncertainties, like whether the solution meets the needs, whether it will work as expected and others. There are three main classifications of such uncertainties.

Håkansson et al. distinguished such types of uncertainties as need uncertainty, transaction uncertainty and market uncertainty (Håkansson et al. 1976).

Need uncertainty relates to the situation when a buying organization does not know exactly what product or what amount of it to buy. This lack of knowledge upon making a decision is crucial here, and hence need uncertainty is likely to be higher for new purchases. Also, It is typically higher in the case when the need itself is more important. *Market uncertainty* comes from difficulties of supplier's choice for a buyer. These difficulties depend on alternative suppliers – how different they are from each other and how changing these differences are. They can be overcome by increased knowledge, but it can be costly – evaluating different options before making purchasing decision require additional time and efforts. *Transaction uncertainty* stands for uncertainty that the buyer is exposed right after a transaction has been agreed. Delivery can spoil a product, delays can shift time frames of project schedule and so on. This kind of uncertainty is also dependent on relationships and communications between a buyer and a seller. (Håkansson et al. 1976)

According to Cardozo, there are also technical uncertainty and acceptance uncertainty (Cardozo 1980). He added technical and acceptance uncertainty, thus resulting in existence of five types of uncertainties.

Technical uncertainty means that the product performance may be not appropriate in the buying organization's setting. *Acceptance uncertainty* implies that a buyer can be reluctant to purchase a product, even if the need is clearly defined. The researcher presumes that the level of uncertainty can be lower with credible information, and such information can be obtained by the experts in the organization. (Cardozo 1980)

One more classification was proposed by Sharma (1998) and comprises goal uncertainty, resource uncertainty and process uncertainty. *Goal uncertainty* is "the uncertainty concerning the similarities and differences in the goals of the alliance partners" (Sharma 1998, p.514). Therefore, goal uncertainty comes as equivalent of social uncertainty, stated by other authors. Social uncertainty refers to anticipation of another party's behavior. *Resource Uncertainty* stems from the resources the supplier possesses. High level of resource dependency is intrinsic to business markets. The customer lacks knowledge "of the resources controlled by the other party, as well as their importance and usefulness" in delivering the market offering (Ibid). *Process Uncertainty* is heavily related to resource uncertainty. It is defined as the "uncertainty concerning the manner in which the resources of alliance partners can be combined to achieve a mission. This type of uncertainty arises because the resources of the … partners are heterogeneous" (Ibid).

4.2 Customer reference practices

Ability to mitigate these uncertainties is fostered by successful business marketing strategies. In order to decrease high risk perceived by potential buyers, industrial suppliers of complex solutions try to increase credibility with the use of *customer references* (Salminen and Möller 2006). Customer reference is a customer relationship and related value creation activities that a firm leverages externally or internally in its marketing activities (Jalkala and Terho 2011).

Actors in market situations characterized by high uncertainty tend to rely on historical experience when evaluating their potential exchange partners (Podolny 1994). Potential customers cognize the status of supplier's real exchange partners – previous or existing. If customer leads do not have direct evidence of company's performance, they pay attention to previously delivered projects as signs pf prior performance.

Customer references are proposed to contribute a lot to reduce perceived risk and uncertainty to buyer's benefits in purchasing situation and supplier selection. Anderson and Wynstra found out that customer references serve greatly as value evidence in complicated offerings (Anderson and Wynstra 2010).

Customer reference marketing is widely applied in a number of different business fields. For instance, industrial technology and service providers (ABB, Eaton) utilize client case studies and customer success stories and publish them on their websites, large IT firms (Microsoft, Dell, IBM) have properly designed ongoing customer reference programs aimed to evoke their business customers to participate in different reference activities. Eventually, customer reference marketing has become an integral part of B-to-B marketing for many companies. (Jalkala and Salminen 2010)

There is another notion that is similar to customer references to some extent – word of mouth (WOM). WOM is "informal communications directed at other consumers about the ownership, usage, or characteristics of particular goods and services and/or their sellers" (Westbrook 1987, p. 261). Basically WOM is considered to be informal interaction between customers, mainly beyond activities of marketers, while customer reference marketing implies intentional suppliers' practices aimed at leveraging customer relationships portfolio. Word of mouth also pertains to B-to-B markets, and some customer reference initiatives may boost positive word-of-mouth, although bad customer references may trigger negative WOM and spoil the supplier's goodwill. (Jalkala and Salminen 2010)

Salminen and Möller offered the classification of all customer reference practices into external and internal (Salminen and Möller 2006). For external purposes the supplier display references to potential buyers and other stakeholders. For internal reasons the supplier applies customer references inside the company via different practices, like internal case studies and the use of a customer reference database (Salminen and Möller 2006).

Jalkala and Salminen identified different customer reference practices, both internal and external, utilized by companies in the study (Jalkala and Salminen 2010). The table 1 contains practices of external customer reference marketing and its corresponding functions (Jalkala and Salminen 2010, table 3). It should be noted that supplier's control over reference marketing practices decreases from the beginning of the list (where it is high) to its end, depending on corresponding practice and the role of a reference customer. Functions and practices are not tightly connected.

Table 1 – Practices and functions of external customer reference marketing

Customer reference marketing practices	Function of reference-marketing practices
• Reference lists • Success stories, customer cases, case studies, ROI-studies • Sales presentation reference slides • Audio/video testimonial • Recorded reference interviews/podcasts • Press releases • Articles in trade journals • Promotional material • Customer presentations at seminars and conferences • Reference calls • On-site reference visits • Customer events and meetings • Social media	• Provide indirect evidence about experience • Enhance credibility through status-transfer effects • Demonstrate and concretize the offering • Provide indirect evidence of previous performance • Demonstrate delivered customer value • Serve as a certificate of passing through a selection process • Signal an enhanced market position • Provide indirect evidence about the functionality of the technology • Generate positive word-of-mouth

References are highly relevant while assessing technological risks since they display evidence that other companies have applied the technology and it works well. Customer reference marketing enables the supplier to show indirect evidence of the functionality of the solution or technology and therefore reduce the perceived risk of a potential buyer and other stakeholders, for example financiers. (Jalkala and Salminen 2010)

By analogy with external practices and functions for external customer reference marketing, practices and functions of reference marketing utilized for internal purposes are shown in the table 2 (Jalkala and Salminen 2010, table 4).

Table 2 – Practices and functions of internal customer reference marketing

Customer reference marketing practices	Function of reference-marketing practices
• Lessons learned and best-practice exercises • Systematic analysis of a well-documented portfolio of customer references • Measuring delivered customer value from reference cases • Selecting and documenting “iconic cases” • Internal success stories and “solution of the month” types of announcements • Internal reference case descriptions and “reference black books”	• Enhance organizational experiential learning and reduce redundancy • Enhance understanding of customer needs and internal competences • Develop credible value propositions • Aid in customer-led offering development • Motivate personnel • Educate and train personnel

Therefore, customer references can be utilized for the following:

- status transferring from reputable customers;
- communicating an improved market position;
- specifying and demonstrating offerings;
- indirect demonstration of experience, prior performance, technological functionality, and delivered customer value.

For internal purposes, customer references are useful for:

- assisting organizational learning;
- developing understanding of customer needs and internal competencies;
- boosting offering development;
- personnel motivating and training through internally shared success stories. (Jalkala and Salminen 2010)

Customer references portfolio can be applied as an important resource pool for learning and training purposes, for instance, analysis of reference cases leads to understanding of customer needs and internal competences and serves as a part of the transformation process from a product orientation towards a solution orientation (Jalkala and Salminen 2010). In terms of supplier-customer relations and purchasing decision-making, the main functions of customer references are reducing potential customer's perceived risk and arisen uncertainties and increasing the supplier's credibility. The key mechanisms for customer reference marketing are status transfer from reputable reference customers, validation from reference customers' testimonials and demonstration of experience and prior performance. These mechanisms have particular underlying factors, specific situations where they are likely to appear and corresponding customer reference practices. Companies may wish to focus on some of them depending on circumstances, they must take appropriate practices for achieving a desirable effect.

4.3 Customer references as marketing asset

Marketing resources are defined as any attribute, tangible or intangible, physical or human, intellectual or relational, that can be deployed by the firm to achieve a competitive advantage in its markets (Hooley et al. 2005). Customer references are collected within build relationships with customer companies and often treated as the most important kind of marketing assets (Hooley et al. 1998). They have long played an important role for suppliers of complex solutions and technologies with the main forms of reference visits and reference lists accompanying the offer.

Customer references portfolio can be considered as a part of a firm's customer-based assets. Customer relationships are one of the most valuable resources that a company possesses (Håkansson 1987). Customer-based assets, including brand names, customer loyalty and current market position, are the most important type of marketing assets (Hooley et al. 1998).

Many researchers found out that customer reference can facilitate sales and promotion of solutions (Jalkala and Salminen 2010). Some authors discovered “referral effect” of customer references. For example, Baum and Oliver argued that supplier’s benefits coming from advertising recent deal with prestigious customer is similar to the value from the endorsement of licensing agencies (Baum and Oliver 1991), Rao compared them with benefits from winning certification contests (Rao 1994). Davies and Brady coined the term “economies of repetition” (Davies and Brady 2000). This notion implies organizational tools in uniting routines and lessons learned from completed single projects. They can be applied with a set of stories for future projects that will be conducted more efficiently and effectively. The authors studied organizational capabilities and learning in suppliers of complex systems and found that the firms strove to capture experience from closed deals and apply the lessons learned in subsequent projects (Davies and Brady 2000).

Customer references can be utilized as a knowledge base for customer needs. Penrose (1959) applied a notion of “inside track”, which implies information about emerging customer needs that can be acquired by existing customer relationships and applied for developing new offerings and technologies. A supplier is supposed to closely interact with key customers within customer reference practices, that may give in-depth understanding of customer needs (Penrose 1959).

Customer reference portfolio enables identifying and evaluating customer’s value and thus can underlie in building credible value propositions. Then, identified value drivers and assessed customer’s value can help to achieve value-based competitive advantage. (Walters 1999) Quantifying the value given to reference customers can help suppliers to foster their value-assessment capabilities.

According to Grabher, “economies of recombination” is a benefit derived from new combinations of existing elements and by-products taken from previous projects. It can be achieved through reuse of knowledge modules learned from earlier projects (Grabher 2004). Reference marketing can serve as “a schema for offering development” and facilitate value co-creation with customers. The major point in this process is efficient application of existing elements of customer knowledge by reconfiguring knowledge-management systems around customers instead of products. Customer references can be used as an instrument for internal motivation and as a tool for training and educating personnel. Successful cases from the past transmit positive experience into the present for the personnel of the company and help them to feel involvement in company’s success and may inspire motivation (Jalkala and Salminen 2010).

Thus, customer references can be leveraged in many forms of marketing assets. Externally, customer references serve as strong and effective sales and promotional tool. External functions of customer references enhance other marketing assets – they build reputation, increase market credibility and company's client base. Internally, they can be viewed as a template for organizational learning, a knowledge base for customer need and market sensing and understanding of internal competencies, a basis for building credible value propositions, a schema for offering and new product development, an instrument for internal motivation, and as a tool for training and educating personnel. (Jalkala and Salminen 2010) Current trends in B-to-B markets, such as the shift towards value-added solutions (Davies and Brady 2000) and expanding value co-creation with customers emphasize the importance of customer reference marketing.

4.4 Adoption of customer reference marketing

In order to utilize customer reference marketing, particular steps should be passed. Jalkala and Salminen proposed a conceptual framework for customer reference marketing implementation that includes three interrelated processes – building, documenting, and utilizing the customer reference portfolio (Jalkala and Salminen 2008). The mechanism is depicted in Figure 8.

The first defined stage of the customer reference portfolio stands for company’s activities to engage customers to contribute as references. It comprises company’s initiatives in identifying and selecting target reference customers, motivating customers to act as references, formally agreeing about reference activities and balancing the customer reference portfolio. Building the customer reference portfolio requires building up new customer relationships and creating value for those customers for utilizing them as references. Customer’s eagerness to endorse and act as a reference is positively associated with relationship quality (Huntley 2006). Therefore, good customer relationships are a prerequisite for customer reference marketing, particularly if the reference customer is highly involved in the process (Salminen and Möller 2006). The study of Jalkala and Salminen revealed that at this stage companies can apply the following tools: price reduction, extra guarantees, extra services and support and others (Jalkala and Salminen 2008).

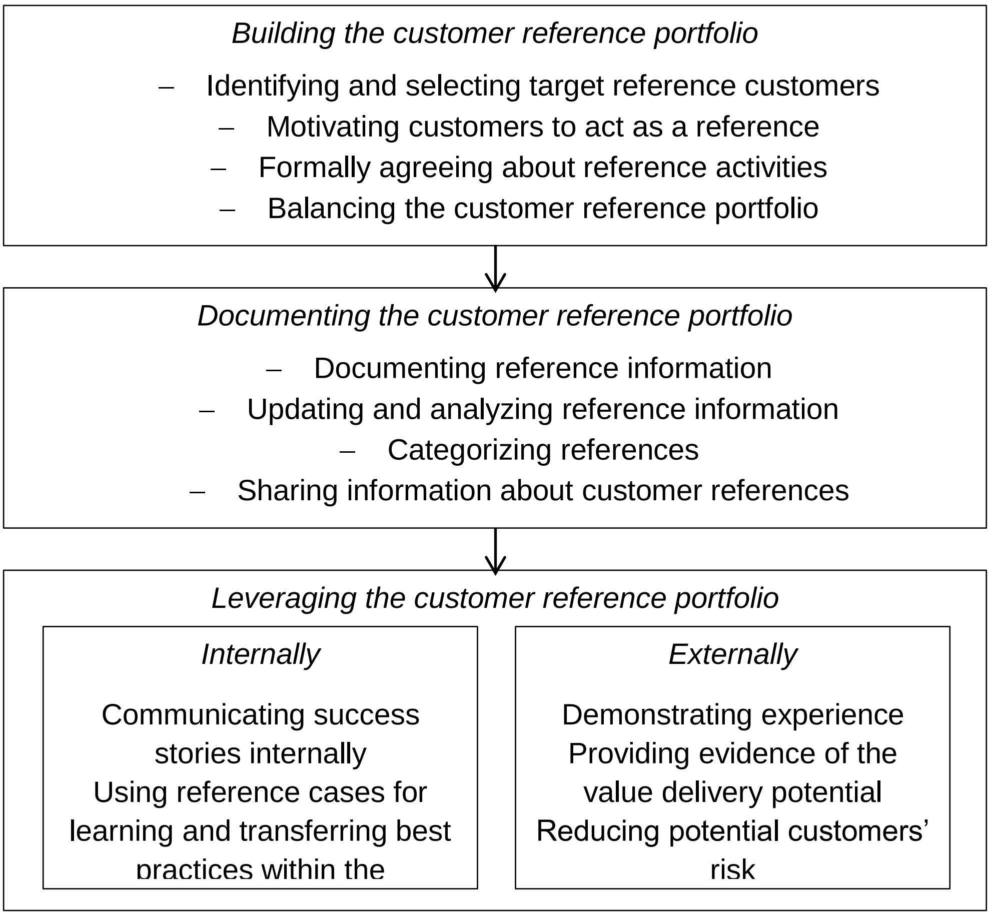

Figure 8 – Implementation of customer reference marketing (Jalkala and Salminen 2008)

The next stage relates to company's efforts to document information concerning customer references. It covers such practices as documenting, up-dating and sharing reference information and categorizing references. Knowledge acquisition and relational elements are also involved while establishing and maintaining customer relationships along with economic considerations (Yli-Renko and Janakiraman 2008). A supplier is suggested to enhance its competitiveness by building, managing and utilizing its customer relationship portfolios continuously (Jalkala and Salminen 2008).

The management of customer reference portfolio reckons processes of collecting, updating and analyzing reference information, monitoring customer satisfaction and reference relationships, identifying key references and maintaining relationships with them. The results of the Jalkala and Salminen research demonstrate that for maintaining relationships with reference customers, suppliers tend to apply different customer programs and clubs, arrange conferences and workshops for existing customers, develop partnership model or have strategic customer operations. Typically companies have specific routines both at unit's and company's level. The most common categories of references are confidential and public, but some companies have market area-specific, service or technology-specific references. In order to manage reference information, company may utilize CRM or other specific information systems, reference portal, monitor customer satisfaction and problem installations. (Jalkala and Salminen 2008)

The third stage consists of two substages – internal and external. The step of internal leveraging of customer reference portfolio contains practices to utilize customer references within the organization which involves using reference cases in offering development, communicating success stories to motivate employees, and using reference cases for learning and transferring best practices within organization. Evaluating equipment capacity for new customers, lessons learned from reference projects, finding solutions for other customer industries are example of outcomes in internal utilization of customer references. (Jalkala and Salminen 2008)

The step of external leveraging incorporates company's activities to communicate customer references to potential customers and other stakeholders. It includes such issues as demonstrating experience and competence, providing evidence of the value delivery potential and reducing buyers' risk by communicating references to existing and potential customers and other stakeholders. Companies achieve external utilization of customer references by reference visits, press releases, publishing success stories, customers' interviews. (Jalkala and Salminen 2008)

5 FORESTRY IN RUSSIA

The Russian Federation has about 20% of the world's forest resources. The total area of Russian forests equals 1,18 billion hectares (ha), among which 892 million ha are actual forest land with 83 billion m^3 of the growing stock. Annual allowable cut is nearly 600 million m^3 in recent years. (Karvinen et al. 2011) In terms of available timber volume, Russia is placed second after Brazil and takes fourth place after the USA, Brazil and Canada concerning logging volume. (ARRISMF 2013)

All forest resources in the country are owned by the Russian Federation, and their administration is shared between federal and regional levels. Only 15% of Russian forests are leased (Karvinen et al. 2011). The main reason for dissolution of lease contracts (52%) is systematic failure of payment execution during a year (ARRISMF 2013). Regional institutions are responsible for forest management as a whole, protection and rational utilization, whereas federal authorities specialize on public policymaking, controlling laws and regulations-based forest relations, carrying out a national forest inventory (NFI).

Russian forestry market possesses a huge potential for innovative LiDAR inventory method proposed for Arbonaut. The scales of Russian forests as well as proximity to Finland and cross-country collaboration and similar climate conditions make it a desirable market to operate in. On the other hand, Russian forestry stays obsolete in many aspects and forest users may be not ready to adopt such solutions. The pricing can be also crucial since price levels are much lower in Russia, though good economies of scale can be achieved, considering squares of Russian forests.

5.1 Classification of Russian forests

Russian forests are grouped into three types – production forests (for commercial use, about 52% in area size), reserve forests (remote areas, not supposed to be used for logging in the nearest 20 years, 24%) and protection forests (perform valuable functions, like shelterbelts, 24%). Most forests in Russia belong to boreal (88%) and are formed by species of larch (35,8%), pine (15,6%), spruce (10,1%), cedar, oak, beech, birch (15%) and aspen. They constitute to 90% of land covered with vegetation. Tree species in Russia are classified into coniferous (68,4%), soft deciduous (19,4%) and hard deciduous (2,4%). (ARRISMF 2013; Karvinen et al. 2011) The distribution of forest-forming tree species across Russia is shown on Figure 9. (ARRISMF 2013)

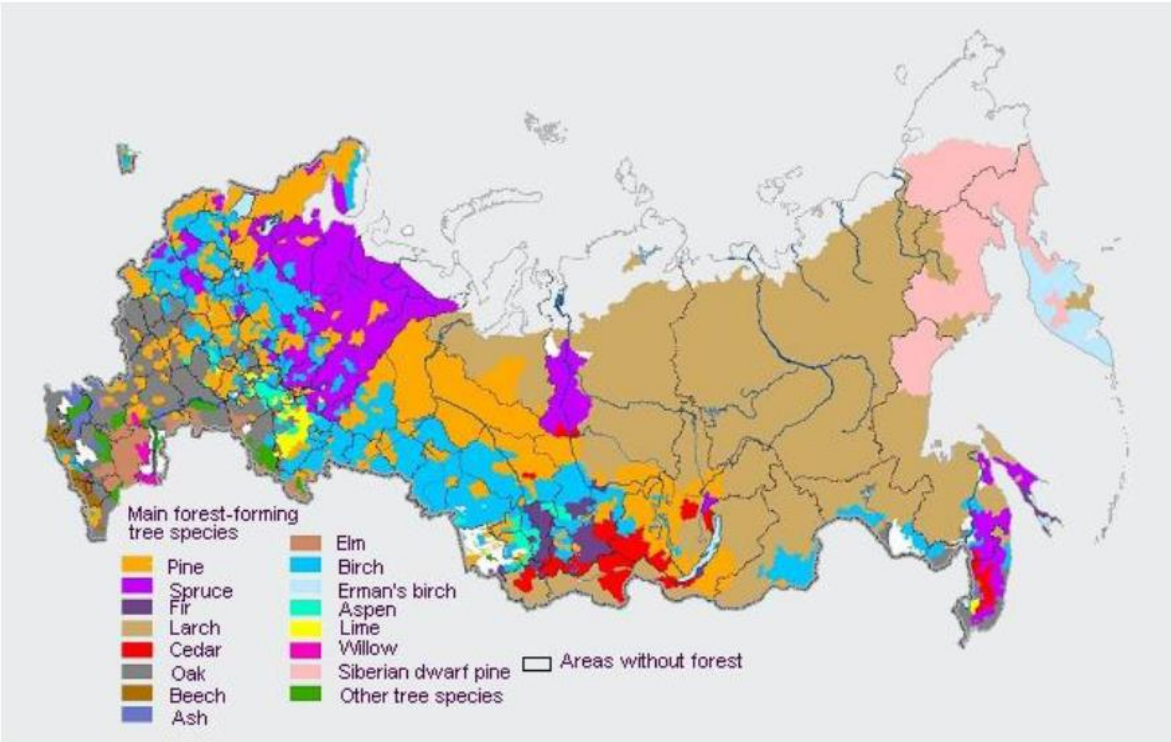

Figure 9 – Distribution of dominating tree species in Russia (ARRISMF 2013)

Concerning age-classes applied in Russian forestry, there are ten of them – for every 20 years for coniferous species (and some others, such as oak) and 10 years for the most of deciduous species. There are five development classes: young, middle-age, maturing, mature and over-mature stands. Almost half of the Russian forests belong to the mature and over-mature classes. (Karvinen et al. 2011) The permission for cutting is based on age consideration, for example, maturity stage is 101-160 years for coniferous species. The rotation period in Russia is commonly 120-140 years, longer than, for instance, in Finland, where this value is 80-100 years (Karvinen et al. 2011).

Forest resources are classified into two categories: *forest fund* (lesnoy fond) – main group that amounts to 97,2 %, and forests not belonging to the forest fund (2,8 %). The land area that, potentially, can be covered by forests, except protected areas and forests belonging to the armed forces and municipalities, correspond to the forest fund, which is submitted to Federal Forestry Agency (Rosleshoz). (Karvinen et al. 2011)

5.2 Forest administration at different levels

The main regulatory document in Russian forestry is the *Forest Code* of the Russian Federation (lesnoy kodeks), which governs the protection, management and utilization of forests. All forests are subject to the Forest Code, regardless of their administrative body. The latest Forest Code was issued in 2006 and brought into action on 1 January, 2007. It stood out from previous documents for delegating decision-making power from the federal level to the regional, broader rights and obligations of leaseholders. The most essential change of new legislation in the use of forests was the endeavor to make long-term leases the main form of forest use (in return of short-term harvesting licenses). The code underwent loads of amendments since 2007. (Karvinen et al. 2011)

Different development programmes and strategies also regulate Russian forestry policy along with the Forest Code as well as legislations indirectly related to forestry, for example, customs duties. There are such means of regulations at the regional level as *regional forest plans* and other forest planning documents, which determine goals and operations in a particular Federation subject. *The Act on Priority investment Projects* is also one of the means of the forest policy, striving to boost forest industry by providing privileges in raw material acquisition and mandatory payments for the companies investing in Russia. Along with the Forest Code, Land Code, Water Code, Civil Code and Federal Law on Environmental Protection govern forest sector operations – totally several hundred documents. (Karvinen et al. 2011)

The Federal Forestry Agency “Rosleshoz” (Federalnoye agenstvo lesnogo khozyaistva) and the regional executive authorities are the main authorized bodies in Russian forestry. The subordination of the Federal Forestry Agency has changed many times, currently it is submitted to the Ministry of Natural Resources and Environment since 2012. Main functions of Rosleshoz are public policymaking, legal regulation, forest monitoring and control over regional authorities. It has territorial body in each Federal District.

The structure of forest administration at the regional level may have three or four levels, as it is shown on Figure 10 (Karvinen et al. 2011; ARRISMF 2013).

Various forest ministries, departments and committees can be the highest regional authorities below the Government of Federation subject. *Federal districts* (lesnichestvo) and *forest parks* (lesopark) are primary local organizational units, their number and frontiers are defined by the Federal Forestry Agency. They are further subdivided into three to seven smaller administrative units – *forest ranges* (uchastkovoye lesnichestvo). (Karvinen et al. 2011)

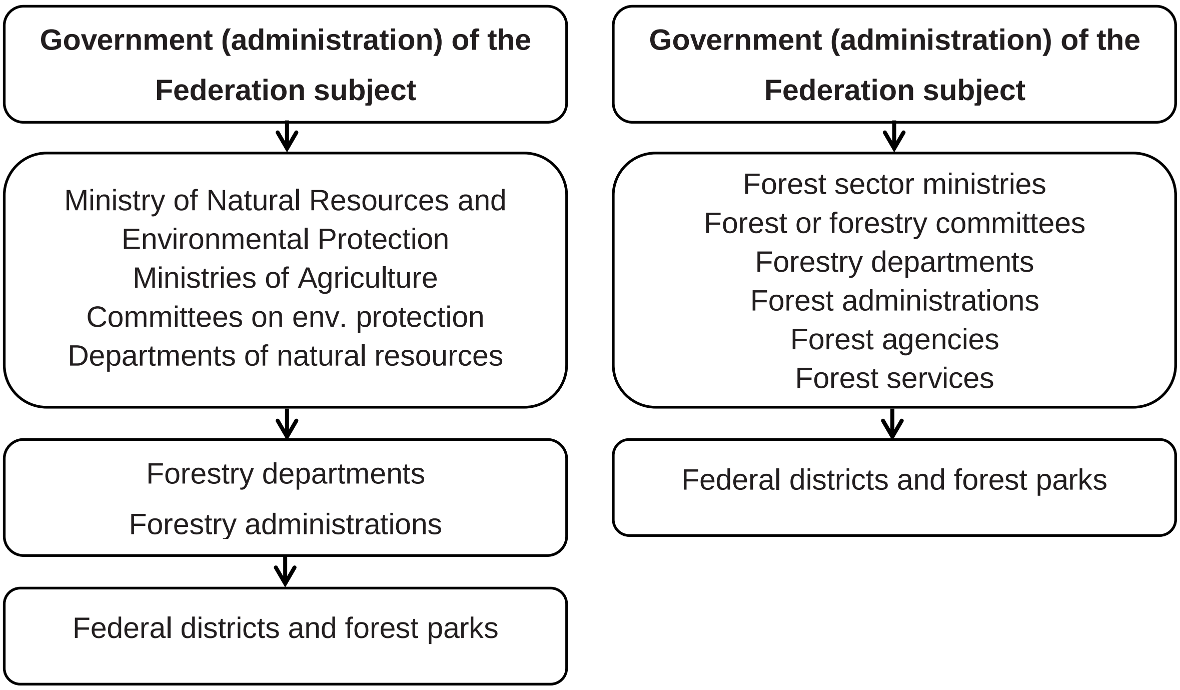

Figure 10 – Possible structures of forest administration at the regional level (ARRISMF 2013)

5.3 Forest use and reporting forest information

The right to use forests is given by the regional forest authorities on the basis of an auction, except for priority investment projects. Forests can be leased on a long-term for 10-49 years, but a leaseholder, fulfilling contract obligations well will be given a preference to conclude a new lease contract once the first one is expired. A short-term sale/purchase contracts can be also tied up for less than one year usage. The fee for forest use is calculated on the basis of annual allowable cut for sale/purchase contracts (the stand is used for timber harvesting) or leased surface area (for other purposes).

A *forest management plan* (proyekt osvoyeniya lesov) is to be presented to the regional forest authorities once a forest use right is received. It is the basic operational plan that determines the practical use of forests (Karvinen et al. 2011). Only after a forest management plan is approved, forestry activities in the corresponding area are allowed. The validity of the plan is limited to ten years, and the plan is based on either existing materials or newly conducted forest inventory, if a user wants to have it done. Forest management plan comprises the following information: description of the leased forest site and current growing stock; plan for forest use (for example, harvesting or recreation activities); plan for infrastructure building for forestry operations, harvesting or wood-processing (forest roads, fire guard towers); plan for forest protection and regeneration, and plan for use and protection of water bodies, flora and fauna (Karvinen et al. 2011).

The forest user informs authorities about conduction of planned forestry activities with the *forest declaration*. This document should be submitted to the local forest district before the start of business activities, and must be in line with forest management plan. It is done for the upcoming year, and lists operations according to tree species, area and felling volume. (Karvinen et al. 2011)

The fulfillment of all mandatory procedures and requirements is controlled by the forest district. A forest user must also submit four times a year a *forest use report* (otchyet ob ispolzovaniyi lesov) that contains information about fellings done within the reporting period, and a *forest regeneration report* (otchyet o vosproizvodstve lesov) that comprises information about realized forest regenerations and other silvicultural activities. (Karvinen et al. 2011)

The major document concerning forestry at the regional level is a *regional forest plan* (lesnoy plan subyekta). It states the objectives in forestry for a particular region. The plan is drawn up for ten years, and it contains information about forest resources, their usage and needs for protection and regeneration, based on the forest management plans and inventory data. While making a plan, regional planning documents and particularly socio-economic development plans are considered. (Karvinen et al. 2011)

For every forest district and forest park, *silvicultural regulations* (lesohozjaistvenny reglament) are drawn up. Depending on intensity of forestry activities and objectives of regional economic development, they are valid up to ten years. The regulations describe conditions and restrictions for forest use, and requirements for forest protection and regeneration on the area of the particular forest district or park, for example, harvesting age and types of allowed forest use. While compiling a forest management plan, a forest leaser should consider both the regional forest plan and silvicultural regulations. The flow of reporting documents on different level is presented on Figure 11. (Karvinen et al. 2011)

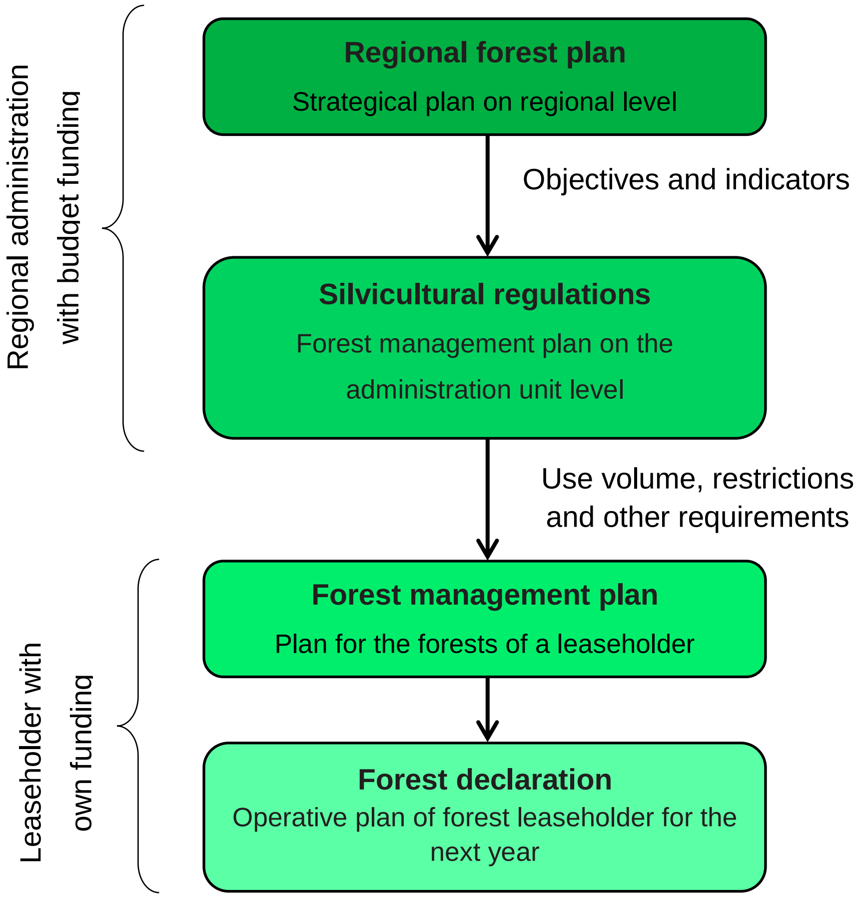

Figure 11 – Forestry reporting documents hierarchy (Karvinen et al. 2011)

5.4 North-West Russia

North-Western Russia is the geographical focus of this research. In terms of forestry, it has the country's best infrastructure, industrial traditions, export market expertize and labor force. In addition, Northwest Russia is in close proximity to European markets and Russia's largest cities. There is a relatively high concentration of forest clusters. The region has the leading position in manufacturing of major wood products. More than half of Russian forest products used to be produced in Northwest Russia. Though, products with low added value dominated (Dudarev et al. 2002). Therefore, it is one of the most promising Russian regions for this research with high potential for LiDAR implementation.

The total area of the forests in the region is 117 million ha, while 76% of this amount is forest lands. The growing stock is 10 billion m^3 and its annual increase is 130 million m^3. More than half of forest resources in Northwestern Russia are located in the Republic of Komi and Arkhangelsk region. The number of logging companies in Northwest Russia was about 5000 among 15000 all over the country as of 2011 (Karvinen et al. 2011). The coniferous species dominate in the North-West Russia, except few regions.

6 FOREST INVENTORY IN RUSSIA

Forest inventory serves as a basis for forest planning. The smallest forest management unit is a *tree stand* or *subcompartment* (vydel) that is characterized by relatively homogenous site, concerning such parameters as stand structure, age and density. *Planning compartment* (kvartal) is a rectangular forest unit, bigger than a tree stand, with the longest side ranging from 0,5 to 4 kilometers. Compartments are separated by cutting *rides* running usually from north to south or from east to west. In remote areas there are no rides and boundary lines are marked with a hammer. The poles with a number are erected at the crossing of boundary lines that enable ascertaining each compartment. Boundary lines are transportation routes and convenient for positioning. The compartments form a forest district. (Karvinen et al. 2011)

The most important inventory indicators are *stand volume, age, basal area, mean stem diameter, mean height, number of stands per ha,* and *stand density.* All indicators are much the same used in Finland, except *relative density* (otnositelnaya polnota) – the proportion of basal area of the stand to basal area of an ideal stand (possesses density 1.0). Forest inventory data is stored by the forest district and the regional forest authorities, information in digital form is available since 1998. (Karvinen et al. 2011)

6.1 Forest inventory types

The Russian Federation has forest resources assessment system called *National Forest Inventory* (gosudarstvennaya inventarizatsiya lesov) that is aimed at collecting objective data on forest resources at national and regional levels, creation of federal information resources and also has control function over forestry operations by remote monitoring. The NFI was launched in 2008 and is supposed to be completed in 2020. It will cover all forests in the Russian Federation, not only those belonging to the forest fund, and include qualitative and quantitative information about conditions of Russian forests. Its fulfilment is the responsibility of Roslesinforg, works are done on state contract base. (Roslesinforg 2013) National Forest Inventory applies satellite and remote sensing methods along with field inventory (mainly establishing circular sample plots), forest plans and forest monitoring information. Remote sensing enables monitoring of violations in forest use, like illegal logging. As of 2009, infringements were observed on about 10% of harvesting sites. NFI is aimed at controlling fulfilment of obligations by forest users and validity of their reporting figures with the use of aerial photographs and remote sensing. (Karvinen et al. 2011) The planning of works in NFI is done in accordance with the state program

“Development of Forestry” for years 2013-2020 (Roslesinforg 2013; Ministry of Natural Resources and Environment 2013). The claimed precision requirements for growing stock assesment are shown on Figure 12. (Roslesinforg 2013)

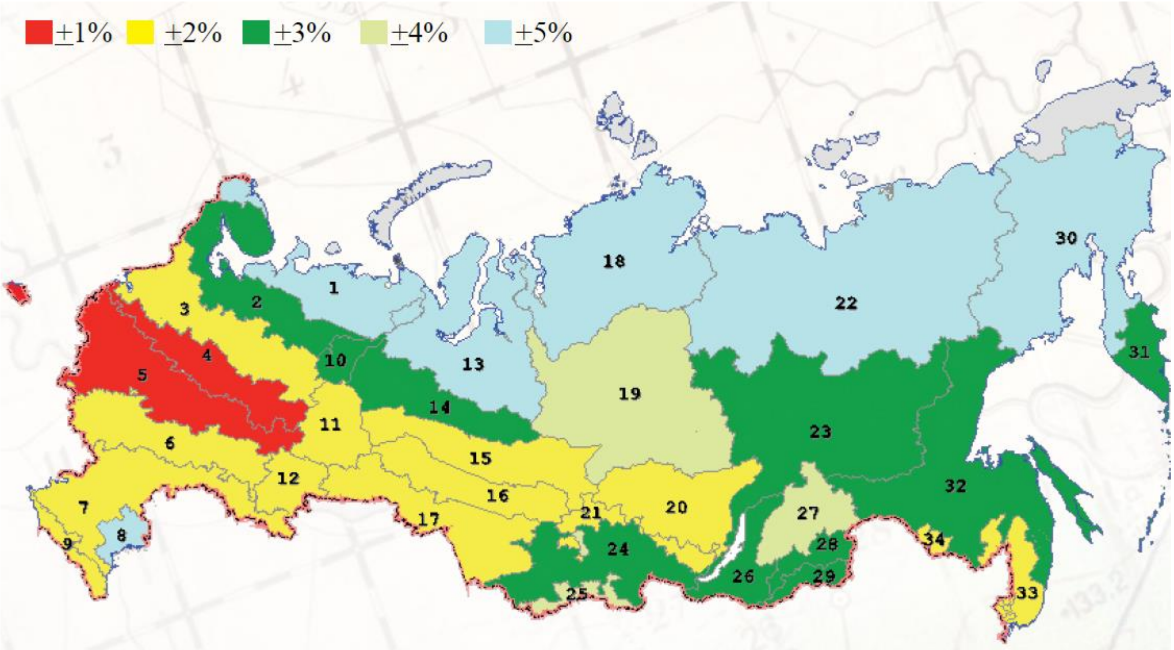

Figure 12 – Precision requirements in growing stock measurements (Roslesinforg 2013)

Forest planning at compartment level includes *forest management planning* (lesoustroystro) and drawing up a *forest management plan*. Forest management planning comprises taking measurements, forest resource calculation, and composing of a treatment plan. Thus, forest inventory is a part of forest management planning process. Forest management plan is a 10-year strategic plan for the leased site, demanded by the authorities. Taking on-site inventory for updating information for compilation of a new plan is not mandatory at the moment, but the existing data are commonly outdated, and it can be a must to prepare a qualitative document. A leaseholder starts preparing the forest management plan after signing a lease contract. This task requires obtaining relevant material (for example, cartographic), analyzing existing forest management planning information, working with GIS systems, and most likely conducting on-site forest inventory and agreeing silvicultural activities with regional officials. (Karvinen et al. 2011)

The data on forest resources, their use, ecological condition, and protection are compiled in the *State Forest Register* (gosudarstvenny lesnoy reyestr). Forest districts collect information on happened changes and along with specialized monitoring organizations submit it to the regional authorities annually, that is further forwarded to the state company

Roslesinforg, which maintains the Register. The information is public, but subject to fee. (Karvinen et al. 2011)

Private companies that have forest operations conduct a forest inventory mainly in two cases – while *making out coupes* or *coupe demarcation* (otvod lesosek) that is done constantly as a prerequisite for harvesting and while preparing forest management plan that is supposed to be done every ten years on the whole leased territory. It should be noted, that up-to-date forest management plan data can be used while making out coupes, but many companies have conducted forest management plans long time ago, therefore these data are outdated and cannot be used.

6.2 Normative documents

According to the Forest Code (2015), forest inventory (taksatsiya) is done for determining, monitoring and assessment of qualitative and quantitative characteristics of forest resources. The concept implies establishing boundaries of subcompartments, defining dominating and secondary tree species, evaluating diameter, height and timber volume, growth conditions, conditions of natural regeneration and other characteristics of forest resources. Forest inventory is included in forest management planning. Positioning and delineations of boundaries of forest sites is bound to positioning and delineations of compartments and subcompartments within established boundaries of forest districts and forest parks. (Forest Code 2015, articles 69, 69.1)

Requirements on fulfillment of forest management planning are set in *Forest Management Guidance* (Forest Code 2015, article 67). Each forest is assigned one of three forest *management category*. Forest management category is an indicator that shows how detailed and precise an inventory should be done. It is defined by the size of compartments (the intensity of forest operations or other factors) and dictate minimally accepted size of subcompartments. (Forest Management Guidance 2011)

The forest resource assessment system underwent drastic changes with the enforcement of current Forest Code in 2006. Prior to this, detailed forest plans were made for the whole Russian territory as a governmental initiative on budget funding at forest district level. Forest management planning was taken every 10-15 years. Currently, forest management planning can be done by private companies as well as governmental forest inventory (regional branches of Roslesinforg), though forest users are also eligible to do it themselves. Plans are ordered by forest users. Transition period is still going on and fulfillment of the first National Forest Inventory is in progress, therefore currently there is a lack of available up-to-date information on forest resources. (Karvinen et al. 2011)

6.3 Forest inventory methods

Forest Management Guidance distinguishes four main methods for forest management: ocular, ocular and measuring, photo-interpretation and data updating. Combinations of methods are also allowed. The guidance contains requirements and methodologies of taking measurements and calculations. (Forest Management Guidance 2011) While making out coupes forest users can apply field inventory that include: enumeration methods (complete, strip enumeration, fixed-radius sample plots) and measuring methods (based on circular relascopic plots). Their utilization depends on coupe size and other parameters. Suggested methods and appropriate conditions are presented in table 3 (Zagreev et al. 1991, p.193).

Table 3 – Conditions for forest inventory method application while making out a coupe (Zagreev et al. 1991, p.193)

Method name	Coupe size, ha	Application conditions
Complete enumeration	Less than 3	All forest types
Circular relascopic plots	3 or more	All forest types
Strip enumeration Circular fixed-radius plots	3 or more	Forest areas with dense underwood, low-located tree crowns or other conditions, hindering utilization of angle gauges
Materials of forest management planning with checking by field inventory	10 or more	Forests of third forest management category; big felling area of forests of second category, if allowed by authorities

In general, the variety of inventory methods used in Russia does not differ from the ones used in other countries. It includes remote sensing and aerial photographs, field inventory and ocular estimations. The decision-making on selection a particular method is commonly based on price considerations – currently a leaseholder pays for forest planning, and cheaper and simpler methods are favourable. However, selection of forest inventory method is very much dependent on needs and financial capacity of a forest user. The cheapest and comparatively imprecise method is data updating, field inventory and remote sensing methods are more precise and costly. (Karvinen et al. 2011)

In the matter of measurement precision, studies show that currently used methods tend to underestimate the growing stock of mature and over-mature stands by 5-15%. However, methods used prior to this in the northern regions overestimated it by 30-50%. The standard error is claimed to decrease to 3% level owing to method development in recent years. (Karvinen et al. 2011)

Limits of accidental errors for all four methods are stated in the annex of Forest management guidance for growing stock, mean height, species composition, mean diameter and undergrowth volume per ha depending on forest management category. Systematic and root-mean-square (RMSE) errors are determined for the following indicators: age, growth conditions/site class, merchantability class, stand density and general value for all the rest. The guidance also says that precision requirements are defined by the purpose of usage, geographic position, current knowledge of the area, and intensity of forestry activities. The margin of errors narrows down in the following succession: photo interpretation, data updating, ocular and ocular and measuring methods. (Forest Management Guidance 2011) In other words, Forest management guidance treats ocular and measuring method (field inventory) as the most precise and photo interpretation as the least precise method.

6.3.1 Data updating

Data updating (aktualizatsiya) is basically an office image interpretation of remote sensing data. Some forest districts and authorities do not admit reports based on this method.

The method implies making changes to the information on previous forest management planning. Automated data updating model is applied. Recalculations of mean height, mean stem diameter, age and some other parameters are done automatically. Species composition, site class, density, forest site type, growth conditions and underwood conditions cannot be estimated by the model. (Forest Management Guidance 2011)

Data updating can be accompanied with further on-site inventory with establishing relascopic or fixed-radius plots. Their amount depends on felling area size. There are acceptable margin of errors (for example, not more than 15% for growing stock volume), mistakes in merchantability classes separation are not allowed. In the case when any of these margins are infringed, forest inventory based on materials of forest management planning is not accepted and should be done by another method. (Zagreev et al. 1991)

In the sites where natural disasters or forestry operations took place, field inventory or photo-interpretation is applied. The calculated data are checked with logical control (analysis of updated inventory descriptions) or field inventory control (20-30 subcompartments are chosen by random or systematic sampling for each forest-forming tree species and inventoried by ocular and measuring method). (Forest Management Guidance 2011)

6.3.2 Field inventory

In Russian forestry, field inventory is conventionally separated into measuring and enumerations methods. Current issue of Forest Management Guidance does not prescribe enumeration methods separately. Though, these two basic groups can be combined between each other and with ocular inventory.

Enumeration methods suggest fencing of inventoried forest site, making enumeration itself (describing every tree), cutting of average (*model*) trees and their measuring. The enumeration is characterized by determination of tree number with separation into stories, species, thickness classes and into *merchantability classes*, if needed. Merchantability class defines how a wood will be used, the separation is generally done into *commercial wood* (delovaya drevesina), *fuelwood* (drovyanaya drevesina) and *semi-commercial wood* (poludelovaya drevesina). Stem diameters are measured at the height of 1,3 meter. Enumeration is done in teams of three workers. (Zagreev et al. 1991)

Enumeration can be *complete* or *partial*. Complete enumeration is the most precise, since it is done on the whole territory. Though, it is very labor-intensive and usually applied on relatively small sites. Partial enumeration (mainly *strip enumeration*) is usually done for large squares (usually more than 10 ha), only parts of a felling area are surveyed with establishing of sample plots (at least on 8 – 12% of total area). Sample plot in this case is made as a rectangular or a strip of five-ten meter width along the longest side of subcompartment or a sight line. Accurate assessment of plot squares is the main precision criterion. (Zagreev et al. 1991)

There are several methods for growing stock volume determination. However, all the methods, except visual, apply this formula:

$$M = \sum G \times H_{cp} \times F_{cp}, \quad (2)$$

where *M* is the volume, $\sum G$ is total basal area (calculated after enumeration is done), H_{cp} – mean height (measured for selected model trees) and F_{cp} – tree form factor (characterizes tree stem density, measured for selected model trees). Otherwise, volume can be determined by special volume tables. (Zagreev et al. 1991)

Ocular and measuring methods rest on combination of ocular estimations with field inventory (selective measurements and enumeration). Depending on presence of underwood and visibility of forest stand, circular relascopic or fixed-radius sample plots are set. Their amount is determined by the annex of Forest Management Guidance and depends on subcompartment size, species composition (percentage of dominating tree species) and stand density. (Forest Management Guidance 2011)

The main difference of *measuring methods* in contrast with enumeration is that basal area, used for calculation of growing stock volume, is assessed not by tree enumeration, but by distant measurements with a device called *angle gauge* (or *relascope*). It simplifies the inventory and decreases labour costs significantly, but not the precision level. Therefore, measuring methods are widely applied. (Zagreev et al. 1991)

Basal area per one ha is defined by species with the angle gauge in *relascopic sample plots*. Mean diameter is measured at breast height for average tree of each species. The precision of measuring methods depends not on angle gauge's construction, but on amount of sample plots and right place selection. The amount of circular relascopic plots is assigned by coupe square, its homogeneity and stand density. Growing stock volume can be calculated by the formula (2) or special alignment charts and tables. (Zagreev et al. 1991)

Reference materials (tables, charts, formulas) are commonly used while training and conducting real ocular inventory (Zagreev et al. 1991). Aerial and space imagery is also analyzed to complete inventory characteristics. The amount and dislocation of sample plots (relascopic, fixed radius circular sample plots) are preliminary determined by photo interpretation as well previous forest management planning materials. Aerial and space photos also help to define homogeneity level of forest stand, age and density groups. (Forest Management Guidance 2011)

Circular fixed-radius plots tend to apply where application of relascopic sample plots is problematic due to dense underwood or low-located tree crowns. Within the range of established radius, complete enumeration is done. This method is similar to strip enumeration, except some nuances in using devices. Allocation of sample plots is the same as in circular relascopic plots. (Zagreev et al. 1991) Parameters, such as mean height and mean stem diameter, are calculated as arithmetical mean of measured representative trees. Before establishing circular fixed-radius sample plots, their radius is defined, depending on stand density and mean diameter (described in the annex of the Guidance). (Forest Management Guidance 2011)

6.3.3 Ocular method

Ocular method is a type of on-site inventory that implies ocular (visual) estimations of inventory indicators with taking measurements for ascertaining some indicators (one-two measurements of stand basal area, mean height and diameter). Ocular inventory is conducted from compartment lines, rides and other walking areas. (Forest Management Guidance 2011)

Ocular method is usually applied for very large squares, where utilization of enumeration and measuring methods is hardly possible. Pure ocular method stands for visual estimations of inventory parameters. Thus, good qualification, expertize and rich experience of inventory worker is the main condition for satisfactory results in ocular inventory. (Zagreev et al. 1991)

Combining appropriate ocular estimations of mean height, relative stand density with relevant usage of reference materials and corresponding simple calculations leads to adequate and quite precise information of growing stock volume. The methodology of ocular inventory and availability of reference materials makes an inventory worker consider tree species, site class and age of stand. (Zagreev et al. 1991)

6.3.4 Photo interpretation

Photo interpretation (remote sensing) method is based on analysis and measurements of qualitative stand characteristics by aerial and space photo scrutiny. Photos should be in line with requirements on their scale and resolution, stated in the annex of Forest Management Guidance. Analysis and measurements of photos is done by special computer appliances or stereoscopic devices. (Forest Management Guidance 2011)

Subcompartment boundaries, species composition, age class, mean height and diameter, site class, density, growing stock volume and some other parameters should be ascertained with defined precision. Obtained information is compared with materials of previous forest management planning, and if drastic differences present, the data are checked and corrected if needed. GIS technologies are applied for data digitalization and processing. (Forest Management Guidance 2011)

Photo interpretation is often used in combination with other inventory methods. It is commonly applied on initial stage of field inventory for marking out stands. However, specific requirements for assessing inventory parameters should be met, and finding appropriate space images can be impossible. Therefore, usage of aerial imagery is more widely spread. Photo interpretation is favourable for remote area, where on-site inventory is challenging.

6.3.5 LiDAR

Remote sensing is the “measurement of object properties on the earth’s surface using data acquired from aircraft and satellites” (Schowengerdt 2007, p.2). LiDAR is an active remote sensing method that is applied in many fields, including forest inventory. LiDAR (Light Detection And Ranging) structurally is an active sensor that emits laser pulses and measures the backscattered signal (Suárez et al. 2005). According to the placement of a system, LiDARs can be classified into airborne, space borne and ground based. Structurally, LiDAR systems can be categorized into discrete return or full waveform, in accordance to the way how information signals are recorded. Discrete return systems grab a limited number of discrete return impulses (one, two or several), while full-waveform systems record continuous intervals. In addition, LiDAR systems can be classified corresponding to a footprint size into small-footprint (one meter or less) to large-footprint (tens of meters) (Kelley and Tommaso 2015). Full-waveform systems have much bigger footprints, than discrete return (10 – 70 m and 0,2 – 0,9 m accordingly). (Means 1999; Lim et al. 2003). Large footprints allow detecting forest canopy and underwood volume, whereas discrete return systems record only a limited set of forest elements (Lim et al. 2003). Though, either system can define canopy height that enables calculation of other forest parameters through correlation (Lefsky et al. 2001). High data volumes (thus, slow processing) and complexity of full waveform systems led to wider commercial application of discrete return systems (Kelley and Tommaso, 2015).

The most common LiDAR systems are small-footprint, discrete return airborne laser scanning (ALS) systems. They consist of four main components: a laser scanning unit, a global positioning system (GPS), an inertial measurement unit (IMU) and a computer to store data (Kelley and Tommaso 2015). Inventory can be done by small-footprint LiDAR at individual tree, plot and forest stand levels. The method can delineate separate trees at individual tree level for mixed forests (Chen et al. 2006; Li et al. 2012). Discrete return systems can define canopy parameters well at the plot level, such as canopy height, canopy base height, canopy cover and basal area (Jakubowski et al., 2013). Processing of LiDAR data is done on standard computers and includes extraction and geo-coding of data by proprietary software with further classification and analysis of the data with proprietary or third-party software (Lim et al., 2003). Such systems are able to obtain high-precision data with 15-20 centimeters RMS vertically and 20-30 centimeters horizontally (Suárez et al. 2005).

Although performance and capability of LiDAR systems heavily depends on system structure, laser location methods possesses general relative advantages: 1) availability of much data shortly after acquisition – laser point clouds, separated by corresponding earth objects, digital terrain models and 3D models of objects, tied to coordinates; 2) guaranteed precision – usually claimed precision of 15 centimeters is achieved by simply fulfilling the guide requirements; 3) absence of extra works (like establishing orienteers) for coordinates allocations – the system uses surface GPS stations, that require only appropriate placements and coordinates data supply; 4) high productivity – covering of 500-1000 square km per work day was achieved (depends on point cloud density, acquisition bandwidth, shooting scale and other parameters); 5) capabilities for night time work and work in any season; 6) wide range of applications. (Medvedev et al. 2007)

The main disadvantage of LiDAR (and many other aerial inventory methods) is its strong dependence on meteorological conditions. Low cloud cover, thick haze, sand storms and heavy winds may prevent data collection (Arbonaut 2011). Other disadvantages are mostly the results of dynamic process (the device is constantly moving) and limited shooting angles (the device is located above inventoried objects). They include: precision decrease with shooting height increase, height limits, insufficient precision level for some geodesic applications, discrete type of data and eye hazard for people within the inventoried area. (Medvedev et al. 2007)

The method can produce more precise measurements with higher pulse densities. It can be achieved by repeated airplane flights, decrease in the flight altitude or the speed of the plane, or by independent increase of pulse rate frequency and scanning rate. Economies of scale is relevant in LiDAR method, the costs per ha decrease with enlarging square being inventories. Jakubowski et al. (2013) researched relationship of measurements precision to the pulse density in mixed-conifer forests and found that relatively valid and precise values of tree height (mean and max), total basal area, stem diameter at breast height (DBH) (mean and max), and shrub height can be acquired by LiDAR with pulse density of one pulse/m^2. Parameters, such as tree density, canopy cover, shrub cover, and mean height to live crown base require pulse densities higher than one pulse/m^2. (Jakubowski et al. 2013)

6.3.6 ArboLiDAR

ArboLiDAR is the solution offered by Arbonaut. It is tailored to process data of small-footprint discrete return sensors (with one pulse/m^2 density). The methodology employs LiDAR, Color Infrared Imagery (CIR), GPS ground control plots as well as non-parametric estimation methods. ArboLiDAR offers automatic delineation of forest stands, where stand-defining layers (timber height, vegetation density and/or hardwood percentage) are obtained by LiDAR and CIR. The stand segmentation is done with proprietary segmentation tool and results in digital maps with stand polygons of homogenous timber characteristics. (Arbonaut 2015)

As far as precision of LiDAR is concerned, it is claimed to be higher than in traditional field inventory. It is a complex issue and depends on type of timberland – commonly the more homogenous a forest site is, the higher the accuracy. The examples of LiDAR measurement precision at sample plot level, acquired in boreal forests with three species groups, are presented on table 4. (Arbonaut 2011)

Table 4 – Example of LiDAR measurement precision at sample plot level (Arbonaut 2011)

	Predicted value	Measured value	bias	bias%	RMSE	RMSE%
TOTAL						
mean dbh	20.5	20.4	-0.1	0.0	3.0	14.7 %
mean height	15.6	15.6	-0.1	0.0	1.2	7.9 %
basal area	20.3	20.3	0.0	0.0	2.7	13.3 %
volume m^3/ha	151.2	156.9	5.7	0.0	22.4	14.8 %
stem count	1278.9	1273.1	-5.8	0.0	286.2	22.4 %
PINE						
mean dbh	21.1	22.0	0.9	0.0	4.1	19.3 %
mean height	15.8	16.3	0.6	0.0	2.2	13.9 %
basal area	12.1	12.2	0.1	0.0	3.5	28.8 %
volume m^3/ha	89.6	91.3	1.7	0.0	26.1	29.1 %
stem count	606.5	622.9	16.4	0.0	230.8	38.0 %
SPRUCE						
mean dbh	22.0	24.1	2.1	0.1	5.5	25.1 %
mean height	16.4	17.1	0.8	0.0	3.0	18.5 %
basal area	5.9	5.9	0.1	0.0	3.3	55.6 %
volume m^3/ha	47.3	52.8	5.4	0.1	26.8	56.6 %
stem count	404.2	402.4	-1.8	0.0	238.6	59.0 %
HARDWOOD						
mean dbh	14.0	14.2	0.2	0.0	5.8	41.5 %
mean height	13.0	12.4.	-0.6	0.0	4.0	30.8 %
basal area	2.3	2.1	-0.2	-0.1	1.5	64.8 %
volume m^3/ha	14.2	12.9	-1.4	-0.1	10.6	74.7 %
stem count	268.1	247.7	-20.4	-0.1	176.8	65.9 %

LiDAR offers some unique features. It can produce a digital terrain model (DTM) with high precision (claimed to be better than 15 cm for a grid of 1×1 m), by which a tree height is defined, but it can have many other applications, such as surface conditions defining for forest road and harvesting planning. (Minguet 2015)

The amount of forest indicators directly measured by LiDAR is limited, therefore it is advisable to use also other sources, for instance, aerial photography, that significantly broadens evaluated parameters set, particularly vegetation types. (Chen et. al 2012) Arbonaut combines ArboLiDAR technology with satellite and aerial imagery, and field sample plots for measuring parameters, like species composition. Current LiDAR's state of the art does not allow species separation (usage of one wavelength with high point cloud density and several wavelengths for this purpose is in development and testing phase). LiDAR technology enables determination of age of stand, height, and stem diameter. Then parameters (mean height, mean diameter) are calculated separated by species. LiDAR allows considering clearly-defined underwood in a stand composition, but it has serious limitations. (Minguet 2015)

Modelling of a forest stand is an obligatory part of ArboLiDAR and requires field measurement on sample plot level accompanied by LiDAR and imagery data. In such a way, remote sensing data is calibrated with field measurement and these correlations are applied for the whole area. The number of plots and variables used in the method depends on the forest indicators needed. Modelling allows estimations of volume (m^3 per ha), height (m), stem diameter (at 1,3 meter height), basal area (m^2 per ha), stem number and age by tree species at tree stand level. Aerial imagery is also used. (Minguet 2015)

6.3.7 Trestima

Another modern inventory method is offered by Finnish forestry IT-company Trestima Ltd. The company offers the specialized software in forest inventory that can be used on wide range of devices (smartphones with Android or Windows Phone OS). Trestima actively promotes its solution on Russian market. Unfortunately, the lack of third-party publications concerning this inventory method does not allow producing its objective descriptions and comparison with other methods owing to its novelty. However, high evaluation of this method by Finnish Forest Sciences Society (Innovation award in 2013) and field professionals makes it worth reviewing.

The method basically implies observations and taking photos on a smartphone with further processing and cloud calculations. The boundaries of the stand that must be inventoried are preliminary inserted. The worker is captured and monitored with the use of GIS systems after reaching the place. After taking sample photos, stem width and height are estimated, and tree species are defined in the cloud service. Calculated species parameters can be reported to the mobile device during a measuring session, so the worker can see the results and standard error values in real time. Some photographic conditions may require additional assistance of a human operator. (Trestima 2014, Trestima 2015a)

Stem diameter at breast height and tree height are estimated by photos with the help of a ruler attached to the tree. Estimated parameters include species composition, total basal area, stem volume, stem diameter distribution, and proportion of main wood assortments. Age of a stand, site class, soil conditions are defined manually. Canopy cover (crown closure) can be also assessed by taking its photos from the ground. It helps to determine the volume and density of a stand. (Trestima 2015a, Trestima 2015b)

The company claims the following benefits of Trestima in relation with traditional forest inventory: results objectivity (human factor is almost absent), precision (less than 10% standard error is announced, measurement can be retaken with the use of feedback), high productivity (average measuring speed is under five minutes per ha – more than 100 ha per working day) and documentation (samples with coordinates are stored in the cloud) (Trestima 2015a). In addition, method simplicity for a worker should be mentioned and low implementation requirements (a supported device with a good camera, a ruler and account in the system). Checking the results of photo-interpretation or laser scanning inventory is claimed to be among possible applications of this method (Trestima 2015b).

6.4 Forest management and inventory problems

One serious problem of Russian forestry is legislative – there is a lack of coordination between institutions regulating forest relations. Supervising bodies tended to develop their strategies separately. Federal Forestry Agency underwent many changes in terms of supervising institution, and their responsibilities in forestry were not clearly separated. Currently the strategic plan “Development of Forestry” for years 2013-2020 is being implemented by the Federal Forestry Agency, generally aimed at increasing effectiveness of utilization and protection of Russian forests. (Karvinen et al. 2011; Ministry of Natural Resources and Environment 2013)

Decreasing area and quality of coniferous forests as a result of extensive use, growing volume of damaged forests owing to insufficient forest protection and monitoring, problems in hiring highly skilled employees, low productivity of labour are among other forest management problems. (Karvinen et al. 2011)

In addition, "Development of Forestry" states such problems of Russian forestry as low timber harvesting percentage in comparison with other countries (not more than 30% of AAC, forestry's share in GDP is only 1,7%), outdated machinery, low developed infrastructure (insufficient building of forest roads), decrease of forest area of valuable tree species and illegal logging. Lack of qualified personnel in forestry and low labour efficiency are also criticized. (Ministry of Natural Resources and Environment 2013)

In terms of forest inventory, a set of problems is connected to the enforcement of the Forest Code issued in 2006 and the changes that it brought in. The forest management planning became a responsibility of forest leasers that arouse a lot of criticism and led to great decrease in annually inventoried forest area. Forest users commonly views forest inventory as an extra expenditures and try to avoid minimize them. Therefore, up-to-date forest resource data is becoming unavailable. This poses a problem for officials to monitor cutting volumes. The quality of conducted inventories and forest management planning is questionable, it does not always meet requirements. Also, the acceptance of NFI system has been criticized as too hasty, Russian forestry was not ready for it. (Karvinen et al. 2011)

Insufficient precision of forest resource assessment, outdated forest management planning and low application of modern information technologies (including remote sensing) are seen as systematic problems. About 70% of forests have outdated forest management planning material (more than ten years) and forest management planning has not been done on three million ha at all. Increase of remote monitoring on forest use is an objective in one subprogram and is claimed to reach 89% by 2020 (63% as of 2013). (Ministry of Natural Resources and Environment 2013) Therefore, the potential for LiDAR technology in Russia is huge, taking into account the tremendous scales of Russian forests and need in rapid adoption and fulfillment of NFI.

7 DECISION-MAKING IN FORESTRY

Decision making in forestry is complex, as it considers versatile processes (timber harvesting, recreation and other activities) and aspects (ecological, socioeconomic, and political). Forest management system regulations, as well as climate and growth conditions differ vastly and are of great importance. Owing to this complexity, evaluating an alternative becomes problematic for decision-makers as it involves high amount of criteria. It requires a multi-objective approach and analytical methods to manage this variety of contradictions and find a tradeoff. (Ananda and Herath 2009)

In terms of decision-making in this research, selection if forest inventory method is studied. Data accuracy is highly important criterion, but it leads to costs increase. There is a contradiction in here, since costs minimization is also an objective (Kangas 2010). A level of error, typically characterized by root mean square error (RMSE), is the common evaluation parameter for precision of forest inventory methods. This value stands for the difference between estimated and real values. Errors owing to inventory information do not tend to be considered and analyzed properly on a long-term scale, as contrasted with forecasting timber prices and harvest costs, success of regeneration and growth/mortality of trees (Eid 2000). Selection, based on tradition, usually take place, while seeking out optimal acquisition method is not a common practice. Inventory method choice in terms of defining changes and updating information is even more challenging. (Kangas 2010)

Knoke and Weber (2006) assume that forest management planning has the main goal of considering stakeholder’s economic interests and sustainability goals along with social and ecological aspects. Buongiorno and Gilless (2003) view the major objective in forest sustainability, including timbering sustainability and biodiversity preservation. Thus, forest sustainability can be a part of a selection process for forest inventory method.

7.1 MCDM approaches

Multi-criteria decision making (MCDM) is a common approach for resolving forest resource management conflicts. It systemize resource management information for strategic planning, communication and better understanding by quantifying the value of ecosystem services in a non-monetary fashion. MCDM is useful for decision making and decision support for policy makers. (Ananda and Herath 2009)

The framework of MCDM can consider complex multiple objectives on a long-term scale with respect to uncertainties, risks and complex value issues (Nijkamp et al. 1990). Typically the process includes the following steps: defining objectives, selection of criteria for measuring objectives, determination of alternatives, aligning criterion scales with corresponding units, assigning relative weights to each criterion, application of mathematical algorithm for alternatives' ranking, and decision upon an alternative. The methods of Multi-criteria decision making are highly relevant for forest management and planning problems. (Ananda and Herath 2009)

Main classification of methods is proposed by Hajkowicz et al. (2000) and implies dividing into continuous and discrete methods. Continuous methods try to identify an optimal amount of alternatives, which can differ infinitely for various decision problems, and include linear programming, goal programming and aspiration-based models. Discrete MCDM methods have finite number of options, a set of objectives, selection criteria and a method for alternatives' ranking (Hajkowicz et al. 2000). Discrete methods can be either weighting or ranking methods, and each category can be further subdivided into qualitative, quantitative, and mixed methods (Nijkamp et al. 1990). They differ on the type of used data.

There are value and utility-based approaches that use mathematical functions to define preferences of decision-makers. The most common approaches include *Multi-attribute value theory (MAVT), multi-attribute utility theory (MAUT)*, and the *Analytic Hierarchy Process (AHP)*. The research of Ananda and Herath found that more than one MCDM method or a hybrid approach should be used to make the planning process most efficient. AHP can be used in combination with other methods to gain hybrid models so that highest synergetic insights can be obtained. (Ananda and Herath 2009)

7.2 ANALYTICAL HIERARCHY PROCESS

Analytic Hierarchy Process (AHP) is a simple yet powerful tool for effective decision-making introduced by Saaty (1977, 1980). It is used for structured logical decision-making in many areas of business management and in many business fields. AHP model measure benefits from subjective managerial inputs using multiple criteria. The inputs are transformed into scores to evaluate given alternatives. (Handfield et al. 2002)

The hierarchy method of the AHP has various advantages: AHP is based on easily obtained managerial judgment data, possibility to utilize inconsistent judgments and perceptions, and the availability of convenient software, for example "Expert Choice" (Calantone et al. 1998). Handfield claims that the major advantage is that the building of hierarchy diagram requires structuring the problem. Thus, the method forces a manager to formulate explicitly the objectives and selection criteria and quantifies them by assigning relative numerical values. In such a way, decisions become more rational. The AHP tool enables managers with taking into account all the relevant criteria, their relative weights and interactions. The tool can be widely applied for any decision goal, especially it is valuable when a number of criteria and sub-criteria is high. (Handfield et al. 2002)

The basic steps of the methodology include (Vaidya and Kumar 2006):

1. The problem statement.

2. Determining the goal and all actors, objectives and the outcome. It involves:

- Defining the goal of the decision task
- Enlisting the people whose expertise is needed to build and evaluate the model
- Defining the decision-makers

3. Selecting the relevant criteria which have an influence on the decision

4. Structuring the problem and building the hierarchy tree of different levels comprising goal, criteria, sub-criteria and alternatives (shown on Figure 13).

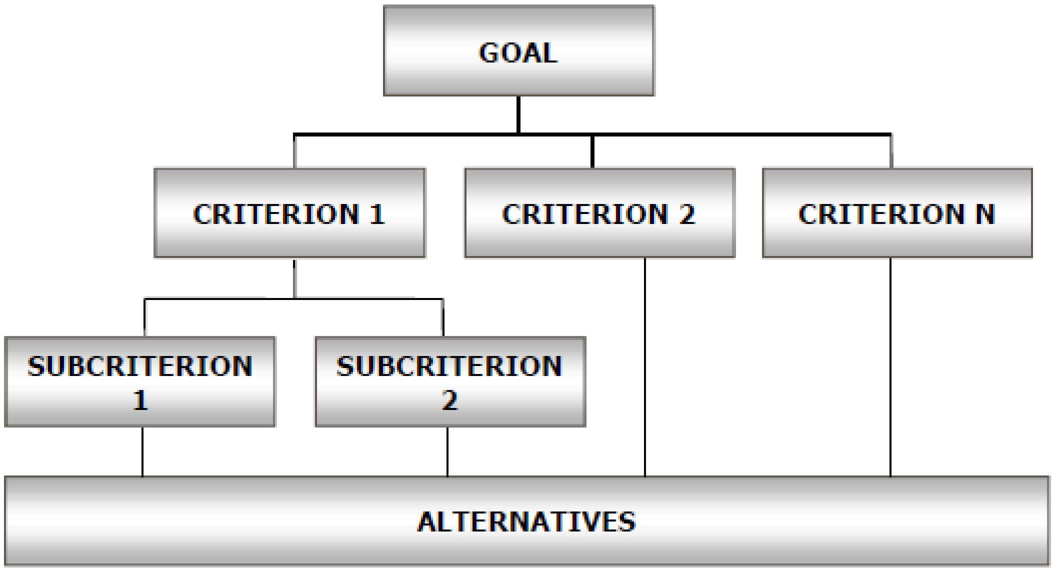

Figure 13 – AHP hierarchy tree

5. Weighting the criteria by the pair-wise evaluation. Each element should be compared with all the others on the corresponding level and evaluated on the numerical scale. The procedure requires $n(n-1)/2$ comparisons, where n is the number of elements.

6. Assessment of the alternatives. Calculations are done to find the maximum Eigen value, consistency index *CI*, consistency ratio *CR*, and normalized values for each criteria and alternative.

7. If the results of these calculations are satisfactory then decision is made on the basis of the normalized values, otherwise the procedure is repeated till these values are framed in a desired range.

Both quantitative and qualitative information can be compared in this method with the use of numeric values on a pairwise evaluation scale. The comparison is done with the grades ranging from 1 to 9. The meanings of the numeric codes are as following: 1 – two factors are *equally important*; 3 – one factor is *slightly more important* than the other; 5 – one is *strongly more important*; 7 – one is *very strongly more important*; 9 – one is *absolutely more important*; 2, 4, 6, 8 are intermediate values of one criteria over the other.

Obtained comparison data can be analyzed with either regression analysis or an eigenvalue technique. The latter technique implies construction of reciprocal matrices. Saaty (1977) proposed defining relative importance of criteria by the right eigenvector of the largest eigenvalue of pairwise comparison matrix (*preference matrix*) A:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, \quad (3)$$

where a_{ij} represents the comparison values for criteria *i* and *j*. (Ananda and Herath 2009). The diagonal elements are equal or "1" and the other elements will be reciprocal to the earlier comparisons. There is a basic, but very reasonable, assumption for pairwise comparison: for instance, if attribute A is absolutely more important than attribute B and is rated as 9, then B must be absolutely less important than A and is valued as 1/9. These evaluations are conducted for all factors to be considered, usually not more than 7, and the matrix is completed.

The right eigenvector method also enables testing for inconsistency. The perfect consistency is reached, when AW = nW, where A is the n×n comparison matrix and $W=(w_1, w_2, \dots w_n)^T$ – priority weights of criteria. Saaty (1977) suggested the following equation: $AW = \lambda_{max}W$, where λ_{max} is the maximum eigenvalue (Perron root) of matrix A, and proved that the largest eigenvalue λ_{max} is always greater than or equal to the number of elements in comparison *n*. (Ananda and Herath 2009)

If needed, a relative performance of each alternative can be gained for each criterion separately with the same approach. A reciprocal preference matrix is built for each criterion to demonstrate a trade-off among all alternative for that particular criterion. In a similar way, a vector of weights is calculated. When calculations for all criteria are fulfilled, they constitute the matrix of performance weights $n \times m$, where n is the number of criteria and m is the number of alternatives. In order to get an overall score for each alternative, the n matrix of criteria weights is multiplied by the matrix of performance. (Handfield et al. 2002)

Analytic Hierarchy Process is applied for a vast variety of purposes: planning, selecting a best alternative, resource allocations, resolving conflict, optimization and others (Vaidya and Kumar 2006).The AHP is used for many tasks in forestry, for instance, it is widely applied for strategic forest planning, mainly in Finland (Ananda and Herath 2009). AHP also facilitates decision-making tasks in technology management, such as technology selection, make or buy decisions, NPD project portfolio priorization, evaluation of new product concepts and evaluation and priorization of customer needs.

8. ANALYSIS OF RESULTS

Totally 14 companies participated in the research. The issue of company's size was essential while sampling as one of requirements was choosing big solvent companies if possible. Several introductory questions can characterize operations scale of companies: size of forestland (for forest leasers), amount of employees, key clients and geography of business operations. The answer categories were introduced to the following parameters: the amount of employees (for all) and forest size leased (only for forest leasers). The letter parameter is not acceptable for forest inventory providers (2 companies), governmental establishments (2) and GIS system developer (1). Exactly half of the companies (7) has from 50 to 500 employees, four companies have more than 1000, and three companies have less than 50 employees. In terms of forestland leased, the majority of companies (7 out of 9) has more than 100 thousand hectares and only two companies have 50-100 ths ha. Another measure of company operations' scale for logging and woodworking companies is their annual cutting areas. At this point, there are two indicators – annual allowable cut (AAC) and actual annual cut.

To narrow down the amount of data for analysis, we limit the number of questions to twelve. For convenience's sake, we divide these questions into two sets. Analyzed questions as well as research questions are coded for further utilization. The codes are put in brackets.

The first set includes questions that will help to answer first two research sub-questions: *What are the customer needs in forest inventory information in Russia?* (RQ1) *How are these needs met?* (RQ2)

– How frequently do you need to acquire up-to-date information about forestland? (FR)
– What methods do you (your suppliers) apply in forest inventory? (MT)
– What forest inventory information does your organization (its clients) need for forest management planning? (IN)
– How do you utilize obtained information (for what purposes)? (UT)
– How do you process forest inventory data? How are they diffused within you organization? (PD)
– What precision is required for these purposes? Are you satisfied with precision of the methods in use? (PR)

The second set of questions mainly with the last research sub-question: *What is the customer perception of forest inventory methods?* (RQ3)

– What are your criteria of forest inventory method choice? What is the most essential in forest inventory method choice? (CR)
– What are advantages and disadvantages of the used forest inventory methods? (AD)
– Do you think the currently applied forest inventory methods are up-to-date? (RL)
– Are you familiar with airborn scanner LIDAR forest inventory method? What do you think of it? In your opinion, is it suitable for Russian market conditions? (LD)
– Which management level is responsible for deciding on necessity of forest inventory, choosing suppliers and procurements? (for subsidiaries) (MN)
– What quality-related problems do you deal with in inventory methods? (QP)

This second set of questions contributes to marketing and product development aspect. Some questions (RL, LD, QP) directly facilitate answering the main research question about innovation's potential implementation in Russia: *Is LIDAR technology viable for forest inventory in Russia?* (RQ)

Some companies did not answer full set of questions due to their confidentiality policy, or they were reluctant or unable to answer. In such cases, "N/A" (meaning "not available") is present in corresponding table rows. Governmental establishments, forest inventory providers and GIS developer answered the reduced set of questions due to their profiles, and the question list was modified for them. Each company case commences with a short profile description with further analysis of answers in a narration form. Firstly, forest inventory companies are analyzed followed by forest leasers, governmental establishments and, finally, GIS developer.

8.1 Company A

The company makes business in providing comprehensive services in the field of forest management planning for forest leasers. The services include forest reproduction activities, such as sowing, planting and tending, as well as making out a coupe and forest inventory for clear and selective fellings. Clients are mainly forest leasers. It is in Russian property and employs 60 full-time employees with bigger amount in high season. The company is located in Arkhangelsk region and operates in this region and neighboring areas (Komi, Vologda regions). The company is involved in inventory process while making out coupe demarcation and refreshing materials of the last forest management planning for compilation of Forest management plans.

The company's clients are willing to get up-to-date information constantly, because it is required for planning of their operations. This is especially relevant for large forest users, whose production is much resource-intensive. Contracts are concluded annually for particular forest stands. Enumeration and measuring methods are used for the purpose of forest inventory, ocular inventory and inventory, based on aerial imagery, are not applied. The most common method is strip enumeration. The customer companies need the following forest inventory information: realizable timber volume, size classes division and species composition for business planning. Species composition is commonly different from what is shown in Forest management plan. The information is utilized for making up a forest declaration and logging planning. As far as processing of information is concerned, the company applies stumpage appraisal programs developed by forest managing organization "Sevlesproyekt". In these programs volume, species composition, separation into size classes is calculated, plotting and putting plots on maps are completely done. In such a way, all calculations are produced electronically. Company's customers are mostly large companies, and they are interested in maximum precision ("cube in cube"). The company could not provide it with their methods, and there is a number of peculiarities, not depending on inventory method choice. If an error is within 10%, it is treated as good.

In the matter of forest inventory method selection, the respondent states quality, maximum precision, partly productivity (labor costs) and financial costs as very essential criteria. The company deals mostly with established customers, and a particular inventory method is stipulated in model contracts. Considering advantages of the enumeration, the interviewee explains that strip enumeration is treated (at least used to be) as the most precise, and it is very simple to understand for workers. There is a lack of qualified personnel - many workers do not have specialized education, and the company trains them itself. This method is quite understandable – how to take a sample, how to carry out an enumeration on these samples. Another advantage is that the company can simply check conducted inventory, control a worker after the inventory is done - engineers can go to a spot-check and select one sample inside a plot, make an enumeration on it and compare with the results brought by the worker. A disadvantage for a strip enumeration is high labour intensity (if done properly); a four-man team does this work. Forest inventory done by fixed-radius circular plots method can be carried out by two men in 1,5 times or even more faster – there is no need to mark the borders. The company's representative views this method as not less precise. He reveals that it became more convenient with new technologies, and many companies switch to this method. Currently applied methods are seen as up-to-date (instrumental, measuring and enumeration methods) for those companies, that are willing to know real values. The interviewee is not familiar with other methods that can help to define a volume and species composition on particular sites with defined precision. These methods will stay applicable in Russia for a long time, especially for big forest areas. Company's representative has never heard about LiDAR technology, but expressed interest and willingness to familiarize with it. On his opinion, this method has a wide coverage and thus viable in Russia, granted proper precision and productivity are provided. He believes it can be applied in European North and Siberia. It can be adopted by Russian market, if customers are satisfied with quality price ratio, and precision is fulfilled.

By respondent's opinion, the forest inventory problems include out-dated merchantable single-tree assortment tables. They were compiled long time ago (second half of 20th century) with the use of obsolete devices; computer programs can measure those data much more precisely, though in some localities the renewal work is being done with the use of new technologies. There is a lack of qualified stuff. A human factor often plays a crucial role, especially when new technologies are implemented. One more problem is a missing feedback while logging – if present, results obtained from forest inventory could be compared to real logging figures. This problem has many aspects – onboard computers installed in harvesters utilize other tables, there is a remaining human factor. In this case, it is hard to determine what amount of wood was logged on a particular plot. Sometimes customers complain that there is a divergence between real figures and inventory indicators, but since there is no smoothly running feedback mechanism, it is hard to find a mistake. The interviewee believes that handling this problem can increase inventory precision. The tables should be revised depending on a habitat (boreal, midland forests). He also mentions outdated legislation as a problem.

For illustrative purposes, main insights from the interview are presented in the table 5.

Table 5 – Main insights from Company A

Parameter	**Value**
Company type, location	Forest service provider, including forest inventory, Arkhangelsk region
Demanded frequency of information	Constantly
Inventory methods applied, why	Enumeration and measuring methods (easy to comprehend, high precision). Mainly strip enumeration
Inventory methods not applied, why	Ocular inventory (requires special trainings), aerial imagery (low precision for both)
Demanded information	Merchantable timber volume, size classes division and species composition.
Purpose of usage	Making up a logging report and logging plans
Processing of information	Only electronically, stumpage appraisal programs
Precision desired and satisfaction with existing precision	Maximum precision (“cube in cube”) is desired, 10 % is normal
Criteria of methods choice	Quality, maximum precision, partly productivity (labor costs) and financial costs
Overall relevance and satisfaction with existing methods	Yes, will stay applicable for a long time
Awareness of LiDAR, opinion on it	No, viable in Russia, granted proper precision and productivity is provided
Quality problems	Outdated merchantable single-tree assortment tables, lack of qualified staff, human factor, missing feedback while logging, outdated legislation

8.2 Company B

The company’s business is design engineering on territories related to forestry, aesthetic forestry and municipal facilities. The activities include drawing up Forest management plans for different utilization purposes, certification of green plantings on streets, avenues, parks and making out some other documents. It employs less than 50 workers. The company is located in Central Federal District, and it operates in Russian regions. The company replied in written form, thus most answers are short.

The company claims that, based on Forest Code's clause, a forest leaser has to obtain information about forestlands one time, once a leasing agreement is concluded and positive decision is made on drawn-up Forest management plan by expert commission. Then the leaser should strictly follow this plan. The usage of particular inventory method depends on inventory purpose; both existing and developing methods can be applied, if they are of proper precision. Photo interpretation of high-resolution satellite imagery and field inventory are widely applied at the moment. On interviewee's opinion, remote sensing with sample plot surveys and others are more likely to be applicable in Siberian and Far East federal districts. For carrying out coupe demarcation and drawing up layout of felling areas, mensurational descriptions, by subcompartments, are required which include the following information: age of a stand, mean height and mean stem diameter (required by acting regulations), stand volume in felling area, presence of valuable underwood, forest type and growth conditions (for a proper regeneration). Inventory information is used for stand felling and for the situation, when a leaser company deforests an area supposed to be felled later and needs information where to take timber resources. Forest inventory information is processed in computing centers of forest management companies with the use of proprietary or purchased software; there is no joint system in Russia so far. While transmitting information from one organization to another, specific programs convert data. In small quantities, information is processed manually. Answering the question about inventory precision, the company refers to Forest management guidance, where precision requirements are stipulated for each inventory method. The company is satisfied with them.

The criteria that company sees as the most essential in method choice are the task in hand and funding. It states that there is no shortage of methods to choose from. What comes to advantages, the interviewee claims that all existing methods are appropriate, but the smaller a subcompartment is, the less likely modern and developing inventory methods can be applied. On-site inventory should be done on small subcompartments. The only disadvantage of applied forest inventory methods is their labour costs; there is no need in cutting a sight line or measuring a ride when there are high-quality satellite images at disposal. All applied inventory methods are seen as contemporary. The company utilizes all abovementioned methods in its work. It is familiar with LiDAR, but does not work with it. The company believes that there are no problems in terms of quality of inventory methods; it is about workers' proficiency, honesty and performance. So, the main point here is qualified personnel that is familiar with inventory methods and can apply them depending on circumstances (given task).

Most essential insights are briefly listed in the table 6.

Table 6 – Main insights from company B

Parameter	Value
Company type, location	Forest services provider, including forest inventory, Moscow
Demanded frequency of information	Once, for a Forest management plan
Inventory methods applied, why	High-resolution satellite imagery with office photo interpretation and field inventory Only on-site inventory for small subcompartments Depending on inventory purpose, any method can be applied (both established and developing)
Inventory methods not applied, why	No
Demanded information	Age of stand, mean height and mean diameter, stand volume in felling area, presence of valuable underwood, forest type and growth conditions
Purpose of usage	Stand felling and need in information where to take timber resources
Processing of information	Computing centers of forest managing companies, no joint system in Russia so far. While transmitting an information - data converting programs.
Precision desired and satisfaction with existing precision	Satisfied, conforms with requirements of Forest management guidance
Criteria of methods choice	Given task, funding
Overall relevance and satisfaction with existing methods	Yes
Awareness of LiDAR, opinion on it	Yes, more likely to be applicable in Siberia and Far East Russia
Quality problems	No problem, only workers' proficiency, honesty and performance matter

8.3 Company C

The company is the biggest woodworking company in Russia. Its operations range from forest regeneration to deep wood processing and making end products. It holds a forestry, logging and chemical processing (pulp, paper and paperboard). The company has three branches, one of them is in Arkhangelsk region, and each branch consists of woodworking and timber sourcing enterprises. It leases forest areas mainly for a long term (49 years) with total square size of 5,7 mln ha, forests belong to second and third management categories. Annual allowable cut for the company is 11 mln m^3 with real logging volume of 8-9 mln m^3 per annum. Its main customers are located in China, Europe and Russia. The company gives employment to about 20 ths men. The company is owned by Russian (50%) and American (50%) shareholders.

The company in accordance with established system believes that a forest management should not be older than 10 years. It had to make out forest management actions on 2 mln ha on its own funding, without government's help within last 5 years. The company wants to go on with it, based on the same 10 year-period intervals. The following forest methods are used: ocular and measuring inventory for forest management, strip enumeration and circular sample plots while making out coupes. The main information that the company needs in forest inventory is species composition and stand volume along with merchantability class. The information is needed for strategic (forest management materials) and operational planning (inventory information while coupe demarcation) of business. Strategic planning in terms of timber sourcing stands for knowledge, what timber species and volume can be supplied to plants, operational planning stands for annual felling volume and forest roads construction. The information is processed with the use of GIS software, once information is inputted, it is processed, and stumpage appraisal and assortment plan are done. The company claims that forest inventory precision is appropriate for strategic planning purposes, but not for operative planning purposes. The desirable precision is within 10%. Average error on stand volume is 15-30% in forest management planning, depending on forest management category.

In terms of criteria for method choice, the interviewee answers that there is no variety of existing methods. What concerns forest management inventory, different methods can be applied, depending on forest category, but the main criterion is precision and price balance. Application of a particular enumeration method while making out a coupe depends on stand characteristics. There are established rules, and the company follows them. As for advantages and disadvantages of applied methods, there is not much to talk about. The disadvantages are precision and time frame – the process is labour-intensive. As far as relevance of applied methods is concerned, company's representative supposes that new remote sensing technologies seem very promising, but the main point is achieving balance between precision and costs increments. The company explores possibilities of such methods to increase the precision, but there is no unanimous opinion within company on them so far. In relation to LiDAR technology, the interviewee thinks that methods using laser scanning appear to be relatively expensive. The company sought out such methods and did not find good-price solutions – a company can get very high precision, but the price is just too high. The interviewee admits that it can decrease over time. As it was already notices, the company needs precision mostly for operational planning purposes. All its felling areas are scattered quite much around the leased territories, that is not appropriate for remote sensing methods (they cover quite wide zone, not particular segments). Thus, it results in large volume and high costs. However, the interviewee presumes that LiDAR technology can be viable on Russian market, it can suits some forest enterprises purposes. Suitability depends on company's size, forest sites, its dispositions and given tasks.

What comes to decision-making management level, there are specialized departments in all branches, where employees based on their experience understand how much obsolete information affects quality of making out coupes, that are held annually. In case of serious errors or obsolete materials of forest management planning, and possibility to transfer big amount of stands into ripe category, these specialists initiate new forest management. They substantiate an investment request, and the forest management is ordered, if the request is approved. Insufficient usage of cutting-edge technologies is stated among the main problems in forest inventory quality. There is no lack of qualified personnel. In different branches forest inventory is done differently - either by employees or by contractors.

Most essential insights are listed in the table 7.

Table 7 – Main insights from company C

Parameter	**Value**
Company type, location	Woodworking company, pulp and paper production, a branch in Arkhangelsk region
Demanded frequency of information	Every 10 years for forest management planning
Inventory methods applied, why	Ocular and measuring inventory for forest management, strip enumeration and circular plots while making out coupes
Demanded information	Species composition, stand volume, merchantability class
Purpose of usage	Strategic and operational planning of business
Processing of information	GIS software, where stumpage appraisal and assortment plan are done
Precision desired and satisfaction with existing precision	Satisfied for strategic planning purposes, but not satisfied for operative planning purposes. The desirable precision is within 10%.
Criteria of methods choice	Management category for forest management inventory, main criteria - precision and price balance. Application of a particular enumeration method depends on stand characteristics while making out a coupe.
Overall relevance and satisfaction	No, precision and time frame are disadvantages,

with existing methods	main aim – reach balance between precision increment and costs
Awareness of LiDAR, opinion on it	Yes, laser scanning methods appear to be relatively expensive. Inappropriate (high costs) when sites are scattered - remote sensing cover quite wide zone, not particular segments. But can be viable on Russian market.
Management level making decisions	Specialized departments in all branches, where experienced employees evaluate necessity. Request should be approved by management
Quality problems	Insufficient usage of cutting-edge technologies, but there is a number of problems. No lack of qualified personnel.

8.4 Company D

This respondent represents a group of companies, and its business is wood logging and management of forest enterprises. Annual actual cut is around 1,5 mln m^3. Leasing agreements are concluded for 49 years (long-term). Main clients are wood logging enterprises, harvesting machinery suppliers, forest management companies and forest service companies. It supplies wood logging enterprises located in Arkhangelsk region. The company is in Russian private ownership and employs more than 1000 men.

The company constantly needs up-to-date information; it would like to have it every 3-5 years at minimum costs. All allowable methods are applied, but the company is interested only in ocular and measuring inventory for forest management planning since this is the only method that is accepted by authorities for giving felling permission. Different sample plots methods are utilized. The whole forest management planning takes from two to four years and costs around 20 mln roubles for one forest district in Arkhangelsk region. The company applies all possible methods for internal purposes, like aerial photo interpretation, but changes cannot be made to State Forest Register based on this information. The simplest method is data updating, but it is not accepted anymore. The company applied space imagery and information ordered in Roslesinforg. The information needed in forest inventory includes forest site’s plan and margins, its and stand’s characteristics, purpose and volume of forest utilization, scale of works in forest protection, conservation and restoration, and subcompartment-based mensurational description. Obtained information is used for searching forest sites for logging, carrying out works and making up Forest management plan and other documentation. A cartographic and text documents are submitted in hard copies and electronically. Several departments are interested in such information. It is not processes in the company at all, but comes in ready, refined form. It is initially ordered in handy form, so any worker can easily use it. As for precision of information, 20% margin of error used to be applied, now it is 10%. The desirable precision is about 3-5%, but the interviewee thinks this is not possible and inventory methods cannot enable it so far. Thus, the company is satisfied with 10% accuracy, and it is fulfilled.

In the matter of criteria for inventory method choice, only inventory made by ocular and measuring methods allow the company to start felling works. The only requirement is compliance with the legislation. All information is needed on subcompartment level. As far as disadvantages of forest inventory methods are concerned, information ordered in Roslesinforg is quite outdated (1-2 year-old information) and it is expensive. The interviewee could not say formulate any advantages. The respondent thinks that currently used methods are relevant, though new, more time-efficient and less labour-consuming methods should be involved. Ideally, the company would like to get real-time information. Company's representative believes that forest inventory companies – Russian, Scandinavian - utilizing new information systems, provide useful information, though it cannot serve as a basis for making changes in SFR. The interviewee was not familiar with LiDAR technology. He presumes it would be expensive, but showed interest to have a look on the results it provides and compare them with space imagery results. The requests for deployment of new methods is that they should be more time-efficient, less labour-consuming and acceptable by the authorities for making changes into forest management materials and SFR. The main problem in quality of forest inventory methods is human factor. The quality depends on worker's qualification and work experience. The interviewee presumes that there is a lack of qualified personnel in Arkhangelsk region and employee turnover in forestry.

Most essential findings are presented in the table 8 below.

Table 8 – Main insights from company D

Parameter	**Value**
Company type, location	Wood logging, working and management of forest enterprises, Arkhangelsk region
Demanded frequency of information	Ideally, real-time information, in reality - every 3-5 years
Inventory methods applied, why	Ocular and measuring methods, solely accepted by authorities for giving felling permission and making changes to SFR, space imagery and information by Roslesinforg for internal purposes
Inventory methods not applied, why	Data updating, not accepted anymore

Demanded information	Subcompartment-based mensurational description along with forest site's plan and margins, its and stand's characteristics, purpose and volume of forest utilization, scale of works in restoration etc.
Purpose of usage	Searching forest sites for logging, carrying out works and utilizing as material for Forest management plans and other documentation.
Processing of information	No, comes in ready, refined form. A cartographic and text documents are submitted in hard copies and electronically
Precision desired and satisfaction with existing precision	Desirable precision is about 3-5%, but the company is satisfied with 10% accuracy, and it is fulfilled.
Criteria of methods choice	The only requirement is compliance with the legislation. All information is needed on subcompartment level
Overall relevance and satisfaction with existing methods	Yes, though new, more time-efficient and less labour-consuming methods should be involved. Forest inventory companies, utilizing new information systems, provide useful information, though it cannot serve as a basis for making changes in SFR. Information ordered in Roslesinforg comes quite outdated and it is expensive.
Awareness of LiDAR, opinion on it	No, but presumes it would be expensive, but showed interest to have a look on the results it provides and compare them with space imagery results
Quality problems	Human factor. The quality depends on worker's qualification and work experience. There is a lack of qualified personnel in Arkhangelsk region and employee turnover in forestry.

8.5 Company E

The company is a timber industry enterprise (*lespromhoz*) within a group of companies and provides wood logging, extraction and dispatch to sawmills within the group and to Arkhangelsk pulp and paper mill. The company lease forest sites on the area of more than 100 ths ha in Arkhangelsk region for a term of 49 years. The enterprise has 350 employees. It is Russian owned. Annual actual cut is more than 380 ths m^3 as stated on company's website.

The company would like to obtain timely information once a year. The last forest management planning was held in 1997, but the materials (in values of mean stem diameter, mean height and volume of stand) are updated while making out coupes. Some parts of timber are missing due to dead standings or windthrown trees in subcompartments and forest stands. No dying is observed currently, and a young stand is growing up. Forest inventory is done by field mensuration with circular relascopic sample plots. Information that the company needs most from forest inventory comprise square subject to drying. Forest restoration is scheduled for those sites, though the quantity of young stands is high, and no artificial regeneration is needed. Collected inventory information is utilized for making out Forest declaration, and growing stock and timber quality estimations. It is also needed for FSC certification that the company is planning to acquire. Forest inventory information is processed by computer software. The output is stumpage appraisal. Growing stock and timber quality data are handled electronically, while the maintenance task card is done manually. The company is generally satisfied with inventory precision, an acceptable error is 5-10 %.

The main criteria company applies while choosing inventory method are simplicity and lowest possible labour-intensity. However, the quality to price ratio will dominate as the main criterion in the future. The chosen method (circular relascopic sample plots) requires less human resources in comparison with strip enumeration that is more labour- and time-consuming. Relascopic sample plots method is less labour-intensive, though its results in the same quality. Company's representative views its disadvantage in not observable parts of a plot, though resulting error is acceptable. As regards to relevance of applied methods, they are treated as contemporary, but the interviewee claims that they would find an appropriate cutting-edge method enabling less margin of error. Staff training is held in the company, and skills are upgraded every 2-3 years, but no new methods are taught there. Company's representative was scarcely aware of LiDAR technology. After familiarizing with its capabilities, he believes that the methods cannot be cheap a priori, since aviation is used. It can be only feasible for large squares under the aegis of some governmental happening, for SMEs such method seems to be costly. The main factor in terms of quality of forest inventory methods is a human factor – personal education and involvement matter as well as enough time allocated and lack of haste. Difficult accessibility of particular forest sites, shortage of time to get there, lack of amenities in work conditions are also seen as inventory problems. Company possesses such sites, and preliminary work for forest management is done in winter times, while inventory itself is held in summer. If an error deviates from 10 % margins, a report cannot be done precisely that will arise questions from forest district's side. The interviewee states that forest districts currently control timber turnover more strictly.

Most essential findings are briefly listed in the table 9.

Table 9 – Main insights from Company E

Parameter	**Value**
Company type, location	Lespromhoz (timber industry enterprise), Arkhangelsk region
Demanded frequency of information	Annually
Inventory methods applied, why	Measuring method (circular relascopic sample plots), requires less human resources in comparison with strip enumeration (that is more labour- and time-consuming). Not observable parts of a plot is a disadvantage, though resulting error is acceptable.
Demanded information	Particularly square subject to drying along with main parameters (mean stem diameter, mean height and volume of stand)
Purpose of usage	Drawing up Forest declaration, growing stock and timber quality estimations, FSC certification
Processing of information	Computer software produces stumpage appraisal; growing stock and timber quality data are handled electronically, maintenance task card - manually.
Precision desired and satisfaction with existing precision	Generally satisfied, acceptable error is held (5-10 %).
Criteria of methods choice	Simplicity and lowest possible labour-intensity; quality to price ratio will dominate for new method's choice
Overall relevance and satisfaction with existing methods	Relevant, but looking for an appropriate cutting-edge method enabling less margin of error. Same methods are taught on staff trainings.
Awareness of LiDAR, opinion on it	Slightly aware, the method cannot be cheap a priori, since aviation is used. Can be feasible only for large squares under the aegis of some governmental happening. Such method is thought to be too costly for SMEs.
Quality problems	Human factor – personal education, interest as well as enough time allotted and lack of haste. Difficult accessibility of particular forest sites, shortage of time to get there, lack of amenities as work conditions are also seen as inventory problems.

8.6 Company F

The participant represents a group of companies. The interviewed company accommodates consulting services to timber industry enterprises. The group of companies and its affiliate companies lease forests, provide logging, woodworking and realization of products. Forest sites are leased for 15-49 years, their total square is more than 100 ths ha. The group of companies employs more than 1000 workers. Its AAC is almost 2 mln m^3, whereas actual cut is 1,25 mln m^3. It exports roundwood to Scandinavia as well as it supplies timber to North-West and Central Russia.

Forest management planning in company is held totally by public funding. The procedure takes 3 years in total. It used to be done every 10 years, data updating without going out to forest was predominantly used lately. Forest management was done very long ago in some stands owing to lack of public money devoted to these purposes. The company would be satisfied with duly completed forest management inventory once in 10 years with subsequent data updating. Outdated information hinders company's operation and submitting reports to supervising organizations. Only field inventory (ocular and measuring method) is acceptable for company's use, as a result of outdated forest management. The company typically applies circular relascopic sample plots. The interviewee claims that ocular method is not acceptable by supervising bodies to submit declaration. It is only useful after inventory is properly done for making sure, that everything is OK. Complete enumeration seems very precise, but it is too much labour-intensive, thus it is used only for relatively small plots. Aerial and space imagery are treated as not acceptable, since wood assortment separation is required, so it is obligatory to detect possible defects in wood, for example hollows. Required inventory indicators include growing stock volume, divided by species, mean height and mean stem diameter, as well as quality values, like separation for timber and fuelwood, for making out assortment plan. Soil and ground conditions are also evaluated during inventory for planning road construction. Information is used mainly to draw up permission documentation properly for supervising bodies. The company also uses it for making production plans (assortment plan, carrying-away plan and sales objective). Transport logistics and supply arrangements also require inventory information, assortment plan is treated as the basis for any further planning steps, thus species composition plays a major role. Information is processed completely electronically, with the use of specialized software for stumpage appraisal. The information in dispersed to production and forest departments. The inventory precision for stand volume as well as species composition is defined on the level of 10% and it is fulfilled. The company is generally satisfied with such precision, because increasing precision leads to usage of complete enumeration (common method with highest precision), thus labour costs rises drastically, and especially it takes much more efforts for big plots and results in 3% precision (comparatively 1 week time to 1 day). The company's representative claims that there is no need in higher precision, since there are many influencing factors, like weather conditions.

As far as selection criteria are concerned, some criteria are statutory, like for plots, less than 3 ha, only complete enumeration is used. Price considerations play a crucial role in inventory methods choice process. If precision is equal, the preference is given to a cheaper one. Also, completion time (labour intensity) matters, as well as presence of underwood. For example, if underwood is high and dense, strip enumeration can be used, but not relascopic circular plots. The company uses three inventory methods at the moment, and the advantage of circular plots over strip and complete enumerations is less labour intensity, and thus it is faster to accomplish. Also advantages of currently applied methods were formulated in comparison new technology solutions, such as the one offered by Finnish company Trestima, based on other company's experience. The interviewee claims that even though it works faster, it mixes wood species sometimes. It needs specific weather conditions to take high-quality photos (no raining completely, good lighting conditions), also they are not duly processed on a computer. So, it does not always provide proper quality, and it costs as traditional methods. The same view company's representative shares on aerial and satellite methods – current technology are not as reliable as on-site inventory. He believes that such methods cannot see wood quality, possible hollows or for example, dried brook. The main disadvantage of used inventory methods is high labour intensity, for example conditions in mini-expeditions appointed for hard-to-reach sites. What comes to LiDAR technology, the company's representative was not aware of it and its capabilities. The authorities require field inventory for making out coupes, and it is rational to do forest inventory once both for internal purposes and reporting (as it is done now). He also believes, that the price must be too high, at least at initial stages, but even if the price is the same as for currently applied methods, the company would rather prefer ocular and measuring method. The interviewee sees LiDAR technology more appropriate for state's purposes, for state-arranged inventory (forest management, NFI), where large areas need to be covered, for example in Siberia. It can be proper for regions, where forest road infrastructure is underdeveloped, while in North-West district has the best value of forest road length per ha among other Russian regions. It can also be appropriate, when forest resources estimation needs to be done in shortest terms, for instance while launching high-investment project. He reckons that LiDAR technology is not relevant for businesses of his company and other forest leasers, at least for logging purposes. The company has maps, some forest management data (even outdated) and very experienced specialists, who knows leased forest territories very well. In Russia it is cheaper to send a worker out in forest, that to apply such technologies. In addition, soil conditions assessment (in Russia, deposits are located deep from the surface) and defining biotopes are essential, as a requirement of FSC standardization, that can be a problem for LiDAR technology.

As regards to inventory methods problems, human factor is a big concern in terms of quality, personal attitude and responsibility plays an important role. Mistakes on initial, inventory phase can lead to large costs as well as spoil company's goodwill in the eyes of customers (in terms of failed supplies). Mistakes within 10% are unimportant, since there is always some amount of wood of different species in stock. Most essential findings are put in the table 10.

Table 10 – Main insights from company F

Parameter	**Value**
Company type, location	The group of companies: logging, woodworking and realization of products, Vologda region
Demanded frequency of information	Once in 10 years
Inventory methods applied, why	Field inventory (ocular and measuring method) - circular relascopic sample plots (lower labour intensity, faster to accomplish), strip enumeration and complete enumeration (the most precise).
Inventory methods not applied, why	Aerial and space imagery are seen not as reliable as on-site inventory methods, cannot define wood quality, possible defects in wood, for example hollows. Trestima mixes species sometimes, needs specific weather conditions to take high-quality photos. Ocular method is not acceptable for reporting, it is only useful after proper inventory is done. Complete enumeration seems very precise, but it is too much labour-intensive, thus it is uncommonly used.
Demanded information	Species composition plays a major role. Growing stock volume, divided by species, mean height and mean diameter, as well as quality values, like separation for timber and fuelwood. Soil and ground conditions for planning road construction
Purpose of usage	Drawing up permissive documentation for supervising bodies. Making production plans, planning transport logistics and supply arrangements.
Processing of information	Completely electronically, with the use of specialized software for stumpage appraisal, dispersed to production and forest departments.
Precision desired and satisfaction with existing precision	Generally satisfied with 10%, that is fulfilled. There is no need in higher precision, since there are

	many influencing factors, like weather conditions.
Criteria of methods choice	Some requirements are mandatory (only complete enumeration is used for small plots). Price considerations, completion time (labour intensity) and presence of underwood (application of particular field inventory methods)
Overall relevance and satisfaction with existing methods	Relevant, new high-technology methods cannot provide required information
Awareness of LiDAR, opinion on it	No. The state requires natural coupe preparation, it is rational to do inventory at the same time. The company would prefer ocular and measuring method, even if the price is the same. The technology is more appropriate for state arranged inventory (forest management planning, NFI), where large areas need to be covered, and in regions, where forest road infrastructure is underdeveloped, for instance, in Siberia. It can also be appropriate, when forest resources estimation needs to be done in shortest terms (while launching high-investment project). Such technology is not relevant for business of Russian forest leasers, at least for logging purposes. Soil conditions assessment is essential as well as defining biotopes, as a requirement of FSC standardization, that can be problematic for LiDAR.
Quality problems	Human factor is a big concern in terms of quality, personal attitude and responsibility plays an important role.

8.7 Company G

The company deals with wood supply. Its business consists of two parts: forest use on the leased territory and procurement from third-party suppliers for company's needs. The company has long-term forest leasing contracts (49 years) with total square of 271 ths ha and AAC of 480 ths m^3, while actual cut is around 450 ths m^3 a year. The company is a Russian subsidiary of Finnish company. Company's key clients are mainly plants inside the group of companies in Russia and Finland, and also partners, to whom the company supplies excess materials. The company employs 250 workers and outsource 2-3 times as much. Main business processes are done by employees, while others are given to subcontractors. It is located in Leningrad region. The company exports ready productions to Europe and Japan and trade on internal market as well. Raw materials are supplied to producers in Leningrad region, Karelia republic and Vologda region above its own needs.

The company constantly needs up-to-date information, the desired periodicity could be once in 1-2 years on general level, but more detailed information is required once in 10 years. Negative natural developments take place every year (wildfires, windthrow, outbreaks of diseases and insects). There is no need in updating information in young stands too often, but, for instance, inventory is needed in windthrown areas. The company utilizes traditional inventory methods (circular relascopic sample plots) along with some modern ones (aerial imagery, GIS, satellite images are applied while outlining borders of felling area). Trestima method is also tested on a particular area. As for forest management planning, it is done by contracting organization, and the company could not control this process. Aerial photo-interpretation was most likely used. The information that the company needs include growing stock volume, by species, age of stand. Depending on age, different parameters are the most important. In young stands, the company needs values of stand's height, density (amount of trees per ha) and species composition. Proximity to roads, site class and inhomogeneity level also matters. For middle-aged stands, essential parameters are growing stock, density, diameter range (for tending). For mature stands, above others, underwood presence and inhomogeneity level are essential. The company utilizes inventory information to draw up permission documentation to correct annual cut values in forest management planning materials (error in volume, error in species always exists). In addition, when there are not much big sites of mature stands (5-10 years perspective), precise inventory information will be needed for road construction to choose more profitable destinations and 10-20% mistake will not be acceptable for this purpose. For information processing two programs are used – MDOL (for stumpage appraisal) and Abris (as a map service), both were developed by forest management enterprise. Information is presented in convenient acceptable form, that can be forwarded directly to forest districts. The company possesses large databases of coupes, logging reports and mensuration descriptions. The company's representative believes that very high precision is not needed for company's business (in terms of inventory parameters itself). However, he stands for increasing precision in positioning of objects, since it is a big issue. Good GPS systems can be costly, and complicated ones require permission to use. Thus, the interviewee is satisfied with current inventory accuracy as precision increase does not give much value for business operation so far. In figures, the company is satisfied with 10% mistake in growing stock, but not with 20%.

In terms of criteria for inventory method choice, the company applies only circular relascopic plots for mature stands while making out a coupe. The plots are preliminary selected, based on forest management materials and aerial photo interpretation. The company's representative supposes, that no company does inventory in young stands, except for demonstrational objects. What comes to forest management, it was done at minimal possible price for big squares, and thus the company achieved the goal. The interviewee treats currently used methods as relevant, since supervising bodies accept information got by such means as official. Company's representative wasn't aware of LiDAR technology, but he was impressed by its capabilities. He thinks that such methods are applicable in Russia, but the main issue is what status obtained information possesses. Such method is proper for internal operational planning, since it cannot be accepted by supervising organizations as legal, official information so far. What comes to internal planning, it depends on price and capabilities that the technology gives. The decisions concerning necessity of forest inventory is made on the level of Russian subsidiary, while decisions concerning using of new technologies are done along with IT development specialists in Finland. Equipment procurement is done by Russian side, within limited budget, but expensive purchasing is decided on the higher level.

In relation to inventory problems, the interviewee claims qualified personnel (human potential and work experience) as a big problem. There is a big difference in materials of conducted forest management planning with reality. The big common problem is position discordance of key orienting points, natural objects, which felling does not affect (ride between compartments, roads, brooks). They were plotted on compartment maps with the use of obsolete methods few decades ago and didn't change since that time. Compartment rides are the objects, to which all forest plots are tied, while any activity is done, like planting, logging or road construction. They are the only orienteering points that exist both in forests and on maps. Such discordances cause problems within one forest land section, but even worse between two sections, resulting in section overlapping or creating a part of unknown ownership. Another problem, that is also nation-wide, is that there are two kinds of information, concerning forest inventory. The first type makes business operation legal, serves as the basis for state-business relations and documents them. Another type is useful for internal purposes of business. It helps to prevent losses and increase efficiency of resources utilization (human, financial). The problem is that there is a big gap between these two blocks of information, they are not connected. One more possible problem that can be urgent for new high-tech inventory methods, especially remote sensing, is inability to detect aspen from birch on different stages, that is very essential. The company also needs information about site conditions, if it is a boggy area or a hill-side, that can be also a problem for laser scanning.

Most essential findings are briefly listed in the table 11.

Table 11 – Main insights from company G

Parameter	Value
Company type, location	Wood supply company, Russian subsidiary of Finnish company, Leningrad region
Demanded frequency of information	On general level, it is needed once in 1-2 years (for example, in windthrown areas), but more detailed information once in 10 years
Inventory methods applied	Circular relascopic sample plots. For outlining felling area borders - aerial and satellite imagery, GIS. Trestima method is tested on a particular area. Aerial photo-interpretation was used for forest management planning
Demanded information	In general - growing stock volume, by species, age of stand. In young stands - stand height, density and species composition (also site class and inhomogeneity level). For middle-aged stands - growing stock, density, diameter range. For mature stands - underwood presence and inhomogeneity level, above others. Terrain conditions
Purpose of usage	Drawing up permission documentation, correcting value of annual cut in forest management materials. Road construction (in 5-10 years)
Processing of information	2 programs are in use – MDOL (stumpage appraisal) and Abris (map service). Information in MDOL is presented in acceptable for forest districts form. The company possesses large databases of coupes, logging reports and mensurational descriptions.
Precision desired and satisfaction with existing precision	Satisfied with current accuracy. High inventory precision does not give much value so far, but precision increase in positioning of objects is desired. The company is satisfied with 10% error in growing stock volume, but not with 20%.
Criteria of methods choice	Only one method (circular relascopic plots) is applied for coupe demarcation. Forest management was done at minimal possible price, and the company achieved its goal. For internal planning criteria are price and capabilities, that the technology gives.
Overall relevance and satisfaction with existing methods	Relevant, since supervising bodies accept information got by such means as official.
Awareness of LiDAR, opinion on it	No. Such methods are applicable in Russia, but the status of obtained information matters. Such method can be proper for internal operational planning, but it is not accepted by supervising organizations as official information so far.

Management level making decisions	The necessity of forest inventory is defined on the level of Russian subsidiary; decisions upon usage of new technologies are done with IT development specialists of the group of companies. Equipment procurement is done by Russian side only within the limited budget.
Quality problems	Qualified personnel (human potential and work experience), big difference between materials of conducted forest management with reality. The big common problem is position discordance of key orienting points, like rides between compartments, roads, brooks. Another nation-wide problem is a big gap between two kinds of forest inventory information - one type makes business operation legal, another one is useful for internal purposes of business. They are not connected. Few more possible problems for high-tech methods - inability to detect aspen from birch on different stages and inability to provide information about site conditions. Also inappropriate growing stock calculation while young growth tending.

8.8 Company H

The company's business is logging. It leases forest on short-term (25 years) and long-term basis (49 years). The size of leased territory is 153,8 ths ha with AAC of 340 ths m^3 per year. The company's main clients are works within the holding company, also pulp and paper mills and boiler stations on internal market. In terms of geography, the company supplies production to Karelia and Finland. It employs 50 workers, since most of the work is done by contractors. The company is located in Karelia, and is a subsidiary of Finnish holding company.

The company needs forest inventory information constantly, and it mainly gets it while making out coupes. If done properly, inventory on the whole leased territory is needed not more often, then once in 10 years, since there are not much changes over this period. Exceptionally, in case of disasters the inventory is done afterwards, but only locally. The company applies only ocular and measuring method. Ocular method is not acceptable. The most essential inventory information includes species composition, growing stock volume and age of stand (though age is fixed in forest management materials). The inventory is done for logging. The company processes information with two programs – Abris+ and MDOL. The information is not stored electronically, contractors provide it only in hard copies. For internal use the company needs only maintenance task card, all other documentation is for reporting purposes. In relation to required precision, the interviewee claims that the company has inventory precision with 7% error level, whereas 10% level is demanded by the state. They would like to have 100% precision, but it is not achievable by any existing method, taking into account average values. But in general, the company is interested in higher precision comparing to current value.

As it was already told, only ocular and measuring methods are used, so there are no proper criteria for method selection. First, visual estimation is done, followed by enumeration with sample plots, covering at least 5% of the inventoried square. The interviewee sees its advantage in ability to check measured values by company itself, in comparison to photo-interpretation and remote sensing. The disadvantages of applied method are high labour-intensity, it is time-consuming, and it should be done with high-qualified staff. As regards to relevance of existing methods, the respondent would like to apply modern methods, that enables to take measurements with 90% precision without going out to forest, but they are not accepted by supervising bodies. Forest management materials are outdated and cannot be used. The company's representative is aware of LiDAR technology and believes it is suitable for Russian market, but price matters. 3D terrain relief model can be very useful from respondent's view. The problem is that only licensed and accredited companies can conduct forest inventory, so that the data are accepted by supervising bodies, otherwise such information can be used for internal use only. The interviewee believes that, if Arbonaut gets all state permissions for its technology in Russia, it will be beyond any competition, even at slightly higher price comparing to traditional forest inventory methods. What comes to decision about having forest inventory, the necessity is determined by Russian management and specialists, while further decision concerning financial aspects is made by higher management in Finland.

In the matter of forest inventory quality problems, the respondent called time and human factor. The company trains contractor's workers itself, but it is also a matter of worker's responsibility. Making out a coupe is repeated sometimes due to mistakes caused by human factor, but in less than 1% cases. Another problem is that the government assign little amount of money on forest management (previously, it was totally ordered and funded by the state). The state try to make forest leasers to do inventory on their own expenses, but it is not clearly stated in the official documents. Serious forest inventory mistakes affect company's business a lot, since it influences AAC and forestry sustainability.

Most essential findings are briefly listed in the table 12.

Table 12 – Main insights from company H

Parameter	Value
Company type, location	Logging, Russian subsidiary of Finnish company, Karelia republic
Demanded frequency of information	Constantly (while making out coupes), once in 10 years for the whole leased territory. Only in case of disasters, local inventory is done afterwards.
Inventory methods applied, why	Only ocular and measuring method. Firstly visual estimation is done, followed by enumeration with sample plots. It is possible to check measurements and make sure yourself, that values are right.
Inventory methods not applied, why	Ocular method, not acceptable for any party
Demanded information	Species composition, growing stock and age of stand
Purpose of usage	Logging, permission documentation
Processing of information	Two programs – Abris+ and MDOL. The information is not stored electronically, contractors only provides it in hard copies.
Precision desired and satisfaction with existing precision	Interested in higher precision. The company currently has 7% error rate, while 10% level is demanded by the state.
Criteria of methods choice	No, only ocular and measuring method is used.
Overall relevance and satisfaction with existing methods	Forest management materials are outdated and cannot be used. Would like to apply modern methods, enabling to take measurements with 90% precision without going out to forest, but they are not accepted by supervising bodies.
Awareness of LiDAR, opinion on it	Yes, it is suitable for Russian market, but price matters. 3D terrain relief model can be very useful. If Arbonaut gets all state permissions for its technology in Russia, it will be beyond any competition, even at slightly higher price comparing to traditional forest management.
Management level making decisions	Russian management and specialists determine the necessity, while higher management in Finland makes further decision concerning financial aspects.
Quality problems	Time costs and human factor (worker's responsibility). The government assign very little amount of money on forest management (previously it was totally ordered and funded by the state). The state try to make forest leasers to do inventory on their own expenses, but it is not clearly stated in the official documents.

8.9 Company J

The company's business fields are logging, sawn timber production and wood constructions. It leases forest stands for 49 years, the size of whole territory is 50-100 ths ha. Main company's customers are construction companies, dealing with building wood houses and other constructions, and plywood and particle board plants. The company's amount of employees is between 50 and 500. It is located in Vologda region.

The company answered in written form, thus answers are short, and some of them are missing. Most essential findings are briefly listed in the table 13.

Table 13 – Main insights from company J

Parameter	**Value**
Company type, location	Logging, sawn timber production and wood constructions, Vologda region
Demanded frequency of information	In line with Forest management plan
Inventory methods applied, why	Measuring and enumeration methods. Getting valid information about forest stand, though labour-intensive and time-consuming
Demanded information	Forest stand characteristics – age of stand, growing stock, amount of underwood and others
Purpose of usage	For taking further actions (forest recreation, tending, forest use report submission)
Processing of information	Two programs – MDOL and Abris+
Precision desired and satisfaction with existing precision	Satisfied, precision of properly done sample plots is very high
Criteria of methods choice	Size of inventoried area, precision
Overall relevance and satisfaction with existing methods	No, specialized measuring equipment and instruments are required
Awareness of LiDAR, opinion on it	No
Quality problems	Quality forest management needs to be done, only human factor matters

8.10 Company K

The company deals with production of laminated beam houses. It leases forest stands for 49 years, leased forests belong to the second forest management category. The territory size is between 50 and 100 ths ha. Main company's customers are construction companies. It employs 50-500 workers, and is a joint venture of Russian and foreign owners. The company is located in Volodga, and it operates on the market of North-West Russia.

The company answered in written form, thus answers are short and they are placed in the table 14 below.

Table 14 – Main insights from company K

Parameter	Value
Company type, location	Production of laminated beam houses, Vologda region
Demanded frequency of information	No less than once in 10 years
Inventory methods applied, why	Ocular and measuring method while making out coupe, precision. Though labour-intensive, time-consuming and costly.
Demanded information	Growing stock volume, species composition, mean diameter, height, forest density, site class, forest type
Purpose of usage	Planning of business
Processing of information	Two programs – Abris+ and MDOL
Precision desired and satisfaction with existing precision	Satisfied with 10%
Criteria of methods choice	Precision (quality)
Overall relevance and satisfaction with existing methods	Yes, relevant for the region
Awareness of LiDAR, opinion on it	No
Management level making decisions	The decision concerning necessity is made by company's management, when there is no more wood of valuable species with required indicators
Quality problems	Costly, lack of qualified personnel, the state is not involved (not interested) in it, controversial legislation

8.11 Company L

The company is a timber and chemical complex. It includes five logging enterprises, two of them deal also with wood conversion, and another one, in addition, is a hunting provider. All enterprises lease forest stands for 49 years, which belong to the third forest management category. Leased forest sited varies in size from 1000 ha to more than 100 ths ha, so, in general, the size of leased forest is more than 100 ths ha. Company's main partners are buyers of ready production, environmental-oriented and defensive organizations, local administrations, producers and suppliers of equipment and others. Totally, the company employs 1023 men. The enterprises are located and operated in Vologda region.

The company answered in written form, thus answers are short, and they are presented in the table 15 below.

Table 15 – Main insights from company L

Parameter	Value
Company type, location	Timber and chemical complex, Vologda region
Demanded frequency of information	Satisfied with procedures accepted in forest legislation and Forest management guidance
Inventory methods applied, why	All methods, allowed by current legislation. Each method can be applied in particular conditions, thus determining its advantages and disadvantages
Inventory methods not applied, why	Ocular methods are not acceptable
Demanded information	All the information included in mensurational description by subcompartments
Purpose of usage	Drawing up Forest regeneration project and other documents, current and forward planning of forest use and management
Processing of information	Special software
Precision desired and satisfaction with existing precision	Satisfied
Criteria of methods choice	Completion time, precision (quality of obtained data) and costs
Overall relevance and satisfaction with existing methods	Yes, satisfied
Awareness of LiDAR, opinion on it	Slightly aware, cannot say for sure, since there are many procedural issues
Quality problems	No, simply existing methods should be applied properly

8.12 Company M

The company is a regional branch of federal state unitary enterprise Roslesinforg. It has many branches all across Russia, headquartered in Moscow. The organization has three main business dimensions – forest management, national forest inventory and cadastral works, but also deals with forest park designing, consulting and others. It employs some 400 workers. This branch business covers Murmansk, Leningrad, Pskov, Novgorod and Kaliningrad regions. The company provides information support mainly to government institutions, regional and federal executive authorities of Russia. It also deals with private companies - forest management companies and forest leasers. The company holds a monopoly in national forest inventory, while there is a competition in forest management planning field.

As far as frequency of inventory information is concerned, the interviewee cannot say from its company perspective, since it does not receive or use inventory information. Though, he assures that forest users need information as often as possible, but it is costly. The respondent thinks that an optimal frequency can be once in 10 years. The current legislation stipulates application of four inventory methods. A consumer company chooses method itself, depending on project budget and governmental grant, but it should be agreed with Rosleshoz. The company reveals that most consumers in European part of Russia choose ocular method or photo-interpretation. In regard to photo-interpretation, satellite images are not likely to be used, though image resolution comes to 50 cm at the moment. Finding images with overlapping is often a problem, but it is needed for 3D effect, that enables to define and measure height, species by tree's crown, lower storey in a quality manner. The required inventory information is subcompartment-level mensurational descriptions, which can contain theoretically up to 300 indicators. These descriptions are converted to databases and processed by a special algorithm. Obtained information serves as the base for companies' operations, strategic and tactical planning. The information is not distributed across interviewed company – the company only processes it with the use of GIS and database management systems. For forest management planning, the company uses proprietary software – LUGIS (forest management geo information system) and ESAUL (united system of forest inventory). The question concerning inventory precision is also not in company's competence, and the interviewee considers this issue as very complicated. The company has average precision with 20% error rate (average precision in data array is usually higher). The interviewee assures that doubling the precision (10% error rate) leads to 10 time increase in costs, though only 25-30% of leased territory is involved in companies' business activity over 10 years. Thus, such high precision is not needed on the biggest part of the territory, and it is treated as lost money. High precision is only needed before having silvicultural practices. In this case, on-site inventory is done to rectify inventory information in forest management materials. Requirements stated in Forest management guidance are conventionally abided.

In the matter of criteria, the interviewee reckons the first criterion that companies use is a necessity of a particular precision and information validity, though precision varies in some methods, depending on concrete situation. Another criterion is financing. Current legislation prescribes utilization of four inventory methods, but they are not used solely. It turns out that, basically, four methods turns into two – ground-based inventory (ocular, and ocular and measuring) and remote method (photo-interpretation and forest management data updating). The main disadvantage of ground-based method is that most of the time (some 70%) is spent on moving from one place to another – time-inefficient, also such inventory is done in fair weather only (not rainy). Another big disadvantage is that this type of inventory is done from the point within, for instance, 50 meter-vision reach, and a worker does not see the whole subcompartment. Most serious mistakes come from choosing wrong sample plots, not representative enough. In addition, one more disadvantage is seasonality (inventory is only done in summertime). Correspondingly, disadvantages of ground-based inventory turn into advantages of remote sensing methods. Thus, such advantages are: possibility of all-season work, women can do such inventory (statistically, even better for this kind of work), a working-plan officer sees the whole subcompartment and can estimate it more properly, and also it is possible to control a working-plan officer at any moment (since he/she is located at the same place as supervisor). In addition, the advantage of remote sensing methods is that it is totally done by measurements, thus it is unbiased. Ground-based methods, on the contrary, imply wide usage of ocular estimations. However, the big disadvantage of remote sensing methods is that a working-plan officer sees only upper canopy and does not see underwood and a forest type. It compensates partly by looking at materials of previous forest management planning. In relation to relevance of existing methods, new forest management guidance is going to be issued soon. The company submitted a proposal of stating three inventory methods – ocular and measuring, photo-interpretation, and measuring and enumeration. They are the most relevant and suitable methods in Russia, on respondent's opinion. Measuring and enumeration method provides the highest precision, needed before silvicultural practices. The company's representative is aware of LiDAR technology. He thinks this method is high-potential, but current state of this technology does not provide high quality with high productivity so far. In other words, it is not economically viable. The interviewee supports his claim with recent experimental application of airborne laser scanning at one location and aerial photo shooting at another location. In order to provide high quality (concerning point cloud of that particular laser) the flight with ALS was held at the lower height (500 m), and much smaller area was covered in longer time. However, the interviewee is aware of new generation lasers enabling enough point cloud at heights of 5-6 km. In summary, he thinks that LiDAR technology seems very promising in the future, when it has advanced technical capabilities, but it will never replace a human in carrying out inventory, though it will increase the level of quality and productivity of remote methods. In relation to decision-making management level, sectorial ministries submit their budgets to Ministry of Finance and Federal Agency for State Property Management, and once they are approved, the ministries gives their lower organizations task to develop their budgets, depending on amount of governmental grant assigned.

Two factors influence the quality of inventory information – human factor and the purpose of forest inventory. Another problem is bias in growing stock assessment towards less values in field inventory. The company along with Finnish partners made tests many times, but the error recurs. There is no such problem in distant methods. One more problem is conducting forest inventory with the only purpose in converting forest stand into mature stand on paper. When mature stands have already been felled, forest leasers seeks for other sites that have reached felling age (based on previous forest management materials). Data updating is applied in this case, without any field measurements, that is not appropriate.

Main findings are presented in the table 16 below.

Table 16 – Main insights from company M

Parameter	**Value**
Company type, location	Federal state enterprise, forest management planning, national forest inventory and cadastral works. Leningrad region
Demanded frequency of information	The question is not in company's competence. Forest users need it as often as possible, but optimal frequency can be once in 10 years, since it is costly.
Inventory methods applied, why	Four inventory methods by current legislation. A consumer company chooses method itself, depending on project budget and governmental grant, but it should be agreed with Rosleshoz. Ocular method and photo-interpretation are mostly ordered.
Inventory methods not applied, why	Data updating without any field measurements that is done with only one purpose – converting forest stand into mature stage on paper – is not appropriate. In photo-interpretation satellite images are not likely to be used, since it is often a problem to find overlapping images for 3D effect (It is needed to define and measure height, species by tree's crown, lower storey in a quality manner).
Demanded information	Subcompartment-level mensurational descriptions (can contain up to 300 indicators).
Purpose of usage	It is the base for companies' operations, strategic and tactical planning.
Processing of information	Proprietary software is used for forest

	management materials processing – LUGIS (forest management geo information system) and ESAUL (united system of forest inventory). It is not distributed across the company, but only processed with the use of GIS and database management systems
Precision desired and satisfaction with existing precision	The question is not in company's competence. The company has established 20% error rate, but doubling the precision (10%) leads to 10 time increase in costs. Average precision in data array is usually higher. Only 25-30% of leased territory is involved in companies' business activity over 10 years. Thus, high precision is not required on ¾ of the territory, and it is treated as lost money. High precision is only needed before having silvicultural practices.
Criteria of methods choice	Necessity of a particular precision and information validity and financing. Inventory methods are not used solely. Basically, four methods turns into two – ground-based inventory (ocular and ocular and measuring) and remote sensing method (photo-interpretation and data updating).
Overall relevance and satisfaction with existing methods	New version of forest management guidance is going to be issued soon. The company submitted a proposal of stating three inventory methods – ocular and measuring (ocular+ocular and measuring), photo-interpretation (photo-interpretation+data updating), and measuring and enumeration (provides the highest precision, needed before silvicultural practices). They are the most relevant and suitable methods in Russia.
Awareness of LiDAR, opinion on it	Aware, method is high-potential, but current state of this technology does not provide high quality with high productivity, it is not economically viable. LiDAR technology seems very promising in the future, when it has advanced technical capabilities. It will never replace a human in carrying out inventory, though it will increase the level of quality and productivity of remote methods.
Management level making decisions	Forest management planning - sectorial ministries submit their budgets to Ministry of Finance and Federal Agency for State Property Management, and once they are approved, the ministries give their lower organizations task to develop their budgets, depending on amount of governmental grant assigned. Forest leasers arrange auctions

	(or competitive tendering) for forest management planning, and the company offering the lowest price wins in 90% cases. There is no established regulation of forest inventory on non-leased territories. For private investments, forest leasers plan inventory works themselves.
Quality problems	Two influencing factors - human factor and purpose of forest inventory. There is a constantly presented bias in growing stock assessment towards less values in on-site inventory.

8.13 Company N

The organization is a territorial body of Federal Forestry Agency. This institution supervises performance of delegated powers and authority in Russian Federation subjects in forestry. It employs from 50 to 500 workers and covers whole North-West Federal district. The organization controls forest management fulfilment, and mainly receives all reports on a way to Roslesinforg.

The question concerning frequency of information is not in organization's competence, but the interviewee thinks once in 10 years is a good frequency for forest management, since changes are insignificant over this period. After enactment of new Forest Code in 2006, forest leasers were bound to make forest management on their own expenses, but the notion has changed that the state should fund it. Forest leasers chiefly make data updating on their expenses. Last forest management was done more than 10 years ago in many Russian subjects, and the organization tries to return these procedures on previous periodicity. Forest management funding comes from the state and private investments of large forest leasers. The organization helps small forest leasers with fundraising. As far as applied methods are concerned, four methods are stated in the current version of Forest management guidance, but new version is going to be issued this year. Federal Forestry Agency stands for canceling data updating method, and it is likely to be excluded. On interviewee's personal opinion, these four methods should be combined in one. The combined method would enable application of particular method depending on the situation. For example, boggy areas are not convenient to survey by ocular and measuring method; taking field measurements in very large squares is inadequately time-consuming; hard-to-reach sites may be surveyed by remote methods. All information obtained during inventory is needed: growth conditions, site class and other parameters (on subcompartment level) are considered while planning. As for purpose of inventory, the organization doesn't receive forest management materials itself. State Forest Register bases on the materials of forest management. All forest management materials are forwarded to subjects of Russian Federation and inputted in SFR, from where any citizen can request information. In the matter of precision, forest inventory should be in line with requirements of Forest management guidance. The organization itself audits forest management materials for every Russian subject biennially, on a selective basis. Field measurements are done in sample subcompartments and compared to forest management data.

The main criterion in choosing inventory method is claimed to be intensity of conducting forestry. In places with low forestry activities, like Siberia or Murmansk region, doing photo-interpretation is enough, field measurements can be done only where they are needed. in contrast, almost 100% of forest in Leningrad region is leased, therefore field inventory must be done there. As regards to advantages and disadvantages, the interviewee asserts that these notions cannot be applied to inventory methods. Data updating does not give appropriate information, thus it will probably be excluded. Other methods are applied depending on the purpose and conditions. Company's representative treats applied methods as up-to-date, since there are no other methods so far. New technologies are emerging, but field measurements are still essential. The interviewee is slightly aware of LiDAR, but in general has negative attitude towards aerial methods (in terms of quality provided). Satellite photographs are applied only during clear felling in order to monitor compliance of plots with sketches. As for relevance of LiDAR technology on Russian market, the interviewee thinks this question is not in the organization's competence. This question, on his opinion, should be forwarded to Roslesinforg, whose specialists should compare this method with others. Only human factor is treated as influencing on inventory quality.

Main findings are presented in the table 17 below.

Table 17 – Main insights from company N

Parameter	**Value**
Company type, location	Territorial body of Federal Forestry Agency, North-West Federal district
Demanded frequency of information	The question is not in organization's competence. Proper frequency for forest management planning is once in 10 years, since changes are insignificant over this period.
Inventory methods applied, why	Four methods are stated in the current version of forest management guidance, but new version is going to be issued this year. The respondent

	stands for stipulating one combined method that enables application of particular methods depending on the situation. Notions of advantages and disadvantages cannot be applied to inventory methods.
Inventory methods not applied, why	Federal Forestry Agency stands for canceling data updating method. It does not give appropriate information and will probably be excluded.
Demanded information	All inventory information on subcompartment level is needed. Growth conditions, site class and other parameters are considered while planning.
Purpose of usage	Planning of business; State Forest Register bases on the materials of forest management. All forest management materials are forwarded to subjects of Russian Federation and inputted in SFR, from where any citizen can request information.
Processing of information	No, the organization does not receive forest management materials.
Precision desired and satisfaction with existing precision	In line with Forest management guidance (some 10% error rate).
Criteria of methods choice	Intensity of conducted forestry. Photo-interpretation is enough for places with low forestry activity, while field measurements are required in places with high forestry activity.
Overall relevance and satisfaction with existing methods	Yes, there are no other methods so far. New technologies are emerging, but field measurements are still essential.
Awareness of LiDAR, opinion on it	Slightly aware, in general the interviewee has negative attitude towards aerial methods in terms of provided quality. The question of relevance is not in organization's competence and should be forwarded to Roslesinforg for comparison.
Quality problems	Only human factor influences forest inventory quality.

8.14 Company P

The company is a developer of GIS-based application software in the fields of forest management planning and forestry. Its key clients are private and state-owned forest management companies, municipal and regional executive authorities in forestry relations and forest leasers. Its business covers around 40 Russian regions, almost all forest-rich regions. Some branches of Roslesinforg and forest districts use company's application. The company is located in Moscow and employs 4 workers in Russia and 5 workers in Czech Republic (partnering company). The company was asked very limited set of questions, because of its special portfolio. Some of the issues questioned for other companies are missing.

The interviewee asserts that forest leasers need up-to-date information every year. Forest management materials obtained 10-15 years ago are not appropriate for their business. There is a conflict of interest between the state and business (forest leasers), since the state did not fund forest management planning, and there is a gap in this procedure from 2006 to 2011. At the moment statesmen insist on having periodic forest management, as it used to be, once in 10 years. In terms of inventory methods applied, company's clients utilize four methods provided by Forest management guidance. Data updating is being refused now, because it is not a proper inventory method. Inventory information is used to draw up Silvicultural regulations, Forest management plan and Regional forest plan. Company's software is applied for Regulations, Forest management plans and parts of SFR, that include inventory descriptions and forest management maps. The inventory information is processed by company's main product – proprietary software. The software serves for data input, control, map digitizing, making up inventory databases and drawing up output forms needed for projects and regulations. In regard to inventory precision question, the interviewee referred to Forest management guidance. Depending on management category, inventory method and estimated parameter, error rate varies from 10 to 25%.

In the matter of relevance of existing methods, the interviewee in general treats application of new technologies strictly positively. On the other side, all new technologies are embedded through governmental institutions, research institutes or government subordinate structures, like Roslesinforg. This is a negative reality and technologies do not come into free Russian market, but distributed through centralized close-to-governmental structures on a monopoly basis. The interviewee reveals that currently governmental structure tries to promote remote methods on market by creating artificial conditions, through official documents, that will lead to monopoly of this structure. He believes that everything done in such manner, on monopoly basis, will fail in terms of quality and affordability. As far as LiDAR technology is concerned, the interviewee is aware of it to some extent, but not competent much in this issue. The technology is not spread in Russia, there are neither clear illustrative examples of its application nor results of such inventory on a commercial scale. Overall, the company is interested in emerging cutting-edge remote methods and their wide utilization.

Main findings are presented in the table 18 below.

Table 18 – Main insights from company P

Parameter	Value
Company type, location	Developer of GIS-based software in the fields of forest management and forestry, Moscow
Demanded frequency of information	Every year, periodic forest management planning once in 10 years.
Inventory methods applied, why	Four methods provided by Forest management guidance
Inventory methods not applied, why	Data updating, completely office method
Demanded information	N/A
Purpose of usage	Drawing up Silvicultural Regulations, Forest Management Plan and Regional Forest Plan.
Processing of information	Company's proprietary software. The software serves for data input, control, map digitizing, making up inventory databases and drawing up output forms needed for projects and regulations.
Precision desired and satisfaction with existing precision	Ruled by Forest management guidance, error rate varies from 10 to 25%.
Criteria of methods choice	N/A
Overall relevance and satisfaction with existing methods	Application of new technologies is desired
Awareness of LiDAR, opinion on it	To some extent. The technology is not spread in Russia, there are neither clear illustrative examples of its application nor results of such inventory on a commercial scale. The company is interested in emerging cutting-edge remote methods and their wide utilization.
Quality problems	All new technologies are embedded through government subordinate structures, like Roslesinforg. New technologies are usually not available on free Russian market, but distributed through these centralized structures on a monopoly basis. Everything done on monopoly basis, will fail in terms of quality and affordability. Some governmental structure tries to promote remote methods on market by creating artificial conditions, through bringing in official documents.

9 DISCUSSION

In order to structure analyzing data, asked questions are linked to the corresponding research questions that are going to be answered in this chapter. Relations are shown on Figure 14. Questions for analysis and code names of questions are stated in the beginning of Chapter 8.

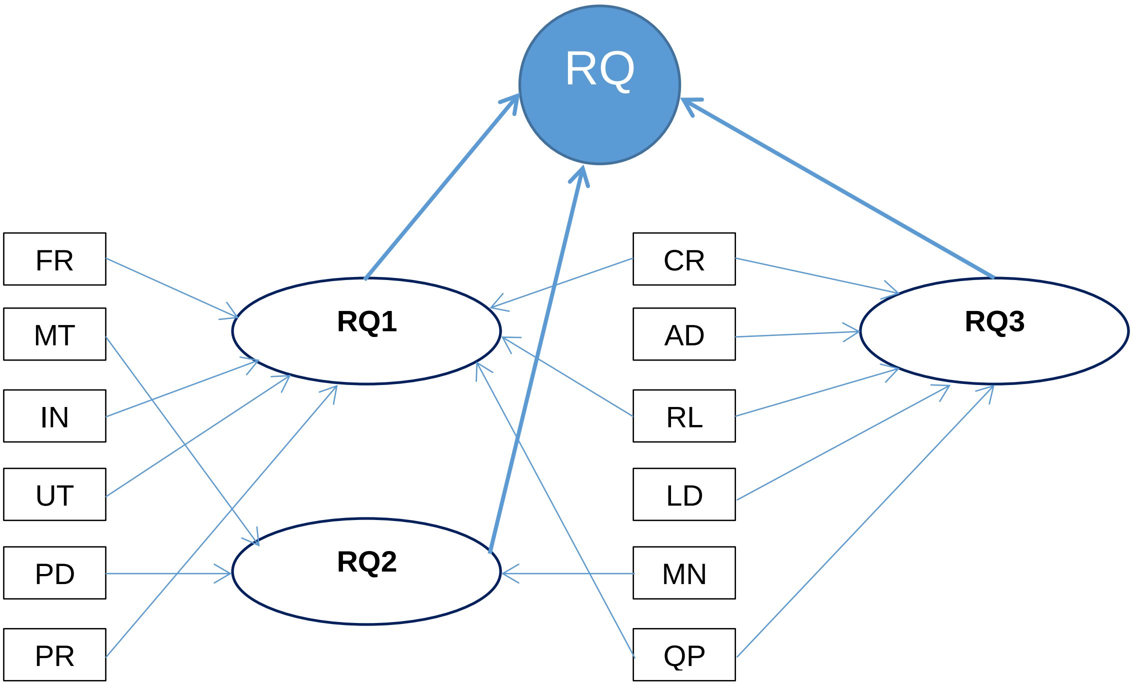

Figure 14 – Data analysis framework

9.1 Customer needs and satisfaction

Customer needs is the first stage of the VOC concept. Customer needs of forest inventory information users can be formulated in terms of desired forest inventory periodicity and precision, particular inventory information. In this way, purpose of usage frames the needs. Decision-making criteria in inventory method selection, perception of currently applied methods and understanding of problems faced in forest inventory at the present time can help to elicit customer needs.

Firstly, the *purposes* of conducting forest inventory in Russian forestry should be clarified. There is a problem here for new technologies deployment. As company G stated, "there are two kinds of forest inventory information. The first type legalizes our activities…and relations between the state and business, it documents them. Another type of information helps us to make forestry operations efficient – avoid unnecessary losses and increase effectivity of financial and human resources utilization. There is a gap between these kinds of information in Russia, they are not connected."

It means, that forest inventory information is basically used for two purposes in Russian forestry – business planning and reporting (inclusive of getting permission for works). *Reporting* from leaseholder's point of view mainly includes preparing of Forest Management Plan, Forest Declaration and Forest use report (see para 5.3). In such a way, permission for felling is granted after acquisition of forest inventory data (while coupe demarcation). As far as state institutions are concerned, forest inventory information is the basis for drawing up Silvicultural Regulations and Regional Forest Plan. SFR is also compiled with the use of forest inventory. *Business planning* comprises strategic and operational planning of business activities, and it covers forest use and management. For instance, a company chooses felling sites on the basis of forest inventory information. Natural disasters take place every year (wildfires, windthrow and others), and the information on forestland should be updated to take further actions. Planning also implies designing of forest road construction, making production, assortment, logistics, and sales plans. One company emphasizes that it will need precise forest inventory information for forest road planning in 5-10 years perspective, when forest sites, closely located to roads, are cut. In addition, companies need forest inventory information in order to get *FSC* (Forest Stewardship Council) *certification*. The certification increase company's credibility and goodwill in the eyes of customers, it is a prerequisite for many consumers (mainly in Europe, not in Russia). In summary, forest inventory information is the base for forestry companies' operations.

In terms of *frequency*, the majority of the respondents need forest inventory information at least once in 10 years (companies C, F, H, K). Some companies argue that changes are insignificant over this period (companies H and N). Most likely, companies were comfortable with established regularity of Forest management planning routine in the past (when it was done by the state), and this periodicity of obtaining information is affordable for them, since forest inventory information is outdated in many forestlands at the moment (about 70%, see para 6.4). The companies agree that 10-year period information should be precise and detailed. Though, some companies argue that forest leasers constantly need information for their operations (forest inventory companies A and M, software developer P). For instance, company G is satisfied with 10-year period information for detailed information (for Forest management planning), but it needs information on general level every 1-2 years. Another desired frequency is once a year (company E) and every 3-5 years (company D). Companies B, J and L are satisfied with inventory frequency supposed in regulatory documents (Forest Management Guidance, Forest management plan). Therefore, there is no unanimous opinion on how frequent a forest inventory should be done, though it can be concluded that completing a forest inventory on the entire territory at least once in 10 years is demanded by all the participants. More frequent inventory is required by some companies, but on more general level or locally. For instance, company H stated that local forest inventory is needed in case of natural disasters (wildfires, windthrows).

As far as desired forest inventory contents (*inventory indicators*) are concerned, in general companies need subcompartment-level mensuration descriptions. There are established forms of descriptions stated in Forest management Guidance. There are different requirements in forest parameters for stands of different age class (young, middle-age, mature). Company G explained it in details during the interview. All the companies extensively answered to this question need stand volume assessment (9 companies). Species composition is also very important (6), wood assortment plan plays the major role in planning for some companies, and therefore knowledge of species composition of stand is vital for them. Mean height and diameter are equally important for forest leasers (5). Sometimes diameter range is needed. Age of stand and growth conditions are also needed (4). Interestingly, that wood quality and size information – merchantability classes (3) and size classes division (2) are important not for many companies, as well as presence of valuable underwood (3), forest density (2) and soil conditions (2). In some occasions, inhomogeneity level is needed or square subject to drying.

The customer satisfaction and customer needs in inventory information *precision* also differ significantly. The most of companies are satisfied with the precision they currently have or may have (companies A, B, E, F, G, J, K, L). Some companies are willing to increase the accuracy, but they find it impossible at present time (maximum precision is desired by company A, 3-5% - company D, 0% - company H). All abovementioned firms have error rate in growing stock assessment within 10% (5-10% for company E, 7% for company H). Company C revealed that the last forest management planning was done with error level of 15-30%. It is satisfactory for their strategic, but not for operative planning, thus the company is willing to increase precision to 10% level. Company F claims that mistakes within 10% (growing stock and species composition) are unimportant, since there is always some amount of wood in stock of different species. Higher error rate is achievable by the method of complete enumeration, but it is very labour-intensive. Company G disclosed that increasing inventory precision does not give much value for business operation, but it is interested in increasing precision of objects positioning. Most participants that are not forest leasers (except A), referred to the requirements of Forest Management Guidance in this question, formulated for each method. Forest Management Guidance stipulates allowable errors at the level of 15-30% for growing stock, 8-15% for mean height, 10-20% for mean diameter and 25-40% for underwood stock estimations, depending on method and management category (Forest Management Guidance 2011, annex 11), therefore imposed constrains are not that strict. Company M requires average accuracy level of 20%. It claims that high precision is not needed for forest management planning – typically 75% of the territory is not subject to forestry operations during ten years, therefore high precision is treated as lost money. It is required only before having silvicultural activities. It should be noted, that the error rate required by private forest leasers is too high, comparing to the one claimed to be adopted in NFI (within 5% for all regions, see Figure 12). In sum, customer needs taking forest inventory with precision of 10% in growing stock assesment.

The *criteria* for selection of forest inventory method correspond to the aspect of priorities in the Voice of the Customer concept. The priorities will be further discussed in para 9.3. In relation to criteria that companies apply in forest inventory method selection, it should be stated that not all companies were able to clearly articulate them. Most likely, it is due to low amount of methods applied in Russian forestry and method selection based on traditions (Kangas 2010, section 7). In addition, preference is usually given to cheap methods (Karvinen et al. 2011, para 6.3). Nevertheless, companies have defined several criteria. The most frequently mentioned criterion is precision (6 times). In this context, precision stands not for error rate, but it general information quality and validity. Price consideration and funding capabilities take the second place (5 companies). Criteria weights are not always equal. For example, financial costs can be the major criterion for some companies (company F), while it is considered only partly in decision-making by others (company A). Labour costs and time spent on inventory (4 times) are the third main criterion. Given task (the aim that the company pursue with the forest inventory) is also (mentioned 3 times) important followed by precision costs balance (2). In addition, the companies revealed that some criteria are statutory. For instance, information acquired by ocular and measuring methods is only acceptable (company D), or management category defines the method. Thus, some companies are guided solely by the legislation. The size of inventoried plot and subcompartments matters, for instance, only complete enumeration (company F) or on-site inventory (company B) is used for small plots. Stand characteristics can matter while making out a coupe, for instance, presence of underwood. If underwood is high and dense, strip enumeration can be used, but not relascopic circular plots. Criteria can change over time, for instance, simplicity of a method dominates in decision-making for company E, though quality to price ratio will be decisive in the future. In the opinion of state organization N, intensity of conducted forestry is essential in method selection. Thus, photo-interpretation is enough for places with low forestry activity, while field measurements are required in places with high forestry activity. In summary, private forest leasers has the following criteria for forest inventory method: quality and precision of information, financial costs and funding capabilities, labour costs and time frames, given task (needed inventory parameters, precision and other), and precision and costs balance. However, statutory and technological restrictions are also taken into account.

In regard to the question of *relevance* of currently applied forest inventory methods, the majority of companies are more or less satisfied with them. Private forest inventory providers think the methods will "stay applicable for a long time" (company A) and "there is no lack of methods" (company B). As for forest leasers, some companies are "conditionally" satisfied. Thus, company D is interested in utilization of new methods, more time-efficient and less labour-consuming. Company E is looking for a modern method, enabling less margin of error. Some companies would like to apply modern methods (companies G, H), but supervising bodies officially accept information got only by traditional methods (it relates to the problem of existence of two types of inventory information). Companies C and J are not satisfied with currently applied methods. State companies are satisfied, though they propose reformulation of allowed methods in new issue of Forest Management Guidance that is going to be issued soon. Company M stands for merging of four methods into two groups (ocular and measuring, and remote) and adding of measuring and enumeration method. It assures that combinations of inventory methods are usually applied in established inventory methodologies (ground-based inventory and remote sensing method). Company N suggests articulating one combined method that enables application of particular methods depending on conditions. Application of new technologies is desired by GIS developer (company P). All in all, customer needs in new methods obviously exist, though governmental restrictions hinder their usage.

In reference to *quality problems* of forest inventory in Russia, only one company supposes that there are no problems at all. The majority of companies (9) claim presence of human factor as a problem of currently conducted inventory. Although human factor always exists, its influence varies for different inventory methods. One more common problem is lack of qualified staff. Though different secondary sources distinguished this problem (see para 6.4), only four (4) companies mentioned it. In addition, outdated imperfect legislation is treated as a problem for two (2) companies, and two state companies also proposed amendments to existing regulatory framework. Company G reveals that Russian forest stands, as contrasted to countries with well-developed forestry (for example, Finland), are characterized by low homogeneity and bigger sizes of planning units. Extensive (and often unsustainable) forest exploitation in general and lack of forest tending (nonadjustable species composition and density) make forest stands heterogeneous and, therefore, not easy to manage. Another general problem in Russian forest inventory is that only ocular and measuring methods are officially acceptable, and changes can be brought in to SFR (company D). Probably, it is not fair for all regions in questions. Company P discloses that there is a conflict between interests of the state and private forestry companies. The state refused conducting Forest Management Planning (there was a gap in 2006-2011) on public funding, since it was basically not interested in updating of forest inventory information, but no clearly defined forest inventory mechanisms (on leaser's own funding) were formulated (company H). Therefore, companies complained about lack of public funding (company G, H), absence of state's interest (company K), high time and monetary costs. In relation to high labour costs, company E sees forest inventory problems in low accessibility of particular forest sites, shortage of time to get there and lack of amenities for workers.

Several issues that the participants noticed refer to precision and quality of conducted forest inventory. Divergence between inventory information and real harvesting volumes is mentioned by companies A, G (concerning Forest management planning) and M (presence of bias in growing stock assessment towards less values in on-site inventory). Company A sees the problem in outdated assortment tables (are applied for assessment) and missing feedback from logging companies (thus errors are hard to detect). According to company G, the common problem is discordance of reference points on maps and in reality. Fulfilment of a nominal forest inventory (data updating without any field measurements for converting forest stands into mature stage on paper) is common, but it should not be accepted, as company M claimed. In addition, insufficient usage of cutting-edge technologies was mentioned by several companies, but there is a problem in their implementation. Thus, company P reveals that all new technologies in Russian forestry are embedded through government subordinate structures and therefore not freely available on Russian market. The interviewee believes that everything done on such a monopoly basis, will fail in terms of quality and affordability. Some governmental structure tries to promote remote methods on market by creating artificial conditions, through bringing in official documents.

9.2 How customer needs are met

This research question is answered in terms of what forest inventory methods are used, how the data is processed, and what management level makes decisions on conducting forest inventory (for few companies).

As far as *forest inventory methods* are concerned, the majority of the respondents apply several methods. Field inventory is the most common (7 companies mentioned it) – both measuring and enumeration methods. Company F has to use on-site inventory owing to outdated Forest management planning. It should be noted, that this problem applies to 70% of forest sites in Russia (see para 6.4). Enumeration methods are mostly applied (5 companies) and relascopic sample plots (3). In the matter of enumeration, strip enumeration dominates, though complete enumeration is also used. For example, company F applies only complete enumeration for small plots. Fixed-radius sample plots are rarely applied (only one respondent company uses it). Company A does not utilize it due to the lack of qualified staff. However, it claims that fixed-radius circular plots are faster and less labor-intensive, though not less precise, therefore many companies start to use it. Satellite and aerial imagery are equally popular (3 companies mentioned each method). However, two respondent companies completely do not apply it. Ocular method is utilized by only one company and four respondents are totally against it. It may be applied only for Forest management planning, but not while making out coupes. Remote and ocular methods are mainly not applied owing to perceived low precision. When it comes to data updating method, only one company applied it, whereas four companies do not accept it (as well as some supervising bodies). This method implies completely office study. Thus, field inventory (measuring and enumeration) dominates in Russian forestry, whereas remote methods (aerial and satellite imagery) are less commonly applied.

In terms of *processing of forest inventory information*, it is processed electronically everywhere with the use of GIS and specialized forest inventory software. It is done in computer centers of forest inventory providers or directly by customer companies. Only company B process small amount of data manually, and company E makes out a maintenance task card manually (while growing stock and timber quality assessment – electronically). Few companies (D, H) stated that they do not store data in electronic form (for internal use), but a contractor provides them with hard copies in convenient, refined form. The most popular programs that companies mentioned are MDOL (software for stumpage appraisal) and Abris+ (map service), four respondents use them. Few companies have proprietary software (M, P). Main software output is stumpage appraisal. It may come in permission documentation form (company G), that is very convenient, since some companies need only maintenance card for internal use, all the rest – for reporting purposes (company H). The software, for instance, serves for data input and control, map digitizing, making up inventory databases and drawing up output forms needed for projects and regulations (company P). In summary, forest inventory information is processed electronically almost everywhere, but the most amount of data it is not stored or distributed internally and forwarded directly to supervising bodies. Forest inventory providers supply information in convenient form, either in reporting or internal usage form (including hard copies).

In relation to decision-making management level on conducting of forest inventory, there are specialized departments at every enterprise that define necessity of forest inventory, at least at relatively big companies. Then the requests are sent to the management (company C). The decision can be positive, for example, if there is no more wood of valuable species with required indicators (company K). When it comes to Russian subsidies of foreign companies, the necessity is determined on the level of Russian management and specialists (companies G, H), while further decision concerning financial aspects is made by higher management. Company G reveals, that the decisions upon usage of new technologies are done along with IT development specialists (in mother company), but equipment procurement can be done by Russian side within limited budget. As far as Forest management planning at public funding is concerned, sectorial ministries submit their budgets to Ministry of Finance and Federal Agency for State Property Management, and once they are approved, the ministries give their lower organizations task to develop their budgets, depending on amount of governmental grant assigned (company M). According to company M, forest leasers arrange auctions (or competitive tendering) for forest management planning, and the company offering the lowest price wins in 90% cases. For private investments, forest leasers plan inventory works themselves.

9.3 Competition of forest inventory methods and appropriateness of LiDAR

In order to compare forest inventory methods performance (including LiDAR), respondents' opinion upon advantages and disadvantages of forest inventory methods are considered along with their perception of LiDAR technology. Customer needs are also taken into account as well as capabilities of methods in accordance with their descriptions in para 6.3 and their application in Russian forestry, discussed in para 9.2. Discussion of performance of forest inventory methods corresponds to the aspect of customer perception of performance in the VOC concept and contribute to answering the third research question.

The following forest inventory methods are reviewed here – measuring method (relascopic sample plots), enumeration (strip enumeration), aerial and satellite imagery, LiDAR and Trestima. Ocular method and data updating are not widely applied in Russian forestry, that is why they are not considered. Measuring and enumeration methods are merged in the group of on-site (field) inventory, aerial and satellite imagery are united in the group of remote methods, and Trestima and LiDAR methods are conveniently referred to modern methods. Respondents were scarcely aware of modern methods, therefore LiDAR and especially Trestima are discussed very briefly. The methods are compared in terms of the main criteria – quality (precision), price, labour costs and time expenditures, functional capabilities (range of tasks solved, ability to determine indicators, ability to check measurements), appropriateness in Russia (acceptance by officials, external restrictions of application).

Both on-site inventory methods are claimed to be precise, enabling valid information (companies J, K). Only company C is not satisfied with their precision. In comparison to remote methods, they enable detecting possible wood defects, for example hollows, that is obligatory for wood assortment planning (company F). In terms of common disadvantages of field inventory methods, they are labour-intensive (companies F, H, J, K), time-consuming (companies C, J, H, K). For instance, work conditions are severe in mini-expeditions appointed for hard-to-reach sites (companies E, F). Companies D and K treats on-site inventory costly (probably, in comparison with remote methods), and company H claims it to be very staff qualification-dependent. Company M reveals that field inventory methods imply wide usage of ocular estimations, thus human factor impact is high. The main disadvantage of ground-based method, on company M's opinion, is that most of the time (some 70%) is spent on moving from one place to another – they are time-inefficient. Field inventory can be done only in fair, not rainy weather, it is also seasonal and is conducted only in summertime. Another big disadvantage is that this type of inventory is done from the point on the ground with, for instance, 50 meter-vision reach, and a worker does not see the whole subcompartment. Most serious mistakes come from choosing wrong sample plots, not representative enough.

However, there are distinctions of on-site inventory as well. Enumeration is claimed to have the highest precision (complete enumeration), the method is technologically simple, and measurements can be easily checked (companies A, H). As for disadvantages, enumeration is more labour-intensive and time-consuming (companies A, E). Thus, relascopic sample plots require less human resources (company E). Company E claims that the information obtained by strip enumeration and relascopic plots has the same quality. It reveals a disadvantage of relascopic plots in not observable parts of a plot, though resulting error is acceptable.

In comparison to field inventory, remote methods are less labour-intensive – there is no need in cutting a sighting line or measuring a ride with high-quality satellite images, as company B claims. Advantages of remote sensing methods in comparison to ground-based methods also include (company M): possibility of all-season work; women can do such inventory (statistically, even better for this kind of work); a working-plan officer sees the whole subcompartment and can estimate it more properly, and also possibility to control a working-plan officer at any moment (since he/she is located at the same place as the supervisor). In addition, the advantage of remote sensing methods is that it is totally done by measurements, thus it is more objective.

However, the big disadvantage of remote sensing methods, from company M point of view, is that a working-plan officer sees only upper canopy and does not see underwood and a forest type. It compensates partly by looking at materials of previous forest management planning.

What comes to LiDAR technology, Russian forest leasers are generally not familiar with it, and it is not applied by respondents. Company P discloses a problem, that the technology is not spread in Russia, there are neither clear illustrative examples of its application nor results of such inventory on a commercial scale. Thus, only company's subjective perceived drawbacks are introduced here. In terms of advantages, LiDAR provides some outstanding functional capabilities – digital terrain model (DTM), forest stratification by defined layers (parameters). Its precision is claimed to be better than in field inventory (by Arbonaut), forest inventory requires less time (technology is time-efficient), human factor impact is low – qualified staff is needed only in office study stage (see para 6.3.6). Though, functional restrictions of LiDAR include inability to distinguish species (ArboLiDAR does it in combination with other methods), inability to define timber size and quality parameters (distributions into assortments).

The main problem is that currently LiDAR-based forest inventory information cannot be officially accepted. Company D claims that even though LiDAR provide useful information, it cannot serve as a basis for making changes in SFR. Company H reveals possible legal problem – only licensed and accredited companies can conduct forest inventory, so that the data are accepted by supervising bodies, otherwise such information can be used for only internal purposes. Company G also thinks technology's application is restricted to internal operational planning, since such information cannot be accepted by supervising organizations as legal, official information so far. This solution is treated to be relatively expensive a priori by companies C, D, E, F (since aviation and high-tech device are used). What comes to technological capacities, company C's felling areas are scattered, therefore application of laser scanning is problematic (scanning is done by rather wide strips). As any remote method, LiDAR cannot see wood quality (hollows in trees, branchiness, crookedness) and site conditions, for example, dried brook, desired by company F. The company treats modern technologies not as reliable as field inventory. Even if the price is the same as currently applied methods, the company would rather prefer ocular and measuring method. Soil conditions assessment (in Russia, deposits are located deep from the surface) and defining biotopes (as a requirement of FSC standardization) are essential for company F, that is also a problem for LiDAR technology. Company G sees LiDAR's drawback in inability to distinguish aspen from birch on different stages (LiDAR does not allow species recognition). The company also needs information about site conditions (soil conditions). State subordinate companies M and N are also sceptic about perspectives of LiDAR's technology in Russia. Company M suggests that current state of this technology does not provide high quality with high productivity (the company made a comparison), it is not economically viable. Interviewee from company N had general negative attitude towards aerial methods in terms of provided quality.

In relation to Trestima method, it is claimed to be even more precise than laser scanning, human factor impact is relatively low, and therefore data are unbiased. It does not require qualified staff, it is technologically simple (for a field worker) and the speed of conducted inventory is very high. Measured indicators are as broad as in traditional field inventory, though some of them are estimated manually, and some parameters are defined with the use of photo-interpretation. Thus, the method determines species composition, wood assortment division, site class and others. (see para 6.3.7; Trestima 2014)

Few respondents were aware of Trestima method and tried it (companies F, G). Company F found it inappropriate (at least, for large-scale inventory). It is faster, but mixes species sometimes, especially when it is dark, photos are retaken several times. The method works properly only in a daylight time with good lighting, without raining and clouds – thus, the method is very weather-dependent. The costs are the same as in field inventory, but on-site inventory is preferable for the company, since Trestima method does not always provide proper quality.

In order to make comparison of technologies, Analytical Hierarchy Process (AHP) is partly applied (see para 7.2). AHP algorithm implies pair-wise evaluations of criteria with further computations. However, the research is qualitative in nature, and the participants were not asked to make any assessments. Therefore, AHP methodology is modified, and the steps comply with AHP algorithm until the stage of pairwise evaluations. In general, comparison algorithm correspond to the framework of MCDM methods (see para 7.1).

1) Problem statement: selection of the method for forest inventory
2) Goals: obtain valid information about leased forest stands (or harvesting sites), get mensurational description on subcompartment level. Actors: forest leaser, forest inventory provider, regional forest authorities (forest district, Federal Forestry Agency branch). Objectives: make out timber harvesting plans, draw up documentation for felling permissions (forest use report, forest declaration, Forest Management Plan), obtain or confirm FSC certification. Outcome: Inventory information in electronic form and (or) in hard copies
3) Criteria, influencing decision: quality, price, labour costs and time expenditures, functional capabilities, and appropriateness in Russia.
4) Alternatives: relascopic circular plots, enumeration methods (strip, complete, fixed-radius plots), traditional remote methods (aerial, satellite imagery), LiDAR, Trestima
5) Hierarchy tree is depicted on Figure 15. Criteria are divided into subcriteria. They correspond to primary and secondary needs in the hierarchical structure of the VOC concept.
6) In order to evaluate forest inventory methods, weights should be assigned to the selected criteria. Since pairwise comparisons were not supposed by research strategy, weights are allocated based on customer's perceptions. Respondents' answers to the question about criteria for method choice (CR) underpin these values, (discussed in para 9.1). All the criteria are important, regardless the frequency of their mentioning. However, the price has slightly less meaning, than quality and labour costs and time expenditures – price to quality (and performance) ratio is one of the most important parameters from companies' perspective. The last two criteria are equally important.

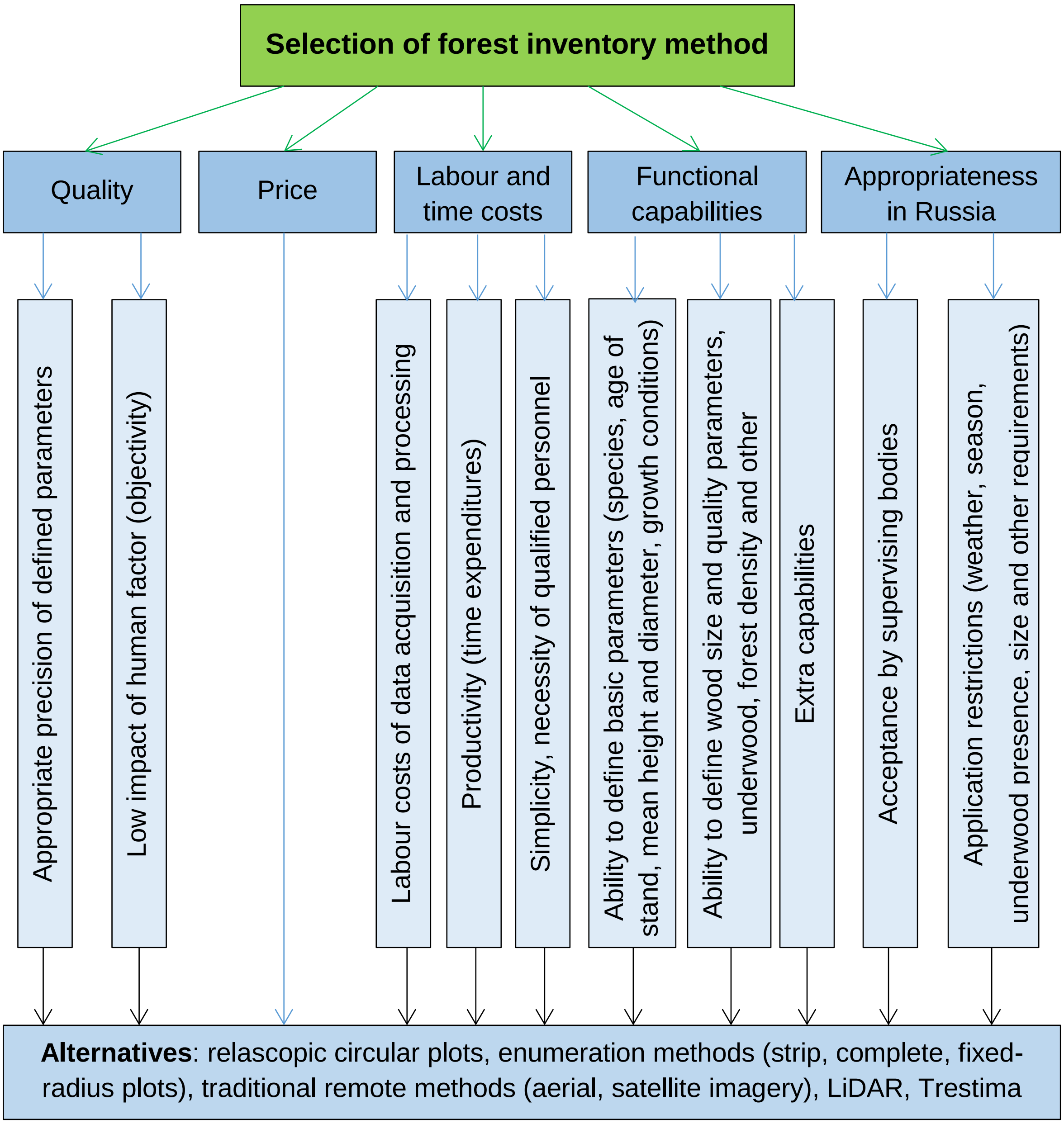

Figure 15 – AHP hierarchy tree for selection of forest inventory method

7) Each method is assigned a value on the scale from 1 to 10 for each corresponding criterion. “1” represents the poorest performance, while “10” is the best performance. Again, assessments are subjective and based on customer’s perceived advantages and disadvantages (AD), importance of criteria and subcriteria, as well as theoretical material. Trestima method assessment is based on the advertised capabilities and judgements of two participated companies. The resulting score of each method is calculated simply by summarizing scores for each criterion with respect to criteria weights. The final scores are presented in table 19.

Table 19 – Forest inventory methods comparison

Method	Quality	Price	Labour & time exp.	Functional capabilities	Appropri-ateness	Final score
Weights	25%	20%	25%	15%	15%	
Relascopic plots	7	7	4	7,5	8	**6,475**
Enumeration (strip)	8	7	3	8	9	**6,7**
Remote methods	6	8	7	2	6	**6,05**
LiDAR	9	6	8	5	2	**6,5**
Trestima	8	7	9	9	1	**7,15**

As far as results are concerned, Trestima method seems to be the most promising for Russian market, LiDAR method (used solely, without field inventory) is placed third, between relascopic plots and enumeration methods. Traditional remote methods seem the most inappropriate. However, the results are very subjective. The amount of participants is low to make any generalizations and technical and acceptance uncertainties are very high for modern methods (LiDAR, Trestima) as they are not accepted by the market so far. Trestima method evaluation is the most questionable.

It should be noted, that inventory methods are not applied solely. They are always used in combinations. Typically, photo-interpretation of satellite images is used along with field inventory while coupe demarcation. In addition, size of inventoried area strongly influences the method choice. In case of small plots, field inventory (complete enumeration) is more likely to be applied. Large-scale inventory and inventory of remote areas require utilization of remote methods. In relation to LiDAR, location of plots also matters. Scattered felling areas (not large in size) make its application infeasible, because economy of scale is inherent to laser scanning. The trust towards modern methods is low, mostly in terms of quality, but some companies test them. Trestima is more appropriate for small plots, while application of LiDAR is relevant for large squares.

9.4 Desirable attributes of forest inventory method

The desirable attributes are discussed in relation to LiDAR (ALS) technology. Customer needs can be divided into basic, articulated and exciting needs (see para 2.2), and the corresponding product attributes, according to Kano model, are categorized as must-be, one-dimensional (primary satisfier) and attractive (delighters) (Kano et al. 1984, see para 3.1). The category of indifferent attributes is not discussed. High customer satisfaction can be achieved by detection and assignment of desirable attributes to forest inventory method.

The first attribute is legality of forest inventory information and its acceptance by officials. It defines if information can be used for making changes to forest management planning material and SFR. It is a must-be attribute for many companies, since they want to combine planning and reporting purposes at the same time. Laser scanning technology does not possess it currently, therefore LiDAR-based inventory information can be used only internally. Presentation of data in the reporting form accepted by the state as well as convenient form for internal use is a primary satisfier.

In terms of forest inventory parameters, ability to define stand volume, species composition, mean height and diameter, age of stand, and growth conditions are must-be attributes. Division into size and merchantability classes (quality of wood), ability to define underwood, forest density and soil conditions are primary satisfiers. Considering the fact, that remote methods and ground-based methods are applied in different conditions, requirements can be different for them. For example, ability to distinguish aspen from birth at different growth stages can be an attractive attribute for remote methods. LiDAR cannot distinguish species, growth and soil conditions, and size and merchantability classes itself, therefore it is used along with other methods in solutions, like ArboLiDAR. As for features, DTM (digital terrain model) and digital maps with separation into clusters by different parameters are attractive attributes.

As far as precision of method is concerned, high precision is a one-dimensional attribute. Most companies are satisfied with 90% precision (in growing stock assessment). However, high precision can be an attractive attribute for remote methods, since they are treated as less precise a priori. Obtaining high-quality valid information without necessarily going out to forest has high customer value. Another attractive attribute that ALS possesses is in its precise positioning of inventoried area. Locations of reference points (compartment rides, sighting lines) as well as other objects' coordinates are directly recorded during the flight. In terms of other criteria, price (affordable) is a one-dimensional attribute. It is one of the most essential considerations, while selecting an inventory method, forest information users are price sensitive. Cheap price could be an attractive attribute. ArboLiDAR price in Russia is supposed to be at the level of traditional inventory methods, thus affordable. High time-efficiency (and productivity) and low labour costs are attractive attributes. Some companies are looking for a new inventory method and they are guided with these attributes mainly, high labour costs are treated as the main disadvantage of currently applied methods. From customer's side, laser scanning has low labour costs, though method productivity is not the shortest. Some aerial imagery-based inventory or Trestima method is faster to complete. The next attribute is high applicability capabilities. It is a must-be attribute. Application of LiDAR, for instance, is restricted by the size of inventoried area. LiDAR is feasible for relatively large squares, as it the sensor covers quite wide and lengthy area (depends on device construction and flight altitude). Thus, application of laser scanning for scattered plots is problematic.

In relation to quality problems, the following attribute can be introduced: information objectivity (low human factor impact). It is an attractive attribute, since human factor was mentioned as an inventory problem by many companies. LiDAR provides unbiased information, human factor almost absents at data acquisition stage, though it presents while data processing. Still, human factor influence is much lower in laser scanning than in field inventory. Technological simplicity is another attribute. It is also an attractive attribute, which means that high qualification of personnel is not demanded. ALS possesses this attribute from customer's point of view, but adoption of LiDAR inventory totally done by the customer is challenging. Other problems mainly relate to Russian peculiarities and conflict of interests between the state and private companies and cannot be transformed into product attributes.

10 CONCLUSIONS

LiDAR technology can be viable for Russian forest inventory market. However, it depends much on details and performance in Russian conditions, since the market is much different from European markets. The main difference lies in extensive model of forest exploitation. The amount of growing stock volumes (in mature stage) is high and forest users tend not to care much about forest tending. Forest inventory does not have that much customer value, as in intensive forestry model. Forest inventory is a must for business planning of forestry companies, but some companies perceive forest inventory as costs only. Felling permissions are granted based on the age of stand; forest sites should achieve established mature stage. Thus, forest inventory with the only purpose of converting tree stands into mature stage on paper used to be common. The shift of forest management planning from public funding to private investments is in transitional stage, responsibilities of forest management funding are not clearly defined. The application of particular forest inventory methods is based on traditions mainly (and purposes). The market seems to be very inertial, modern methods do not have much trust in customer's eyes, most respondents are satisfied with currently applied methods. However, some companies are looking for new, cutting-edge methods, which can better meet their needs.

Quite few interviewed companies were aware of LiDAR. Though, after brief introduction, they were asked to express an opinion on its feasibility in Russia. Five companies answered "yes", one said "can be", one company "could not say". Three companies answered "no", including two state subordinate companies. Based on the interviews, it can be concluded that private companies mostly favors deployment of cutting-edge technologies, such as LiDAR. In contrast, state organizations are against its implementation. It can be explained by state monopolies in some fields of forest inventory. Forest leasers are sceptic about feasibility of LiDAR. On respondents' opinions, appropriateness of laser scanning depends on company's size, forest sites, their dispositions, given tasks. Price also matters, since many customers are price-sensitive. It should be viable, if customers are satisfied with quality to price ratio, and precision is fulfilled, as one company claimed. For some companies, the main issue is what status obtained information possesses. Thus, there are many issues which are not clear so far. Still, there is a need in a time-efficient and low labour-consuming method. Laser scanning forest inventory is placed third among the five most relevant methods in developed comparison model.

Taking into account attributes that ArboLiDAR has, its suitability for Russian forestry is also ambiguous. On the one hand, it has a number of attractive attributes that will excite customers and increase customer satisfaction. On the other hand, it does not possess some must-be attributes that are aimed at meeting basic customer needs. However, it should be noted that all the attributes are relative. Comparing with other remote methods, ALS has significant advantages. ArboLiDAR applies LiDAR in combination with other methods, as well as it is done in currently applied methods in Russia. Therefore, beneficial properties of LiDAR can be combined with benefits of other methods. The main obstacle for ArboLiDAR in Russian market is unacceptance of this forest inventory information by officials (information, accepted by the authorities allows to make changes in forest management materials and SFR). However, new Forest Management Guidance will be issued soon, some changes can be made to formulation of types of applied forest inventory methods and particularly remote methods. Wider application of remote methods is stated in targets of forestry development plan in 2013-2020. Fulfilment of NFI on the whole territory of Russia requires adoption of fast, non labour-intensive, and precise methods, like ArboLiDAR. Moreover, considering large scales of Russian forests and existence of remote located areas make the technology very promising.

10.1 Recommendations

The perception of LiDAR technology by Russian companies is vague, because companies are mostly not aware on this technology, its performance and capacities. Laser scanning is not spread in Russia, there are neither clear illustrative examples of its application nor results of such inventory on any commercial scale. Almost half of the respondents (6 companies) were not aware of this technology at all. About the same amount of companies (5) were slightly aware of it, and only three participants were aware of LiDAR.

Thus, uncertainties about laser scanning technologies are extremely high. Particularly, levels of need uncertainty, technical uncertainty and acceptance uncertainty are the highest, according to classifications of Hakansson and Cardozo (Håkansson et al. 1976; Cardozo 1980). The situation exacerbates with low level of trust towards innovative technologies and strong inertia, demonstrated by respondents. In order to mitigate uncertainties, wider leveraging of customer reference marketing is advisable to Arbonaut. It should be noted, that the company utilize customer reference marketing to some extent. Arbonaut has reference list with globally recognized brands and national companies on its web-site. It conducted joint training in collaboration with Russian university recently. However, customer reference practices should be applied more broadly. Fulfillment of some pilot projects in Russia would be very beneficial, since demonstrating of technological performance in Russian conditions is very essential. Advisable customer reference practices include: success stories, customer cases, press-releases and social media for external usage. Internal usage practices are also advised, such as lessons learned and best-practices exercises or selecting and documenting “iconic cases”. In this way, customer reference portfolio can be leveraged wider as a marketing asset.

Cooperation with Russian companies is also advised. Leading business in Russia in general and especially entering Russian market for foreign companies is very challenging, considering current market conditions and political events. It is especially relevant for the fields, where state influence is high, such as forest inventory market. As this study shows, there is a need in modern forest inventory methods in Russia, though the status of obtained information plays a crucial role for many companies. Negotiation perspectives with state organizations by Arbonaut alone are seen almost futile. Therefore, partnering with Russian companies is vital. Russian companies can lobby implementation of LiDAR technology in negotiations with Roslesinforg and Federal Forestry Agency (Rosleshoz). In case of granting a legal status to LiDAR-based information, customer value of the method will increase significantly. Without official acceptance of laser scanning information, the price of inventory must be lower. As one respondent noticed, if Arbonaut gets all state permissions for its technology in Russia, it will be beyond any competition, even at slightly higher price comparing to traditional forest inventory methods. In terms of private companies, potential Russian partners for Arbonaut are forest inventory providers (for example, participated companies A, B) and some timber harvesting companies. Even though LiDAR technology is not common in Russia, there are cases of its application and testing. Moreover, there are Russian companies, that provide laser scanning, for example, ”Fly-photo” (web-site: http://fly-photo.ru/). There is a Russian web-resource comprising theoretical and practical information about LiDAR along with related geodesic organizations (web-site: www.laserlocation.ru).

In terms of marketing, the promotion of ArboLiDAR can be supported by informative leaflets in Russian, stating method’s benefits and USP (unique selling points) in “bullet points” manner. There is one brochure available online, it is the Russian translation of (Arbonaut 2011). However, it is pretty long and not eye-catching. Adoption of iconographic way of presentation is advisable for this purpose. The good example of such presentation is suggested by Trestima (Trestima 2015b).

As for general recommendations, the solution for Russian users may not have the best performance. Advanced performance indicators can be sacrificed in favour of its price (for example, precision considerations). Good price to quality (performance) ratio is mostly desirable by Russian users. However, customer requirements vary. Leveraging of other methods along with LiDAR should be tailored in order to achieve satisfaction of all basic customer needs. Attractive attributes should be also inherent, for instance, some companies treat 3D terrain relief model as very useful. In case of official acceptance of laser scanning inventory, presentation of inventory data in reporting format should be available.

Participated companies also shared their vision on implementation of laser scanning in Russia. Companies consider this technology more relevant for other regions (not North-West Russia) and for public funding. Thus, forest inventory providers (companies A, B) consider laser scanning inventory appropriate in the regions of European North, Siberia and Far East. Company E suggests that ALS method is viable only for large squares or under the aegis of some governmental practices. Interviewee from company F also sees this technology more appropriate for state arranged inventory (forest management planning, NFI), where large areas need to be covered, for example, in Siberia. It can be appropriate for regions, where forest road infrastructure is underdeveloped, or in cases, when forest resources estimation needs to be done in the shortest time, for instance, while launching high-investment project. He reckons that such technology is not relevant for logging purposes, basically from price considerations. From the point of view of company G, LiDAR feasibility depends on price and capabilities of this technology. State subordinate company M treats laser scanning very promising in the future, even though it is not satisfied with its performance currently. On its opinion, LiDAR never replace a human in carrying out inventory, though it will increase the level of quality and productivity of remote methods.

10.2 Need for future research

This research was focused on North-West Russian and covered mainly three regions – Leningrad, Arkhangelsk and Vologda oblast. Therefore, the other regions can be studied in terms of forest inventory needs and methods. Siberia seems to be the most promising region for this purpose (Irkutsk and Krasnoyarsk oblasts, Yakutiya republic). Another option is to discover European Russia more. The republics of Karelia and Komi, Kostroma oblast and also Perm oblast could be a good focus for the research (Rus' les 2015).

This study comprised 14 companies. This amount is quite few to make generalization on the whole population of Russian companies that need forest inventory information. Bigger amount of companies is desirable. Carrying out a large-scale survey with narrower focus of questions would be favourable to elicit customer needs. It can enable segmentation of companies according to customer needs portfolio for neat tailoring of forest inventory solutions. Participation of more forestry officials of different level is also beneficial. It can help to understand state's requirements and position better.

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APPENDICES

Appendix 1 – Question list

INTRODUCTORY QUESTIONS

- What is your organization's business?
- For how long your organization has leased the forestland?
- What is the size of forestland that you lease?
  1. less than 1000 ha
  2. 1-10 ths ha
  3. 10-25 ths ha
  4. 25-50 ths ha
  5. 50-100 ths ha
  6. more than 100 ths ha
- What types of customers your organization has?
- How many employees does your organization have?
  1. less than 50
  2. 50-500
  3. 500-1000
  4. more than 1000
- What is geographical area of your organization business interests?
- Does your organization have Russian or foreign ownership or is it joint venture?

MAIN QUESTIONS

- What is your organization's role in inventory process?
- How frequently do you need to acquire an up-to-date information about forestland?
- What methods do you (your suppliers) apply in forest inventory?
- What inventory information does your organization need for forest management planning?
- What are criteria of forest inventory method choice? What could be the most important criterion of choice? What department/person is in charge of the choice?
- What could be the most important criterion of choice?
- What are, in your opinion, benefits of the forest inventory method(s) your organization currently use?
- What are disadvantages of the used forest inventory methods?
- How (for what purposes) do you utilize obtained information?
- How do you process forest inventory data? How are they diffused within you organization?
- What precision is required for these purposes? Are you satisfied with precision of the methods in use?
- Do you think the currently applied forest inventory methods are up-to-date?
- Are you familiar with airborn scanner LIDAR forest inventory method? In your opinion, is it suitable for Russian market conditions? Is it suitable for your company's purposes?

- (For regional branches) Which management level is responsible for deciding on necessity of forest inventory, choosing suppliers and procurements? (what powers and authority are deputed to regional branches)
- What issues related to inventory need to be dealt with in the area of quality, methods and services?
- What, in your opinion, could effect on reliability of forest inventory method? How do you assess reliability of the used methods?
- In your opinion, how can possible forest inventory errors (human factor) affect long-term sustainability of forest?

FOREST MANAGEMENT QUESTIONS

- What kind of measures have you undertaken or plan to undertake to improve forest sustainability?
- Has your organization made investments/purchases to ensure forest sustainability? Do you plan make investments in this or some other area of interest? What kind of investments?
- How does your organization cooperate with other organizations? Cross-border cooperation?
- Could you name the most discussed forest management problems in your organization?

Appendix 2 – Participant's profiles

Code	Region, ownership (if known)	Organization's business	Relation to forest inventory information	Size of leased forestland (ths. ha)	Company size Annual cut Employees
A	Arkhangelsk, Russian	Services in the field of forest management	Provider	N/A	N/A 60
B	Moscow	Design engineering on territories related to forestry	Provider	N/A	N/A Less than 50
C	Leningrad, Arkhangelsk, Irkutsk 50% Russian 50% Foreign	Woodworking company (wide range of activities)	User	5 700	≈9 000 ths m^3 ≈ 20 000
D	Arkhangelsk, Russian	Timber harvesting, sawn wood production	User	N/A	1 500 ths m^3 >1000
E	Arkhangelsk, Russian	Timber harvesting	User	> 100	>380 ths m^3 350
F	Vologda	Group of companies Timber harvesting, woodworking, consulting	User	880	≈1 250 ths m^3 2140
G	Leningrad , Foreign	Timber harvesting, procurement	User	271	≈ 450 ths m^3 250
H	Karelia, Foreign 98 %	Timber harvesting	User	153,8	300 ths m^3 50
J	Vologda, Russian	Timber harvesting, sawn wood production, construction	User	50-100	N/A 50-500
K	Vologda, Russian and Foreign	Construction of wood houses	User	50-100	150 ths m^3 50-500
L	Vologda	Holding company: timber harvesting, woodworking	User	> 550	1200 ths m^3 1023
M	Leningrad, Federal state enterprise	forest management planning, NFI and cadastral works	Provider, also software developer	N/A	N/A 400
N	Leningrad, Federal Forestry Agency	Supervising operations of regional forestry authorities	Controller	N/A	N/A 50-500
P	Moscow, Russian	GIS software developer in forest management	Software developer	N/A	N/A 9

N/A – not applicable or not available