Information Management in Solid Wood Fuel Order-Supply Process

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ABSTRACT

The validity and accuracy of information and its fast distribution is significant in effective wood fuel procurement. The authors' objectives were i) to define the solid wood fuel procurement process of regional power plants, ii) to define a conceptual data model for the wood fuel order-supply process and iii) to create an application for managing the process. They did an interview study for representatives of 38 power plants, their fuel suppliers and subcontractors about wood fuel procurement. They studied further six plants and one major supplier with focus group interviews. It was found that a lot of data is available, but it's not utilized efficiently. The authors used a methodology of designing information systems architecture and use-case derived methodology to determine the conceptual data model for the order-supply process and to develop an application to control it. Altogether, the hypothesis of the significant and wide-ranging role of information in the order-supply process was confirmed. The study gives a basis to further develop the systems to manage this information.

Keywords: *Application, Communication, Data Model, Forest Biomass, Forest Energy, Information Architecture, Power Plant, Procurement Process*

1. INTRODUCTION

Monitoring and estimating forest biomass resources, their supply and usage in power plants are the key elements in energy production from wood. Their significance has increased as the use of wood fuel in producing renewable energy for societies has grown. EU's climate and energy targets for the year 2020 include that of all the energy used 20% should originate from renewable resources (European Parliament and Council 2009). In many countries forest biomass has an important role in achieving this target (Europolitics, 2012; Hakkila, 2006; Routa et al., 2013; Röser, 2011; Wolfsmayr, 2013). Interest for wood based liquid and gaseous fuels and their

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production facilities is strong and increasing (Jenkins, 2014), but at present use in solid form as wood chips is dominant (Routa et al., 2013).

Efficient order-supply process is crucial for power plants using wood chips (Kanzian et al., 2013; Shabani et al., 2013). An important factor in this is the management of information. Supply chain and usage of wood fuel become more effective with real time information of its heating value and timely pick-ups of energy wood piles: the efficiency of the incineration process increases and the transportations become more profitable when haulages of wood material with high moisture content are avoided (Acuna, 2012; Röser, 2011). Managing information about available solid wood fuel resources, their accessibility and quality, processing of fuel and its incineration is also required.

Advanced measuring technology, different web-based services and geographic positioning systems provide plenty of valuable data for the procurement process (Hultnäs et al., 2012; Ranta, 2005; Zambelli et al., 2012). However, the utilization of this data and its processing into useful form of information is often not very effective, especially among regional power plants.

In the previous studies there have been several approaches in the field of forest biomass resource management. The following perspectives have been proposed in the literature:

- **Sustainable use of forest biomass:** As the forests' significance as a source for energy increases, there is a risk for excessive exploitation of them. This may cause problems to the forests' natural growth and welfare, and have negative effects on the biodiversity and the forests' ability for carbon capture. With advanced management of wood fuel procurement information the prerequisites for sustainable forest management can be fulfilled and the documents and reports required to verify it produced (Verkerk et al., 2011);
- **National or local forest biomass and bioenergy resources, their availability and future scenarios:** Estimations of the resources and their availability and sufficiency at present and in the future have been topical issues in the studies. They evaluate a nations' or certain areas' capability to fulfill the demands set for bioenergy. The focus is on utilizing the forest resources in a way which ensures the availability of wood fuel also in future (Dhungana, 2009; Muinonen et al., 2013; Ranta, 2005; Tromborg et al., 2011);
- **Mapping optimal locations for bioenergy plants:** Identifying of possible locations for new bio power plants is a central question in profitable forest biomass use. In the studies focusing on this field the biomass resources, their spatial distribution and accessibility in a certain area are estimated to determine the best locations for the plants. Different decision support systems have been developed by using geographic information systems, databases of biomass resources and multi-criteria optimization (Perpiña et al., 2009; Perpiña et al., 2013; Zambelli et al., 2012);
- **The interaction between social, economic and environmental factors:** Some of the studies concentrate in evaluating the possibilities to implement new bioenergy projects and determining the barriers that hinder them. For example, a decision to establish a new bioenergy plant cannot be made based only on biomass resources, but the dynamic interaction between society, economic and environment has to be considered. Multi-criteria analysis has been found to be an appropriate tool to assist in such complex decision making and stakeholder integration (Buchholz et al., 2009; Peura and Hyttinen, 2011);
- **Forest biomass logistics and management of supply chain network:** The wood fuel`s logistics from forest to power plants and effectiveness of supply networks and their design have been surveyed a lot in various studies especially in the 21st century. Their significance have increased due to the growing need and expanded volumes of wood fuel. The issues studied are about machinery and working methods in the forest tract and road side landing,

storing of wood fuel, profitable and optimal transportation routes and distances, fuel and time consumption, role of terminals, structure of supply chain and phase of comminution in it (Christos, 1996; Holzleitner et al., 2013; Kanzian et al., 2009; Kanzian et al., 2013; Karttunen et al., 2013; Kärhä, 2011; Röser et al., 2012; Spinelli et al., 2012; Shabani and Sowlati, 2012; Tahvanainen et al., 2011).

To conclude from the background, the energy use of forest biomass and its supply have been studied widely with many different approaches. However, the management of information involved in the procurement process has not been surveyed as much, and there are no studies on how to effectively process and utilize the information to help bio power plants to control their wood fuel orders. This is the case especially with regional, often small-scale bio power plants that have their own individual practices to handle the order-supply process. Yet, the development in the field of bio energy is increasingly moving towards local production, which emphasizes the significance of these plants and their contractors. Information management is acknowledged as a fundamental element for successful supply chain management, tying together the key operations by subject of the customer, supplier and subcontractors (Xu, 2011).

Our objectives were the following:

1. To determine regional power plants' solid wood fuel procurement process and the data and information needs and their flows in it;
2. To design an information system/architecture to control the data and information and manage their flows in the order-supply process;
3. To develop an application for the order-supply process.

This study is related to the management of wood fuel supply chain network and forest biomass logistics. The study approaches the subject from the perspective of information management in the wood fuel order-supply process. The target group of the study was regional power plants that produce either heat or heat and electricity simultaneously. Their yearly energy production capacity varies from approximately 10 GWh to 50 GWh.

The paper is structured as follows. After introduction, in the section 2 is described the material and method for determining the wood fuel procurement process, a common approach to design information systems architecture and the methodology how the structure of the wood fuel ordering application was designed. Section 3 represents the whole procurement process from planning to reporting by defining and categorizing the functions that comprise it, and section 4 concentrates on the order-supply process's data structure. In section 5 is described the derived application for wood fuel ordering system, and section 6 discusses the study and future research scenarios in the field.

2. INFORMATION MANAGEMENT APPROACH IN WOOD FUEL PROCUREMENT PROCESS

Firstly, we applied *a methodology to design a framework for information systems architecture*, introduced by Zachmann (1987, 1999). Within the presented framework all aspects of information systems architecture are depicted, from high level business strategies to system coding (Schoch, 1995; Sowa, 1992). This methodology has been used in many later studies (Shin et al., 2011; Varga, 2003). The methodology guides to define the model of business, then its data model, and lastly to derive the information system. According to this, in our case, we studied the whole wood fuel procurement process, defined the data model for the order-supply process and derived an application to manage the order-supply process.

We outlined the model of the whole procurement process by defining the operations, factors and parties involved in it, and the time span of the whole process. This was done by reviewing previous studies of wood chip procurement management and supply chain logistics, and conducting an interview among power plants and their fuel suppliers. In the survey there were interviewed managing directors and persons responsible for wood fuel ordering from 38 power plants (57 persons). In addition the fuel supplier organizations were interviewed (eight persons). This was done during years 2012 – 2014 within the EnviTools-project.

Based on the information received from interviews and literature we grouped single operations' according to their positioning in the time span and their relation to other operations. By grouping the operations we were able to segment the whole process into four individual headings: planning, processing, ordering and reporting (chapter 3).

Next we concentrated on the ordering-segment, which is the operational process that takes place according to power plants' prevailing demand for wood fuel. By having control over this core information it is possible to expand the system to process accumulated data further: to provide estimations and conclusions to support procurements planning and for different reporting requirements.

When studying the ordering-segment six of the previously interviewed power plants and one major supplier organization and its subcontractors (forest machinery entrepreneur, chipping/transportation entrepreneur) were chosen to be studied more closely. This included regular meetings with them and more detailed focus group interviews to get a comprehensive impression of their information needs in managing the order-supply process.

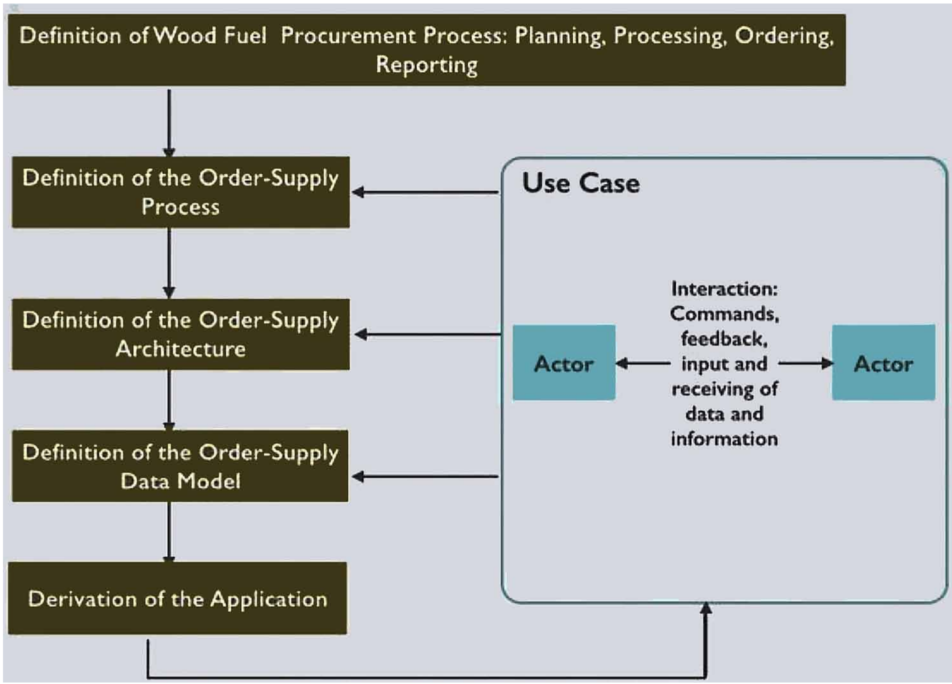
In defining conceptual data model for the order-supply process and to design an application for it, we applied *use-case-driven methodology*. It is commonly used in system analysis and modelling, where sequences of required interactions between system and user take place in a particular environment in order to achieve a particular goal (Kong et al., 2009). The requirements are captured, modeled and formalized in early stages of the development process (Somé et al., 2008). The given set of distinctive use cases are defined by the end users, and the integrated system design is then derived by synthesizing these subsystems or processes into a single consistent whole (Cheung et al., 2005). Within this methodology two objectives are generally recognized to be achieved: the system design must be consistent with respect to the functionalities of the defined use cases, and the system must be correct to avoid erroneous situations, such as capacity overflow and deadlock.

Figure 1 describes the process to design the information system for wood fuel ordering, including the use-case-driven methodology to determine its data model and the design of the application.

In the use-case methodology the actors and cases within the system boundaries are defined, and then each case is observed from the actors' perspective (Kong et al., 2009). We applied this by determining the users of the system (actors) in each operation (use case) of the order-supply process. In our case the end users of the system were the power plant, the fuel supplier and the subcontractors. The information needs and urges to manage the operation were characterized from their aspect.

First the power plants' information needs and use cases were determined by the information received from the focus group interviews. Secondly the supplier organizations needs for information and use cases were clarified with the same principle. After that we started outlining the features of the order-supply process's architecture by merging the requirements of these two parties. The concept of the order-supply process's data model and preliminary demonstration

Figure 1. The process of designing the information system application for the wood fuel order-supply process



version of the application were derived by defining the sub-contractors' use cases and needs for information and by adding the properties to manage them into the system.

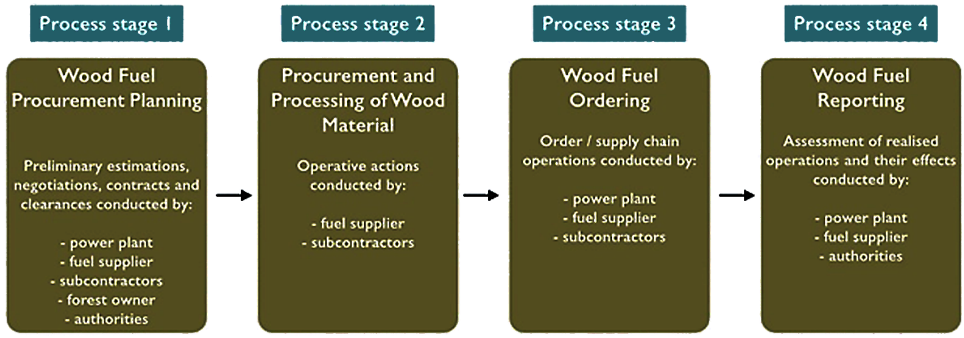
3. WOOD FUEL PROCUREMENT PROCESS

3.1. Segmentation of Process

The participants in the wood fuel procurement process are the power plant, the forest owner, the fuel supplier organization or company, the forest machinery entrepreneur, the chipping/transportation entrepreneur or company, the terminal owners (terminals may be part of the chipping/transportation services) and the authorities. Their needs for information are partially consistent, but they need also a lot of specific information concerning their own operations.

The wood material procurement process consists of four principled stages, of which each is formed by actions and factors characteristic and consistent to the group: i) wood fuel procurement planning, ii) procurement and processing of wood material, iii) wood fuel ordering and iv) wood fuel reporting stages. This is described in Figure 2. The time span between the operations in planning/conducting procurement and ordering can be 1-2 years, between ordering and reporting the time span is usually shorter. The processing of wood material is often conducted partly simultaneously with the planning stage.

Figure 2. Procurement process stages



3.1.1. Wood Fuel Procurement Planning

Wood fuel procurement is planned by yearly basis. Planning is founded on the plant's energy production capacity, the customers' approximated energy demand and the charting of available wood energy resources in the zone of supply (both ready-made stockpiles and required felling and thinning operations). From the order-supply process's perspective the key parties are the forest owner, the power plant, the authorities, the fuel supplier and the subcontractors (forest machinery entrepreneur and chipping/transportation entrepreneur).

The starting point of planning is the megawatt hours that have been produced by wood energy in the previous years. The demand for the coming year is estimated according to this. An adequate energy wood potential in the areas in appropriate distances and its good accessibility is essential for profitable operation (Rauch, 2010; Tahvanainen, 2011; Wolfsmayr, 2013). Reasonable transportation distances also help to minimize the environmental impact due to lower fuel consumption and emissions of haulages. In previous studies distance of approximately 135 km has been found to be the limit for profitable transportations by truck (Tahvanainen, 2011).

The wood fuel supplier needs to have comprehensive understanding of the forest resources within their operating range to be able to evaluate their capability to provide wood fuel in relation to estimated consumption. Based on this the wood trade negotiations with the forest owners and the yearly supply contracts with the power plants can be conducted, as well as the contracts with the forest machinery and chipping/haulage entrepreneurs.

Quarters like forest management associations dispense information about the logging areas that can provide energy wood close enough to power plants. This information is gathered from several sources, for example the forest management plans, national forest inventory data, forest resource services and related mapping services. The role of field investigation is also significant. Lately forest inventories with airborne laser scanning and mapping by satellite imagery have been researched and used (Mäkelä et al., 2011; Nord-Larsen, 2012; Villikka et al., 2012; Wallenius et al., 2012; Xie et al., 2011).

Political decisions, subsidies, environmental factors and authorities' clearances have significant effect on the planning stage; their stability is important when making decisions and evaluating operations' profitability (Kallio et al., 2011; Tromborg et al., 2007).

3.1.2. Procurement and Processing of Wood Material

When the contracts with the forest owner, power plant and subcontractors are done, the fuel supplier initiates logging and thinning operations according to their existing wood fuel storages. The forest entrepreneur who is performing the work on the forest tract conducts the work according to the planned end-use of wood material: usage in wood processing industry or as a fuel for producing bio energy. Often these two purposes are fulfilled simultaneously, so that the logging residues of industrial wood are collected for energy use (integrated harvesting). This is taken into account in the forest entrepreneurs working methods on the site (Kärhä, 2011).

Managing of wood fuel quality and the fluency of the supply chain starts within this process. The storing places of the piles at the forest road side and their construction (including covering) affect to the drying of energy wood; a topographically suitable place with optimal pile structure shortens the drying period and increases the heat value. This period lasts usually from several months to one year, but is occasionally even longer (Acuna et al., 2012; FMA Päijät-Häme, 2013, an e-mail conversation).

3.1.3. Wood Fuel Ordering

Power plant`s demand for fuel is the impulse for starting the procedures the operational order-supply chain comprises of. The fuel quality and timeliness of the deliveries, as well as the supply chain`s overall functionality, are the focal issues.

Yearly contracts form the framework for the deliveries, but the precise orders are made for shorter periods. Power plant estimates its daily demand usually for one week and announces it as megawatt hours to the fuel supplier. In addition, the tree type and form of wood may be specified. In this study the average daily consumption varied from approximately 35 m^3 in the smallest plant to 1000-1250 m^3 in the biggest plant.

After receiving the order, the fuel supplier mobilizes the chipping and transportation entrepreneurs, who get their instructions for daily deliveries for that week. Wood material is chipped at the road side and loaded to transportation vehicle. Chips are transported to power plant`s own storage at a mill-yard or straight to the power plants` silos, from which the fuel is moved to the furnace via different conveyor techniques.

According to the interviews made within this study the above mentioned method (with minor variations) is the most common practice of handling the order-supply chain amongst regional bio power plants and their fuel suppliers. Five of six of the plants that took part in the study are using this method; one has an additional storing in a terminal after chipping at the forest road side. Also other studies support this conclusion; according to Karttunen et al. (2013) 50 – 60% of all forest biomass for energy use is produced by road side chipping. On the other hand, Kärhä (2011) stated that the share of roadside chipping will decrease in the future, and chipping at the plant and in terminals will increase concerning logging residues and small-sized wood.

3.1.4. Wood Fuel Reporting

As the weekly orders are completed, information of them accumulates during the contract-year. This information contains realized values of energy wood’s consumption, moisture content and heat value, which as for are compared to the estimates. The power plant, fuel supplier and subcontractors are able to evaluate their operations` efficiency and competitive strength, and according to the accumulated information different official and environmental reports required by authorities can be formulated. The information received in the reporting phase benefits all the players of the supply chain and provides ability to estimate consumption for the next year(s), judge the functionality of supply chain and thus prepares them for the negotiations for the contracts.

4. THE INFORMATION IN THE ORDER-SUPPLY PROCESS

4.1. Felling, Thinning, Forest Haulage and Forest Road Side Storing

The operations at the forest tract can be considered as preliminary preparations for the order-supply process. They include felling and/or thinning of the wood and its haulage to the forest road side and storing there, and in case of crown mass, also pre-drying period at the tract (Acuna et al., 2012; Routa et al., 2012). To start the work the fuel supplier and forest machinery entrepreneur have to be aware of the following issues that are managed under project-ID number:

- Project-ID:
    - Type of logging (felling, thinning);
    - Size of the forest tract;
    - Tree type;
    - Desired fractions and their shares (whole tree, stem, crown mass, stumps);
    - Location of a work site;
    - Schedule;
    - Nature reserves.

In addition, the fuel supplier has to have information of the tract`s energy wood potential and estimates of the heat value it is able to produce. Other important information to the supplier is the owner of the forest, the forest machine entrepreneur responsible of the contract, cost of the contract and value of the wood trade. In case that the wood is going to wood processing industry and the residues are going to be utilized as fuel, the quarter who is arranging the logging has to be known. All this information is managed under the project's ID-number.

The forest machinery entrepreneur needs information to estimate the requisite and suitable forest machinery. He needs information of the current working conditions in the area: for example, the condition of the forest road network has to be known, and some understanding of the forest tract's topography is helpful. According to this the entrepreneur can evaluate the working conditions' properties of being challenging. Knowledge of topography helps to plan suitable places for the energy wood piles, considering their requirements for optimal drying (Erber et al., 2012; Röser et al., 2011).

Wood material's forest road side storing is long-term storing that lasts usually from several months up to over one year, depending on the tree type and form of wood (Acuna et al., 2012; Jahkonen et al., 2012). The following information is required by the fuel supplier:

- Pile-ID:
    - Storing time;
    - Location of piles;
    - Piles' tree type;
    - Piles' form of wood (whole tree, stems, crown mass, stumps);
    - Piles' weight;
    - Number of piles;
    - Possible reservations for plants.

In addition data of weather conditions during the storage period, estimations of the moisture content and thus the fuel`s heat value are valuable for the fuel supplier (Röser et al., 2011). According to this reservations of the piles for specific power plants can be made. The above mentioned information is connected to piles' ID-number, which identifies each single pile. In a wider context the pile-IDs are included in the project's ID-number.

4.2. Chipping at the Road Side and Transportation

After long-term storing period starts the wood material's processing into wood fuel and its transportations to power plants. The processing can also be done at the power plant or in terminal, but the usual way is to comminute the wood material at the road side landing (Kärhä, 2011). The fuel supplier has to have information of the areas from where to collect the energy wood piles for the power plant in question and further determine the specific piles to haulage and their location. The supplier informs the subcontractor responsible of the area: the subcontractor receives instructions of the piles to be chipped and fetched according to their pile-IDs.

The subcontractor is further informed of the schedule, haulage route and place(s) of delivery. Information concerning the condition of forest roads is important, especially in wintertime and frost heave seasons (Wolfsmayr, 2013). This information is required also by the fuel supplier: the roads may for example need plowing to make the piles accessible, and for this purpose the supplier has to have contracts also with road maintenance services. During the work the subcontractor informs the fuel supplier of the work`s progress: keeping to schedule, contents of loads, truck`s location.

4.3. Receiving, Storing and Heat/Power Production

An important source for information is the acceptance inspection at the power plant's gate. When the truck arrives to the plant, its load is weighed and a sample to evaluate the moisture content is taken (SFS-EN 2010). Information of wood fuel's energy content is gained due to this, and payment for the delivery is often done accordingly. Wood fuel is unloaded to plant`s own storage for short-term period, or to silos to be fed into the incineration process.

It is vital to the plant to have a comprehensive control of the information concerning their storages. The basic issue is the size of the storage: its buffer ability and sufficiency. Based on the information of the wood piles' properties the wood chip batches' and thus the whole storage's heat value can be estimated and compared to the consumption to come. This information is received through the piles' ID-numbers. If the storage is large, it is important to know the batches' storage time. This is because of their decreasing quality properties in the course of time and losses of dry matter after certain turning point in the drying period (Acuna et al., 2012; Wolfsmayr et al., 2013). However, this is usually not the case with regional, often small-scale plants, but with large terminals.

The last phase in the order-supply process is the incineration of wood chips where the heat or heat/power is produced. In this process the heat value of the fuel is the most significant factor, and information about it is received as produced megawatt hours. These are the true values, and it is beneficial to compare them to estimates done in preceding steps of the process in order to evaluate and develop the estimation methods. Information of fuel's overall quality in terms of its purity grade and feeding properties in the production line is other important issue.

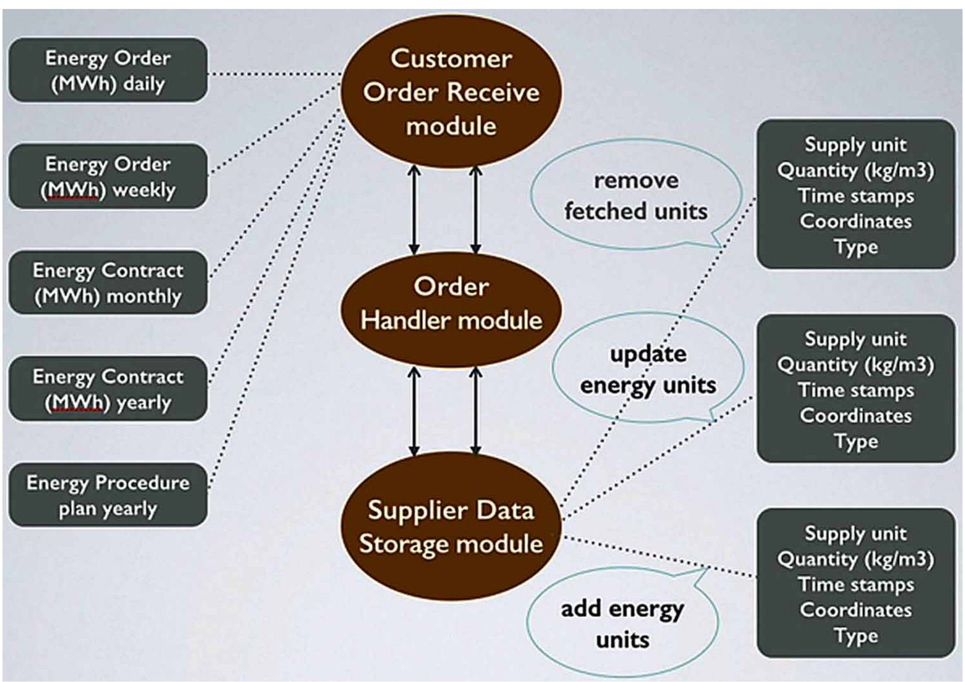
5. WOOD FUEL ORDER-SUPPLY APPLICATION ARCHITECTURE AND DATA STRUCTURE

The basic architecture of the application for wood fuel order-supply system is based on SAAS-principles (Software as a service). It features a portal where power plants and wood fuel suppliers can manage the trade of wood fuel. Sharing of information is common for all users. The detailed design and functions of each participant's interface can be modified to better meet their user-allocated needs. It can be determined, what information is available for each user. The information is transmitted on-line via internet cloud-service. Amongst other attributes, the portal contains ordering form, reporting system and contract management features supporting real time communication. The architecture of the system is light; independent entities can easily be added or removed. The application can also be integrated as a part of a larger bioenergy procurement system.

The customer order receive module (order database) and supplier data storage module (supply database) communicate on-line via order handler module (Figure 3). Order database receives impulses for energy from demand units (power plants or boilers), and transmits these requirements to the supply database. The capability to respond to the requirements is evaluated, and information of this is sent to the order database.

Evaluation of wood fuel resources contains conversion of single supply units' weight or volume into energy content according to their time stamps and the type and form of wood. This data is constantly processed in the application's moisture content estimation model, which is based on green-density tables. As a result, in addition to unit-specific energy content, an ap-

Figure 3. Principle of the architecture of the information system and the information flows in the order-supply process



proximate value for the whole supply pool's energy potential is constantly updated and available. The value varies continuously according to supply units' storing (drying) period. As new supply units become available, the system automatically adds them to the potential. And when an energy wood pile is fetched and delivered to power plant, it is removed from it.

The described modules contain specific databases for the proceeding of an order. When the power plant creates an order and sends it to the fuel supplier, it is stored in the FuelOrders – database. The confirmed order is stored in the same database. The transportation order made by the fuel supplier is stored in the TransportationOrders – database, as well as the confirmed transportation order. When the chipping/haulage company or entrepreneur creates a wood pile, it is confirmed by both the entrepreneur/company and the fuel supplier, and the details of the confirmed wood pile are stored in the WoodPiles – database. The proceeding of an order is described in the Figure 4.

6. APPLICATION FOR WOOD FUEL ORDER-SUPPLY PROCESS

6.1. System Logic

The functioning of the information system application is based on system logic described in Figure 5. The purpose and operation of each of the system entities is described in the sections after the figure.

Figure 4. The proceeding method of an order. D1, D2 and D3 are databases.

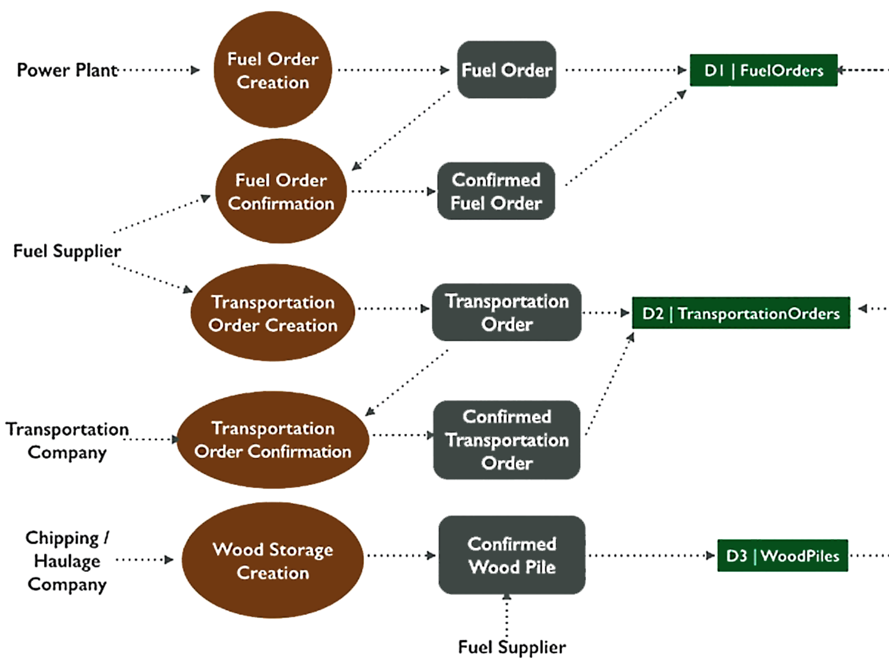
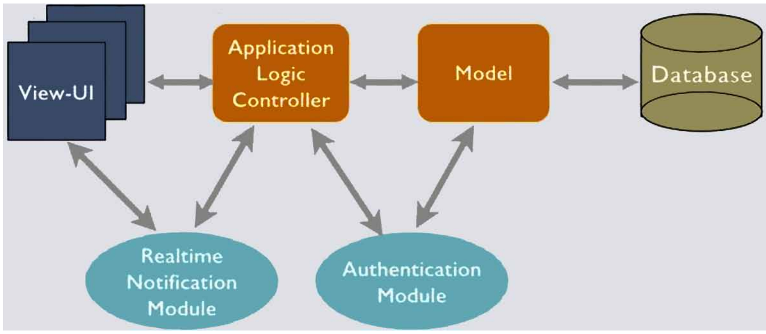


Figure 5. System logic of the application



6.1.1. The Presentation Layer (View-UI)

The View-UI (presentation layer) is the starting point for the power plant and the fuel supplier where they interact with the system. The interaction is comprised of different actions, for example, the power plant is able to place new orders and contracts or to modify the existing ones. The different views inside this layer are always connected with the application controllers which respond accordingly to the user provided inputs. For example, if the person responsible for fuel orders creates a new order, he/she inputs all the required fields in the order form and sends the order. The order is received by the appropriate controller and handled based on the data provided in the form.

6.1.2. Application Logic Controller

The controller is the main engine of the application. It interacts with all modules of the application directly except the database. The main task of the controller is to manage the (business) order logic of the system and to serve as a bridge between the various modules. For instance, when a person responsible for fuel orders wants to make an order, he/she is first presented with the presentation layer (View-UI). Then the browser makes a request to the server. These requests are handled by the controller on the server-side. The controller examines the requests and perhaps makes a request on behalf of the user to other modules and sends back a response to the user accordingly. Each of the main entities in the model has individual controllers. For instance, there is an OrderController which deals with the logic about all orders made from buyer to seller.

6.1.3. Model

Model defines the properties of each role and rules for accessing and updating the role. The model is like a bridge between the database and the controller and hides the implementation of the database to the controller layer. In wood supplier chain, there are mainly four models defined, i.e. the Customer, Supplier, Order and Contract. Each of these four models has a related table in the database. From the Controllers' aspect, any request for an insertion, deletion, updating or query to the database, will firstly call the rules defined by the corresponding model classes. The records in the database are changed based on the rules defined in the model classes. There are mainly two advantages for operating database in this way: Firstly, the rules for operating the database are limited, which means the things stored in the database are well controlled. Secondly, the controller layer is independent of the implementation of the database, and extensions on the database aspect in the future can be easily completed.

6.1.4. Real-Time Notification Module

The Real-time notification module dispatches the messages from client (fuel supplier, power plant, subcontractors) to server and server to client. The real-time feature makes sure that each message is sent to the destination immediately after created, which is an essential requirement for negotiation between the power plant, the fuel supplier and the subcontractors. The main goal of real-time notification is to notify the specific client of the new changes related, and to make the cooperation between two or several users of the information system possible.

6.1.5. Authentication Module

The authentication module is used for authenticating the users (power plant, fuel supplier, subcontractors) during a session's life cycle. It validates the user during login and ends the session during logout. It also manages the access permission of each user. For instance, if a user is not authorized to view a certain page, the authentication module makes sure that access is forbidden for that user. A stateless authentication technique is used which means that the state of the user's session is maintained on the browser instead of keeping the session on the server side. This has a positive impact on scalability. On the other hand, depending on how one uses the application the stateless technique can have a minor security risk. This occurs particularly when a user logs in from one computer and leaves his/her account open and goes to another computer and logs in again. When the second computer logs in, the first computer will not automatically logout. In our case, this is a minor issue compared to the benefit of statelessness during scalability.

6.1.6. Database

The database stores all the information about the orders and the users.

In the following sections there is described the application's features and usage in practice from the perspective of each process and user.

6.2. Forest Haulage

The grab load weights of forwarder or multipurpose machine are summarized automatically as it forms energy wood piles (supply units) at the forest road side. The completed supply unit is identified with a number, and a unit log that includes all the necessary information is created in the application's database.

The unit-specific data can be entered into the log manually by the driver (with cellular phone or IPad), or it can be partly generated automatically. Automatic function can be utilized with the following data:

- Unit-ID;
- Worksite-ID connection;
- Weight;
- Timestamps;
- Coordinates;
- Owner information.

Type and form of wood and additional information are always entered by the driver. Additional information can be for example description of the storage area geography or a picture of the unit. Usually the additional information is to assist fetching the units.

6.3. Usage at the Power Plant

The power plant enters the daily or weekly orders as megawatt hours into the order database via the application's presentation layer. Following information is used: total quantity (MWh), wood type and form, delivery date, place of discharge and desired time-window. It's not necessary to enter all of this information or at once: for example wood type and form can be specified by the supplier, and some of the details can be specified later. However, a minimum level of information is required before the application accepts and forwards the order. Due to its on-line nature, the application responses immediately by indicating the capacity of the supply pool to fulfil the order. Different symbols are used in the presentation layer to clearly indicate the details and progression of the order, like "accepted order" or "obstacle preventing delivery".

With the application the wood ordering becomes faster and more systematic compared to ordering made by phone or e-mail. All the orders are filed within the contracts, and the application informs if the quantities are exceeded or under what is expressed in the contract. With the application it is easy to follow the relationship between the orders and deliveries within desired periods, for example days or years. The application assists in planning the relationship between different wood types. It gives information of ordered quantities of each wood type, and shows how much energy is produced with the wood type in question (in the display there is a real-time graph of the orders and the produced energy). This helps to estimate the designated orders.

The power plant can also use the application for ordering other than wood fuels, for example peat, waste fuel, etc.

6.4. Usage in the Supplier Organization

In the supplier organization, the worksites and the supply units on them are displayed on the application's presentation layer as map-views. The supply units' time stamps and what tree each unit consists of is displayed, as well as in what form the wood material is: crown mass, stumps, whole tree or trunks. The worksites and supply units are identified and shown with ID-number on the map, and according to identification the owner of the wood material and the transportation company responsible for the worksite in question are shown. Transportation company's service properties can be displayed on the view.

When the order is received by the supply database available resources are automatically charted and their energy potential and other properties (wood type and form) are compared to it. If there are un-clarities or the energy potential is in-sufficient, a note about this appears on the presentation layer. The application's on-line communication platform provides a channel to discuss about possible un-clarities between the power plant and the fuel supplier.

Haulage route is calculated with a routing algorithm that takes into account the supply units' time stamps (moisture content), quantity and location coordinates. If determined by the power plant, also the type and form of wood as well as additional information provided by the users is taken into account. This data is combined with digital road maps. If need be the automatic routing can be bypassed manually for example in case that some units are known to require an urgent collection.

The algorithm optimizes the shortest driving distance between the supply units with optimal storing period within the framework of restrictions. According to route optimization a drive list is prepared and an estimation of expected delivery time is sent to the power plant, alongside with electronically signed order confirmation. The order's status is updated on the presentation layer as handled by the supplier organization, and an indication is placed for the transportation company.

6.5. Usage in the Transportation Company

If the order's details are clear, the transportation company signs it and it appears as "accepted order" in the common presentation layer. The order includes the haulage route and supply units to be fetched, as well as the place of discharge and schedule. If confusion of the details arises, the application's communication platform provides a channel to discuss them before the order's acceptance.

In the transportation company's view there is the same information shown as in the supplier organization's case: worksites and supply units on map, their contents and timestamps, recommended collection order, forest road network condition and possible messages and comments added by users. The project-IDs (worksite) and pile-IDs (supply units) are shown on the display. Phrases and symbols are used to provide the user an illustrative impression of the task.

When the driver takes the wood material to the informed place of discharge, the information of supply units' origin or truckload-ID is transmitted to the database. This function takes place automatically when the truck arrives to the plant's or terminal's scales. The order's status is updated as "delivered". The supply pool's total energy potential updates accordingly, as well as the demand pools requirement for energy.

7. DISCUSSION

Information management of biomass derived fuels' procurement process is a promising theme for research that contributes the effective use of bio energy. A study of information's role and its management in wood fuel order-supply process was conducted, due to the need among heat and heat/power producing plants, their fuel suppliers and subcontractors to manage the increasing volume of wood fuel and information involved. A lot of information is available and needed between the order-supply process's participants to get the process work effective. In addition to information flows between the participants, data is received also from measurements, statistics, databases and different geographic information and location systems.

Managing of these data and information flows is often challenging. The data and information consist often of values from factors and conditions altering in the course of time, such as fuel's demand according to temperature changes and its supply, fuel's moisture content, haulage schedules, forest roads condition, availability of machinery, volume of storages, etc. Usually the flows of information are bidirectional between the players, which emphasizes the need for speed and timeliness of communication. Common opinion amongst the parties of the order-supply chain was, that improvement of information management is needed, and it has a great potential in contributing especially the ordering phases efficiency.

Our goal was to study the solid wood fuel procurement process, to determine the data model of the order-supply process, and to develop an application to manage the information involved in it. First we clarified the solid wood fuel procurement process. This gave us tools to identify separate processes of order-supply chain so that they could be segmented into four main categories: planning, processing, ordering and reporting. Categorizing of the separate processes was a noteworthy step in getting an explicit view of the whole process. After clarifying the main categories we concentrated on the operational ordering (order-supply) process. We applied use-case driven methodology to determine its exact data structure by user-originated basis.

As a result we charted the essential data, information and their flows in the order-supply process and the prevailing challenges among regional power plants to manage them. According to this we designed architecture for information system application with features desired by the users: power plant, fuel supplier, forest machinery entrepreneur and chipping/transportation entrepreneur. Basically the application features a portal for the parties of the order-supply process to manage the wood fuel trade. In the system there are two main actors: demand pool and supply pool. These pools are communicating with each other on-line, interchanging information about the need for wood fuel, and the current supply possibilities. The system's on-line nature is important to the users due to their need to be updated of the orders' state. The design of the application's presentation layer combined with the map-views contributes the users' capability for this by offering an informative and clear way to display and interchange information.

In addition to assist in the order-supply process's operational functioning, the application has a great potential to aid planning the next years' operations. For example, by combining certain energy wood piles' estimated moisture content with measured values at acceptance inspection and incineration process, it is possible to achieve more precise estimates of the influence of different storing conditions' details to the heating value (although there are still difficulties with measuring techniques from truck loads and connecting the produced heat/power to the right energy wood batch or load). Thus making the contracts for next years' wood fuel orders could be made more precise when the details of the resources are known. Accurate information of consumption and the heating values of available wood fuel resources help to optimize procurements, transportations and storing both in the forest and in the plants.

However, development challenges are still to be confronted. The system needs to be tested for longer period to get precise results of its usability in practice and in challenging field conditions. An interesting theme is also development of the application to provide different reports for e.g. environmental purposes.

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