

Article

Digital Transformation of Forest Services in Finland—A Case Study for Improving Business Processes

Ville Kankaanhuhta ^{1,*} , Tuula Packalen ^{1,2} and Kari Väättäinen ¹

¹ Natural Resources Institute Finland (Luke), 00790 Helsinki, Finland; tuula.packalen@mmm.fi (T.P.); kari.vaatainen@luke.fi (K.V.)

² Natural Resources Institute Finland (Luke), Currently Ministry of Agriculture and Forestry of Finland, 00170 Helsinki, Finland

* Correspondence: ville.kankaanhuhta@luke.fi; Tel.: +358-29-532-4850

Abstract: This case study introduces an innovation and development concept for agile software tools for the improvement of the productivity and customer experience of forest services. This need was recognized in the context of the opening of forest data and the development of service platforms for a forest-based bioeconomy in Finland. The forest services that were studied covered a continuum from a single type of work, e.g., soil preparation and young stand management through timber procurement, to comprehensive forest property management services. The study concentrated on the needs of micro-, small, and medium-sized enterprises (SMEs), which provide either retail- or business to business (B2B) services as sub-contractors. In addition, the challenges and bottlenecks in service processes detected by other stakeholders were considered. The prevailing service processes were conceptually modelled in order to search for opportunities for improvements in business and ecosystem services, i.e., agile software concepts. For example, we examined whether it would be possible to create opportunities for flexible operational models for precision, resilience, and protection of valuable microsites in forests. These software concepts were developed and evaluated in co-operation with the stakeholders in a co-creative workshop. The technological feasibility and commercial viability of the concepts, as well as the desirability for the customer were considered. The results of this business development process—i.e., agile software concepts and their anticipated benefits—were provided for further evaluation. In addition to the practical implications of this kind of innovation process tested, the potential of these kinds of agile tools for the further development of knowledge-intensive service processes was further discussed.

Keywords: open forest data; LEAN thinking; service processes; timber procurement; forest regeneration; young stand management



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1. Introduction

Open public data and service platforms have been assessed as being able to create financial and social benefits, as well as opportunities for innovations and service development in different lines of business [1,2]. However, opening and sharing data may not always provide all the advantages and business boosting effects expected [3,4]. First, the business specific requirements in a certain sector must be considered. For example, knowledge about the management and utilization of data, functioning business models, service processes and the needs of customers must be acquired. Furthermore, the information about the trends and signals of the change in the operational environments must be acquired.

In Finland, open forest data are provided by several governmental organizations, e.g., Natural Resources Institute Finland (Luke), the Finnish Forest Centre (Forest Centre), the National Land Survey of Finland (NLS), and the Finnish Meteorological Institute (FMI). The National Forest Inventory (NFI) data and satellite image analysis results provided

by Luke are further processed into regional statistics, comparable time series and multi-source inventory map layers [5,6]. The Forest Centre produces remote sensing (RS)- and sample plot-based open forest resource maps with a raster data through light detection and ranging (LIDAR) and image analysis for the forest management and operations planning purposes [7].

Currently, in the Finnish context, open forest data are used, e.g., for screening and selecting customers and their stands for operations, management planning, control and implementation of operations, business transactions, quality management and business strategy, as well as policy implementation purposes [8]. Furthermore, it has been found that good-quality forest data benefit the service providers and forest owners due to efficient planning and decision support, targeting and timing of operations, increased cost-efficiency, reliability and quality of services [8]. Consequently, this new digital resource provides opportunities for profitable business and competitiveness for the forest sector.

LEAN thinking has become more and more common in the management of large forest industry companies and service providers [9–12]. It focuses on providing added value for the customer through reducing poorly utilized production resources, such as time, people, machines, and materials needed [13,14]. Furthermore, continuous improvement, low organizational structures and teams, and empowerment of the front-line workers, especially those serving the clients, are emphasized in the production [13–16]. The main elements of lean management originate from just-in-time management and time-based competition, total quality management, as well as supply chain and activity-based management [9,17,18].

The productivity of LEAN service operations may be improved from the viewpoint of five interrelated elements: cost, quality, speed, dependability, and flexibility, i.e., agility [18–21]. Depending on the sector, type of service and customers, the emphasis and definition of these objectives vary. In the context of the opened forest service market in Finland, flexibility is a particularly interesting element from several perspectives [22–25]. First, it may be manifested in the ability to introduce new or modified services according to the needs of forest owners and their stand properties. Second, it may be viewed in the ability to produce a wide offering or mix of service varieties. These abilities are required, e.g., in the development and production of new concepts for precision forestry, which mitigate the effects of climate change. Finally, flexibility may be observed either in the ability to adjust production volumes, or in the ability to change the timing and scheduling of the operations. In general, flexibility may be pursued by means of better predictive information, mass customization or agile management methods, which are widely used in software and service production [18,26–28].

The potential of conceptual modelling, improving and even re-engineering the forest service processes were considered as a starting point for this study [29,30]. Considering the advances in new information and communications technology (ICT), the idea was to find out what kinds of digital service concepts were missing among the Finnish forest service providers. Particular attention was paid to agility in providing software tools fitting the needs of the local service providers' employees in order to serve the end customers. This is essential especially from the viewpoint of supporting ecosystem services in the near future. The operational models for outsourced workers face completely new challenges for producing flexibly, but precisely, such outcomes in forests, which support resilience and health, carbon binding, and the protection of valuable forest sites. Following the ideology in LEAN thinking and quality management regarding services, the freedom to choose the tools and implement the services, but also the responsibility for the outcome, were provided to the small entrepreneurs and their forest workers [13–15,31]. This was assumed to provide a hypothetical psychological leverage for the intended development and implementation of service processes.

Our first goal was to conceptually model the forest service processes providing new tools and opportunities for the productivity improvements, i.e., agile software concepts. Our second goal was then to evaluate these concepts in co-operation with the stakeholders

in order to reveal their business potential. Our final goal was to evaluate these co-creative innovation processes for further development.

2. Materials and Methods

2.1. Research Process from Conceptual Modelling to Software Concepts

The offerings of forest services in the Finnish market were explored from 2015 to 2019. In this time period, the transactional context of Finnish forest service markets has been changing into open markets [32]. In the conceptual modelling of forest service processes, both the front- and back-office processes and their already digitalized information flows were considered (Figure 1). The results of previous research and development, i.e., semi-structured interviews, action research, and both seminar and project feedback surveys, as well as Finnish Forest Statistics, were exploited [33–36]. The main stakeholders were forest service and ICT-service providers, machine and manual forest work entrepreneurs, as well as representatives of governmental, industrial and non-industrial private forest owners. General background information about the state of the forest service processes were also obtained from Kankaanhuhta [37], Haataja et al. [38], and Väättäinen [39]. As a result, the information required for planning, implementing, and evaluating the activities was obtained.

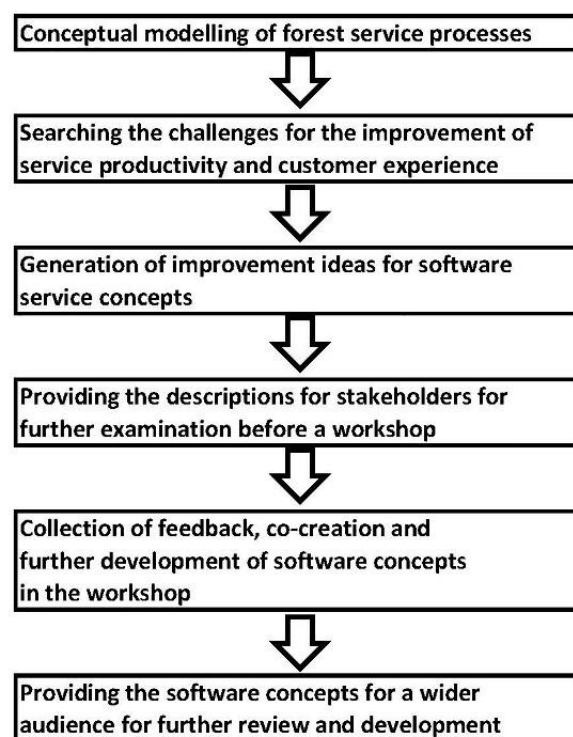


Figure 1. The research process followed in the data collection, modelling and co-creation of software service concepts for forest services.

The challenges and bottlenecks of the forest service processes, which inhibited either productivity or customer experience, were searched for next. Activities ranging from a single type of forest work performed or forest regeneration materials delivered all the way to comprehensive forest property management services were considered. The opportunities for the improvement of services through digital transformation were detected and ideas for software concepts were generated by the research group. These ideas were then provided to the stakeholders for examination prior to a co-creative workshop. In this workshop, the challenges associated with forest service production were discussed and the ideas for solutions, i.e., the software concepts, were evaluated and further developed. Finally, these

software concepts were provided to a wider audience for further review, e.g., in slideshows during seminars, and for software development.

2.1.1. Forest Service Marketing

In the marketing, the starting point was the servitization of forest regeneration materials delivered, work performed, or timber trade confirmed. It was assumed that through providing solutions for these single challenges for the forest owner, the service provider was gradually able to create permanent customer relations, even full-service contracts. In the service marketing management, the customer information based on updating good-quality open forest resource data was considered to be a valuable asset for predicting customer needs. A customer relationship was assumed to begin through three alternative scenarios for increasing the demand. A forest owner may have an up-to-date forest management plan, from which the need for silvicultural activities is derived. On the other hand, there may be a forest resource data-assisted marketing campaign, which triggers the forest owner's need for these services. Lastly, the forest owner may need money, meaning that they contact a service provider, and the timber or energy wood trade negotiations and further needs for silvicultural services follow. In the case of a customer's monetary needs, successful negotiations regarding timber trade result in a contract, and the notification of forest use is sent to the authorities at the Finnish Forest Centre.

2.1.2. Forest Property Management and Timber Procurement Services

The needs of service providers were screened from the viewpoint of productivity improvements and service experience (Table 1). For the needs of small and middle-sized forest entrepreneurs, it was found that customizable timber and service sales tools were missing (CustTmbTrd). Furthermore, the need for improving the cost-efficiency of evaluating the target stands for timber trade was observed. In many instances, the quality of trees still has to be evaluated on-site by the service providers' personnel. In this context, remote controlled self-service data collection by the forest owner through a mobile phone's camera could be developed (RmtVisit). In addition, the need for on-site decision support for the forest property management purposes at the operational, tactical and strategic level was observed (OptimEcon). In particular, the trend towards comprehensive forest property management services was predicted to grow.

Table 1. Software concepts for forest property management, timber procurement and recreational services.

Software or Mobile App Concept	Acronym for App
Agile wood harvesting and transportation planning optimization	HarvPlanOptim
Remote pre-harvest clearing need evaluation	ClearEval
Harvester for hire	HarvHire
Service provider's customizable timber and service trade app	CustTmbTrd
Remote visit to potential stand for business	RmtVisit
Mobile optimization and economics tool	OptimEcon
Customized trade and guide for nature entrepreneurs	NatureGuide
Forest worker's GPS-fitness watch	ForWorkerGpsFitn

At the planning stage of wood procurement, information about site trafficability and the need to clear undergrowth at the felling area is required. Both the visit to the target stand and extra clearing work without the actual need could be classified as extra cost factors, without mentioning the risk relating to damage incurring during harvesting to the remaining trees due to poor visibility for the operator of the harvester. Depending on the service process, a camera-aided mobile tool could be utilized by the forest owner (ClearEval). They could check the target stand and provide information for the service provider.

The planning and implementation of timber and energy wood harvesting and machine relocations are supported by some enterprise resource planning, machinery fleet, and

CAN-bus management tools. However, they have several needs for decision support (HarvPlanOptim). The maps of soil properties, depth to ground water, weather-dependent dynamic water content, and their further processed map layers for the prediction of site trafficability provide opportunities to improve the productivity and sustainability of timber and energy wood procurement [40–43]. The management of timber supply chains requires software tools, which may simulate and optimize the activities according to the local circumstances. The machine entrepreneur-level parameters for this planning tool should consist of, e.g., the size of the service provider, the operational range, the type of machines in the harvest chains, and the management logic for controlling harvesting units and machine relocations. The local parameters for the planning software require the size of stand reserve, the variation of stand size and tree size, as well as parameters for additional activities required by the customer. Furthermore, the seasonal fluctuations in timber demand and the trafficability of logging sites have to be considered in the simulations for annual scenarios. It is also possible that the supply of worker and machine resources from the entrepreneur may not match demand. In this case, a tool for hiring extra machinery may help (HarvHire).

2.1.3. Silvicultural and Forest Improvement Services

The need for forest regeneration services follows the timber trade. Depending on the forest owner, the needs range from soil preparation and forest regeneration material delivery, i.e., seedlings or seeds, to comprehensive service packages. These service packages may consist of basic elements, such as soil preparation, seedlings, and planting work, as well as the evaluation of regeneration results and a guarantee. Some service providers may also offer a value-added package including the early cleaning of the young stand, and insurance covering the damaging agents specified. Since artificial forest regeneration is one of the largest investments in silviculture, some quality control tools for the self-control measurements by forest workers have been developed and later programmed for mobile devices with GNSS or GPS tracking, henceforth referred to as GPS [33,38]. Some of these tools are also combined in enterprise resource planning systems, and the data measured are also used in updating the open forest resource data. However, some of the forest service providers still use paper forms and quality control tools are missing as the service processes are further developed.

A forest regeneration service process is initiated either in the aftermath of timber trade or later when a forest owner contacts the service provider. The first step in the service deal negotiations is the selection of appropriate tree species and regeneration methods, i.e., planting, direct seeding, or natural regeneration. In addition to this, the selection of soil preparation method and its implementation is a crucial factor from the viewpoint of the technical quality of the service [37,44]. In addition, the need for workers to flexibly prepare the soil and plant seedlings of mixed tree species that fit the local conditions of microsites is increasing due to the adaptation requirements dictated by climate change.

Quality control measurements have been developed for the operators of both excavator-based and continuously operating soil preparation machines, i.e., disc trenching and spot mounding [38,45]. However, for excavators only, a digitalized quality control system has been developed, Risutec ASTA, which enables the calculation of proper spots with coordinates at a touch of a button [46]. For continuously operating soil preparation machines, there is a need for GPS-track recording and possibly camera-assisted quality control and feedback (SoilPrepCamera). Furthermore, the ASTA quality reporting system may be classified as a typical standalone agile software tool, with limited interoperability when interfacing with background information systems, such as enterprise resource planning (ERPs), human resource management (HRM), and invoicing systems. Thus, a future customer need would be to build application programming interfaces (APIs) or system integration for the most used systems (InterOpApis, Table 2). In addition to the quality and performance data recorded, the information about the number of planting spots prepared provides cost savings for both the service provider and the customer, since the

accurate number of seedlings needed enables the cost-efficient JIT control of the seedling supply chain.

Table 2. Software concepts for silvicultural and forest improvement services.

Software or Mobile App Concept	Acronym for App
GPS-reporting camera for soil preparation quality control	SoilPrepCamera
System integration and API services (e.g., for ASTA soil preparation gps-reporting system)	InterOpApis
Seedling material identification and tracking	SeedlMatTrack
Seedling storage state and weather monitoring IoT services	SeedlStor-IoT
Seedling supply chain responsibility and Quality Control	SeedlScmQC
GPS seedling counter Quality Control App for planting tubes	GpsPlantingQC
Cloud-based cost prediction for young stand management (stand data and time consumption available)	YsmCostPred
Pre-defined Quality Control sample plots for young stand management	QcSamplePlots
Fertilization guide	FertilGuid

As the seedling material supply chains and storage are explored more thoroughly, at least three needs regarding LEAN tools may be found. The increasing need for tracking the seedling batches in order to control the spread of damaging agents with seedling material creates demand for remotely identifying tracking systems (SeedlMatTrack). Furthermore, this living and fragile material has to be nurtured in different phases of the supply chain, which creates demand for remotely monitoring the state of seedlings and local weather conditions affecting the material (SeedlStor-IoT). Finally, several stakeholders from different organizations have the responsibility for handling and taking care of the seedling lots. So far, comprehensive digitalized quality control systems for this chain of responsibilities have not been widely implemented, although self-control forms and checklists exist in paper format. Thus, there is room for mobile tools aiding in the bookkeeping, handling and control of the state of the seedling material in storage terminals and temporary storage locations (SeedlScmQC).

The planting work follows the delivery of seedlings from storage. At this stage of the service process, two needs may be identified. First, the quality of planting work is still controlled through sample-plot-based self-control measures in Finland. Although the number of seedlings planted may be recorded in paper format or in a mobile ERP system, which may be regarded as the first steps of digitalization, the data collection could be streamlined through a GPS-based seedling counter (GpsPlantingQC). For the future purposes of flexibly operating precision forestry, this could be the first cost-efficient step in the right direction. In addition, the located groups of different tree species could enhance more efficient young stand management (YSM) activities.

In YSM, the prediction of time consumption for the brush saw work is a concrete need in new solutions. Namely, the visit to the new stand costs extra to the service provider, and, on the other hand, the prediction using only the stand-wise forest data has been proved to be too inaccurate [47,48]. One solution for these predictive needs could be a cloud-based application utilizing both forest data and time consumption information from the registries of the service provider's human resource management (YsmCostPred). For example, Uotila et al. [48] provided some predictive models, but the implementation of these algorithms is still lacking. In addition, considering the need for improved accuracy of cost prediction and updating of forest resource data in the context of YSM quality control measurements [33], the locations of sample plots could be pre-sampled for the forest worker (QcSamplePlots). Taking the reliability of current partly subjective sampling by forest workers into account, this could be an improvement that should be considered [38].

In the context of forest improvement services, decision support and implementation tools for forest fertilization may be considered a need in software tools (FertilGuid). For example, the need for the assisted extraction of needle samples from the crowns of conifers with proper sampling from the stand is a good starting point. In addition, the

micro-compartment-based interpretation of the results obtained from the nutrient analysis provides new opportunities for the implementation of fertilization and water conservation.

In the broader context of forest services, forest property management services may be combined with the production of nature and recreational services, especially ecosystem service concepts. For the marketing and implementation of these services, customizable service marketing solutions and co-operation, as well as interoperability between service providers, will be required (NatureGuide). From the recreational point of view, fitness solutions relating to smart devices, e.g., GPS-fitness watches, may be applied for many purposes (ForWorkerGpsFitn). Both active forest owners and brush-saw operating forest workers may find new dimensions for monitoring both their performance and well-being during their activities.

2.2. Workshop for the Co-Creation and Evaluation of the Software Concepts

The conceptual modelling of forest service business processes produced potential areas where the activities could be improved and agile software tools could be applied. These ideas were further presented and tested through interview sessions with researchers and forest and ICT service providers, who were invited to comment on them at the workshop and present their own ideas and products. These interview sessions were carried out from April to August 2019. After the interviews, some of the new software concepts were discarded or modified for the presentations at the workshop. The concepts and the development of their formulation may be tracked. Prior to the workshop arranged at the end of August 2019 in Joensuu, a description of the service processes and all software ideas to be tested was also provided as pre-material for all participants registered. This description, or pre-material, consisted of 15 pages of text and flowcharts in Finnish, and it consisted of all of the original ideas, not just those selected for the presentations. In the workshop, there was the chairperson, subject-matter facilitator, and electronic message-board facilitator. A scheduled plan comprising seven pages containing the keynote presentations, commentaries, time for free questions and comments as well as questions from the electronic message-board was created. The schedule was planned with an accuracy of five minutes. At the beginning of the workshop, the participants classified themselves as forest service providers, ICT service providers, forest owners and other actors, such as belonging to educational organizations and consulting companies (Figure 2).

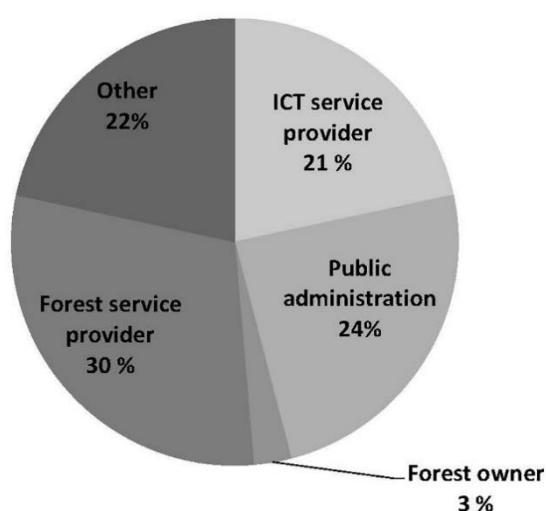


Figure 2. The stakeholder groups at the workshop. The number of participants was 37.

The workshop was opened with introductory presentations about the state of producing, utilizing, and distributing open forest data through service platforms. In addition, the local business potential of forest services was covered using the results of the Finnish National Forest Inventory and MELA forestry model and an operational decision support

system [49]. The region of North Karelia was used as a case area in the examples, but the discussions about, e.g., the advantages and limitations of the utilization of open data in the ICT-service solutions were applicable to the Finnish context of open data.

Next, software concepts obtained in the conceptual modelling of forest service processes were presented following comments by the invited representatives from forest and ICT service providers and the audience. The software concepts were formulated here as ideas for tools with the following description: 1) what the challenge or improvement need detected in the service process was; 2) what kind of idea, i.e., software concept, could hypothetically solve this challenge; 3) what the benefits of this kind of solution could be; and possibly 4) what types of competing solutions there could be. Furthermore, the utilization of open forest data was considered. In order to obtain feedback and opinions from most of the participants, a facilitated message-board service was provided with both fixed ratings from one to five and open comments. This electronic message-board solution by Prospectum Ltd. provided the maximum response rate from all types of messaging devices, since it exploited both short message services (mobile SMS messages) and the Internet. However, the tracking and grouping of the respondents into stakeholder groups was not possible due to the anonymity of single responses. The respondents were asked to rate the software concepts in an interval scale from one to five (1–5) considering three criteria: technical feasibility, commercial viability, and desirability for the paying customers [28,36,50,51]. The formulation of the questions on the electronic message-board was the same for all software concepts: “Give a rating 1–5 for the following software ideas considering the technical feasibility, commercial viability and desirability.”

3. Results

3.1. Forest Property Management and Timber Procurement Services

Comprehensive forest property management and timber procurement services were assessed to require new agile software tools at the stakeholder workshop (Table 3). The mobile optimization and economics tool (OptimEcon) was given the highest mean score (4.3) among the tool concepts that were evaluated (Figure 3). Although there are some desktop tools of this type on the market, the implementation of an easy-to-use mobile application seems to attract interest. The second highest rating was given to the harvester or forwarder rental application concept (HarvHire), with a mean score of 4.0. This score may be assessed as being fairly logical considering the seasonal variation of timber procurement and its direct influence on demand fluctuation for procurement services. In this business, every new operational model and tool for balancing the need and supply of capital-intensive resources was considered welcome.

Table 3. Scores given for forest property management, timber procurement and recreational service software concepts.

Software or App Concept	Mean Score	SD	Range	Responses (n)
Agile wood harvesting and transportation planning optimization app	3.47	0.72	2–5	32
Remote pre-harvest clearing need evaluation app	3.81	0.87	2–5	31
Harvester for hire	4.00	1.00	1–5	29
Service provider’s customizable timber and service trade app	3.74	0.99	2–5	19
Remote visit to potential stand for business	3.91	0.90	2–5	23
Mobile optimization and economics tool	4.32	0.72	3–5	22
Customized trade and guide for nature entrepreneurs	3.68	0.78	2–5	22
Forest worker’s GPS-fitness watch	2.95	1.33	1–5	22

Note: n denotes to the number of responses in the vote for software business potential at the co-creative workshop.

The large Finnish forest industry companies have developed their own mobile applications for marketing their services and navigating forest farms. However, cost-efficient customizable applications (CustTimbTrd) for the purposes of small and medium-sized businesses were found to be missing from the software market. At the workshop, the mean score given for this kind of concept was fairly low. However, the third highest mean score

(3.9) in this software category was obtained by the camera-assisted remote visit to the stand of interest app (RmtVisit).

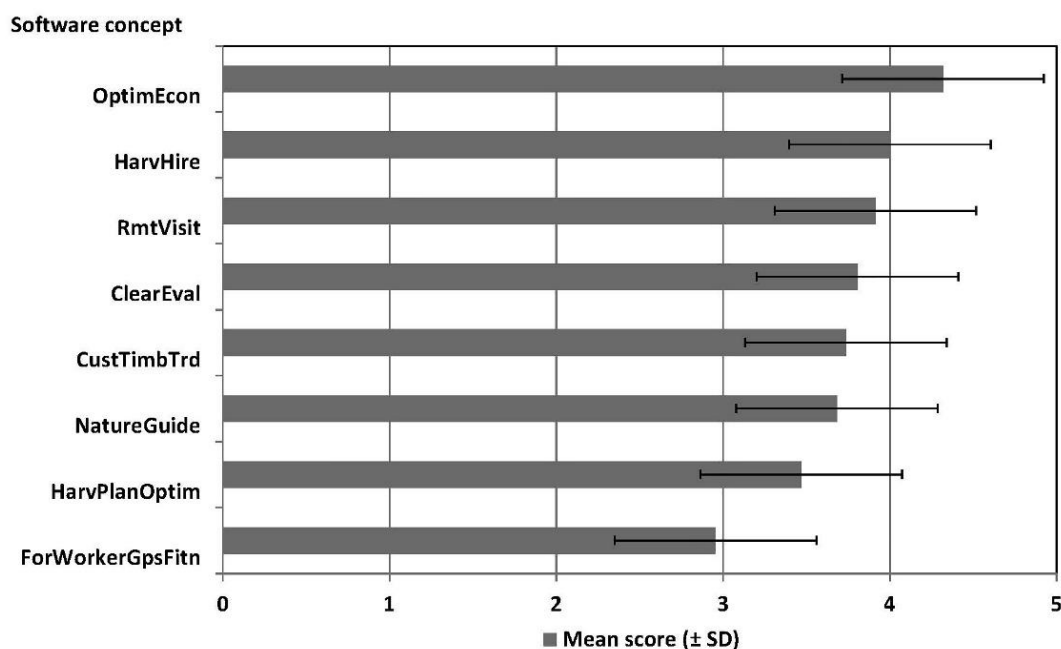


Figure 3. Ranking of software tools for forest property management and timber procurement.

The agile wood harvesting and machine relocation planning and optimization application (HarvPlanOptim) for machine entrepreneurs was given, to some extent, a lower score (3.5), but, considering the several positive comments from entrepreneurs and ICT-service providers, it has solid development potential with a clientele participating in capital-intensive activities.

3.2. Silvicultural and Forest Improvement Services

In Finland, digital transformation of silvicultural services has begun later compared with that of forest property management and wood harvesting services. In recent years, mobile enterprise resource planning and quality control tool service providers have entered the market, but the adoption of these systems has progressed slowly due to the insufficient information transfer and interoperability between these tools and background information systems. In this sense, it was no surprise that the agile development of system integration or application programming interfaces (InterOpApis) for the transfer of forest data was rated as the most promising ICT service area, with a mean score of 4.5 (Table 4, Figure 4).

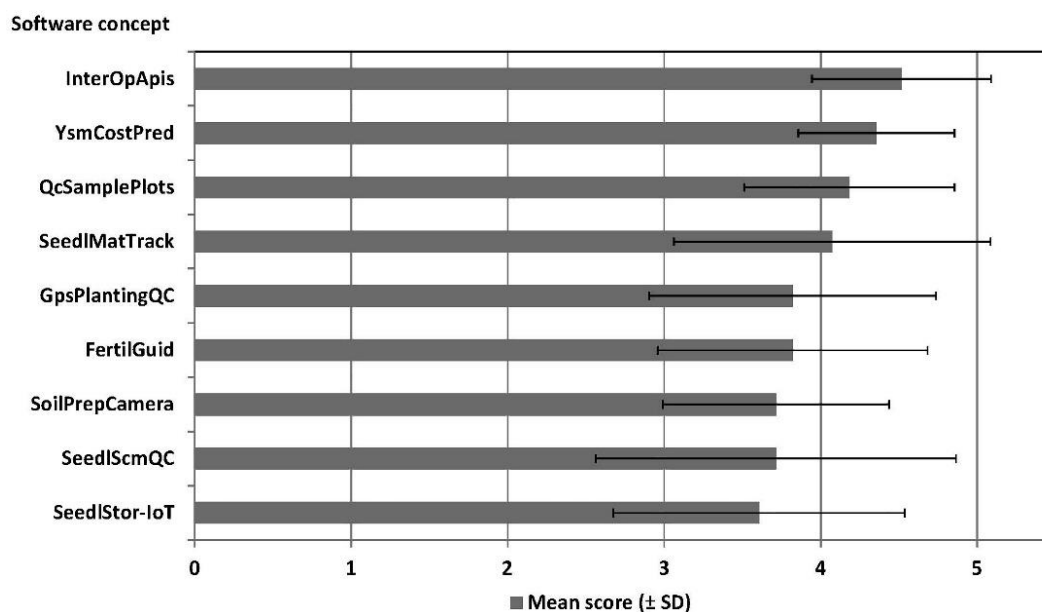
The time consumption prediction software tool for young stand management (Ysm-CostPred) received the second highest mean score (4.4) in the category of agile software concepts for silviculture. This tool concept was an example of software concepts which combine multiple data sources, e.g., open stand data, the time consumption of forest workers and other open data sources, such as the terrain wetness index (TWI), derived from digital terrain models into an updated predictive tool [48]. The cost-saving opportunities of this type of tools are two-fold. The poor predictive power of only using stand data may be improved, and the extra field visits to classify the worksites may be avoided.

The reliability of forest workers' measurements for quality control and forest resource data updates, as well as the precision of estimates for the time consumption of the work, were valued by the participants of the workshop. The pre-defined sample plot feature for these self-control applications (QcSamplePlots) obtained the third highest mean score of 4.2.

Table 4. Scores given for silvicultural and forest improvement service software concepts.

Software or App Concept	Mean Score	SD	Range	Responses (<i>n</i>)
GPS-reporting camera for soil preparation quality control	3.71	0.94	2–5	28
System integration and API services (e.g., for ASTA soil preparation GPS-reporting system)	4.52	0.63	3–5	29
Seedling material identification and tracking	4.07	0.96	2–5	27
Seedling storage state and weather monitoring IoT services	3.61	0.74	2–5	28
Seedling supply chain responsibility and quality control	3.71	0.85	2–5	28
GPS seedling counter quality control app for planting tubes	3.82	1.06	1–5	28
Cloud-based cost prediction for young stand management (stand data and time consumption available)	4.36	0.78	2–5	28
Pre-defined quality control sample plots for young stand management	4.19	0.92	2–5	27
Fertilization guide	3.82	0.86	3–5	28

Note: *n* denotes to the number of responses in the vote for software business potential at the co-creative workshop.

**Figure 4.** Ranking of software tools for silvicultural and forest improvement services.

The seedling material identification and tracking application concept (SeedlMatTrack) was rated as fourth, with a mean score of 4.1. The participants of the workshop may have been attracted by the twofold benefits of the concept. First, the seedling lots delivered to the regeneration area may be traced and withdrawn in a case of, e.g., an epidemic caused by forest pathogens. In addition, the potential improved origin of the seedlings may be recorded in the open forest resource database and utilized both for proof of origin as well as for decision support and optimization software tools.

4. Discussion

In this case study, forest service processes were conceptually modelled for discovering challenges or bottlenecks in order to improve the productivity, customer satisfaction and elements for ecosystem services of these forest services. Special interest was paid to the utilization of open forest data, as well as creating ideas and concepts for agile software tools, which would benefit the local workers who try to satisfy the needs of the customers. Furthermore, the emphasis was to find out what kind of results a customer-oriented approach for co-creating new tools would provide compared with the experience obtained in just sharing the open data and organizing hackathons [4]. In this sense, this research provided an alternative and a proof of concept of how to enhance the adoption and utilization of the open data available. In addition, our approach intended to harness digital

transformation to solve the industry-specific challenges of forest services and not only describe the generic digital maturity and level of common business processes, such as management, business models, human resources, marketing, sales and customer relations management, production, and service processes [52–54].

The starting point for this research was to consider the productivity and service experience of the forest services provided. At the same time, the capacity building for ecosystem services may be considered, since the demand and valuation of them are rapidly increasing [55]. In practice, all these tools, which utilize, create, or update location-based information, may be utilized in creating planning, decision support, operations or quality control tools for precision forestry, supporting improved outcomes from the viewpoint of ecosystem services.

The rate of adoption of ICT among forest service providers depends on their offering of services as well as on the software tools they consider to provide a competitive edge for them. Some of the forest service organizations in the forest industry have been pioneers in digital transformation. Their business models, agile tools and software features could be used as best practices for benchmarking. On the other hand, there may be SMEs which have adopted relatively few technologies for a variety of reasons. For example, the major forest industry companies and Finnish Forest and Park Service have adopted mobile enterprise resource planning and quality control systems, but in the non-industrial privately owned forests, there were large service providers without these tools, or the deployment process is still ongoing. While modelling the service processes, the ideas for agile software concepts were collected, including both at least partly tested concepts by pioneering actors and totally novel, not yet adopted, concepts. The responses of the workshop participants could be cross-checked through selecting both partly adopted software concepts and novel ones. From this point of view, they seemed to be well informed about the development and potential of this line of business.

In the search for the technological feasibility of the agile tool concepts, the availability and application of a certain ICT technique in some fields of business was considered. However, it was left to the judgement of the stakeholders at the workshop as to whether the production costs of a certain ICT solution would be at such a level that it would be appropriate for the customers. The Finnish service providers for forestry applications were reasonably well represented in the commentaries of the workshop. In addition, complementary validating comments were also collected in the results obtained in three seminars afterwards: in Jyväskylä, Helsinki, and Tallinn, Estonia. However, it is necessary to collect more information about the offering, interests and expectations from ICT service providers, which do not provide solutions for forest service providers as yet. These potential areas could include, e.g., seedling material identification and tracking, controlling seedling storage with the Internet of Things (IoT) sensor applications, and the optimization and quality control of the seedling supply chains, as well as precision forestry concepts for the regeneration of mixed-species forests.

Conceptual business process modelling and LEAN-thinking functioned well as a framework for supporting the open data-based digital transformation of forest services. In the broader theoretical context of producing future forest services, the emphasis of unit costs of production, quality, dependability and speed will switch to precise operations and flexible total services, which take into account forest resilience and health, carbon sequestration, as well as the retention of decaying wood and valuable forest sites [18,19]. In the development of agile software concepts, the advantages of co-creative workshops were twofold. They provided a conversation platform about the needs and wishes of different stakeholders, and they provided elements for understanding between different stakeholder groups regarding the future trends and business models, considering also the opportunities of ecosystem services in the forest-based ICT field, which will enhance the co-operation and utilization of open forest data in the future. Above all, the technology seems to be mature. New knowledge-intensive service processes may be developed for the benefit of both forest owners and the forest-based bioeconomy.

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