ROUTING OF SELF-LOADING LOGGING TRUCKS IN SWEDEN

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ABSTRACT

The aim of this study was to map the process which contractors typically use for weekly and daily routing of self-loading logging trucks. 15 hauling contractors from the Södra Skogägarna forest owners association were selected for the mapping. The mapping resulted in a basic process model and 2 main variants. Key performance indicators for both profitability and service were collected for a one-year period. Profitability was measured by net operating margin. Supplier servicer was measured by proportion of transport orders completed within a specified period. The results show that contractor profitability decreased (from 15 % to 1 % net operating margin) with increasing levels of supplier service (from 89.5 to 97 % of orders completed within one month). Within this gradient, those using the complete basic model had an average net operating margin of 4.1 %. Those using a simplified model (with fewer service restrictions) had an average margin of 9.2 %.

Keywords: hauling contractors, truck routing, profitability, service levels

INTRODUCTION

In Sweden, roundwood transport makes up a large proportion of wood supply costs. The high proportion of wood from non-industrial private forest owners and distribution of saw and pulp mills requires the coordination of a number of assortments from scattered harvesting sites to multiple mills. These operations are typically managed by the supply organization (transport service buyer) where central administration contracts transport capacity and then distribute periodic-specific transport goals to regional transport managers and their respective contractors (transport service providers). At the operational level vehicle routing becomes the responsible of the service provider. The supply organization, however normally retains close control over truck transport delivery as a possibility for compensating for disturbances in the other parts of the transport system.

The classic trade-off in the world of logistics is between cost and service. In the forest sector, the most commonly expressed supplier goal is to minimize transport costs for the defined service level. For a contractor the goal it is to maximize profitability within the restrictions of the agreed service level. Much literature is found recommending process improvement both within and between organizations for the purpose of increasing income and reducing costs, however, only a few forest-sector studies are done on this topic. Most earlier studies have been done from supplier, mill and even supply chain perspective, Few, however, have been done from the hauling contractor perspective. Mäkinen (1993, 2001) and Soirinsu and Mäkinen (2009) examine transport contractor profitability purely from a perspective of business strategy and returns to scale. Erlandsson (2008) examines contractor profitability in terms of the task environment which also includes some interfaces with service buyers, but without examining process configuration as an influencing factor.

Aims of this study

The first aim of this study is to map current contractor-level processes for routing of self-loading logging trucks. The second aim is to identify main variants of the process model and see if these differences are linked to contractor service and profitability levels.

METHODS

The study was done in two parts. The first was process mapping and the second was the search for links to service and profitability levels. The process mapping started with personal interviews and the formation of draft processes for individual contractors. When the draft maps for individual contractors were ready the search began for common features linking the different drafts to a general model. Main variants of the general model were then defined and the corresponding service and profitability levels were compared.

Process Mapping

The study was hosted by Södra Skogsägarna, a forest owners association in south Sweden. Multi-truck contractors were randomly selected from each of the organization's 3 regions (East, West, South). The distribution of contractors per region was 6 in the East, 6 in the West and 3 in the South (15 in total). Each of the respondents were contacted first by mail (to explain the aim of the study) and later by telephone (to book time and place for the interview). Participation was agreed to under conditions of anonymity.

The process mapping was based on the methods and nomenclature described by Larsson and Ljungberg (2001) who specify a variant of mapping called design-process where complex structures must be formulated from semantic descriptions in the absence of physically observable activities. Larsson and Ljungberg refer to three levels of detail: process, sub-process and activity. Within this hierarchy any process is assumed to include a number of components including input (which triggers the start of the process/sub-process or activity), activity (which transforms the input), resources (which are needed to do the activity), information (which supports or controls the activity) and output (which is the result of the activity and may be the input for the next activity).

The personal interviews with each contractor also covered a number of themes other than the explicit mapping of the routing process. These included descriptive information on the contractor's enterprise, their cooperation with the service buyer's transport managers and other parameters influencing the contractor's task environment. The interviewer asked direct and simple questions according to a pre-prepared structure allowing the respondent complete freedom to formulate complex answers. The interviewer used a series of empty process diagrams to help formulate the process during the interview. Interviews were recorded on a Dictaphone for future reference. After the completion of the 15 interviews, each contractor's routing activities were defined and named. The draft process maps which were filled in during the interviews were then compared to the recorded protocol and adjusted if required. After this the activities were categorized into sub-processes according to similarities in purpose and level of detail. After this the sub-processes and activities were defined and named.

Service and profitability variables

The chosen service level indicator was the proportion of assigned transport orders completed (all volumes for assortments delivered) within 5 weeks of initiation. This variable is therefore a measure of service offered to suppliers (forest owners with a delivery contract to Södra Skogsägarna). Average values were taken from the service buyers database (based on input from SDC, the central database for Swedish wood transactions). Data was missing for one contractor. The chosen profitability indicator for the contractor was net operating margin defined as the net operating surplus (after financial costs) as a proportion of annual turnover. Net operating margin is a relative term and therefore robust when comparing enterprises of different sizes. Values were available for limited stock companies through the Swedish national database. This data was not available for 4 contractors which had other forms of ownership. The analysis of how enterprise-level service and profitability corresponds with process configuration was done quite simply. Average values of contractor service and profitability are compared between the variants of process configuration. Scatter plots between variables from individual contractors are used to visualize eventual relationships.

RESULTS

The contractors in the study had between 2 and 12 trucks per enterprise and delivered wood to between 5 and 15 mills. Each truck delivered approx 40 000 m3/yr with a typical utilization of 4500 hrs/yr (Tab. 1).

Table 1: Descriptive statistics for the hauling contractors in the study.

	Mean	Median	Max	Min	N
trucks/contractor	4,87	4	12	2	15
mills/contractor	9,4	8,5	15	5	14
m3/yr/truck	47606	39743	100000	32000	14
km/yr/truck	185890	180000	230000	135000	15
delivery distance (km)	80	80	120	50	15
hrs/yr/truck	4525	4500	5405	4000	12

The average annual turnover per contractor in the study was approx. 12 million SEK. The average net operating margin (profit before financial costs as a proportion of annual turnover) was 5 % but varied from -3 % to 15 %. The average service level (% of transport orders completed within 5 weeks) was 93 % but varied from 84 to 97 % (Tab. 2).

Table 2: Service and profitability parameters for the contracting enterprises in the study.

	Mean	Median	Max	Min	N
Net annual turnover (1000 SEK)	12 606	12 873	19434	6309	11
Annual Profit (1000 SEK)	295	206	1123	2	11
Net annual margin (%)	5%	3%	15%	-3%	11
Service level (%)	93,2	94,3	96,9	84,1	14

The typical contractor routing process

After a comparison of all the individual contractor models, a basic model was formed consisting of all the activities which the majority of contractors (8 of 15) used to solve their own routing problems. These activities were aggregated into the 4 sub-processes (Fig. 1). These and their respective activities are described below.

Information gathering (1). This sub-process consists of one activity. Receival of new transport orders (1.1) is a daily activity where the contractor receives new transport orders (delivery responsibility for a specific harvesting site) from the forest owners association. This occurs either through direct contact with the service buyers transport manager or by downloading the new assignments directly from the service buyer's information system. After this sub-process the contractor has a complete list over his transport orders (all harvesting sites where he is responsible).

Preparatory planning (2) consists of 4 activities. This sub-process gives the contractor an overview of the restrictions, priorities and possibilities for vehicle routing. Mill quota follow-up (2.1) is for tracking the contractor's weekly quota for volumes per assortment to de delivered to the respective mills. This activity monitors the volumes delivered so far and how much is left for the days remaining. This activity can also include increases or decreases in the quota if supply or demand conditions require so. Ranking of transport orders (2.2) is when the contractor ranks all the transport orders based on a selection of priority factors. Unless special conditions exists the default priority is based on the data the transport order was assigned (oldest first). Analysis of geographic flow patterns (2.3) is when the contractor examines the patterns of wood flow to see where there exists potential for backhauling. Contact with other contractors (2.4) is for when a suitable wood flow pattern for backhauling exists between contractor transport orders and the contractor makes contact with another contractor to request an exchange of volumes to realize the backhaul. After this sub-process the contractor has a ranked list of transport orders indicating the sequence they should be delivered to meet both supplier and mill service requirements while reducing the proportion of unloaded driving.

Problem solution (3). This sub-process consists of 3 activities. These activities determine how the vehicle routing will be done during the planning period in question. Filtering of infeasible transport orders (3.1) is when the contractor filters out harvesting sites which are temporarily unavailable due to weather conditions or limited opening hours for wood receival at the mill. Clustering of small volumes into whole loads (3.2) is when the contractor locates smaller volumes (of the same mill destination) within acceptable distances to aggregate into whole loads. Search for load sequences (3.2) is when the contractor factors in the working hours of the individual operator and combine loads into sequences that give the operators full shifts that conclude close to their home bases. After this sub-process the contractor has solved the daily routing for his trucks.

Final adjustments (4) – consists of 2 activities. Execution (4.1) is the operators' execution of the individual delivery and detailed planning of the path to each harvesting site for loading. Arranging operator switches (4.2) is when the operators contact each other and agree to an exact meeting place for changing operators between shifts. After this sub-process the contractors routing solution has been executed and operator schedules coordinated in detail.

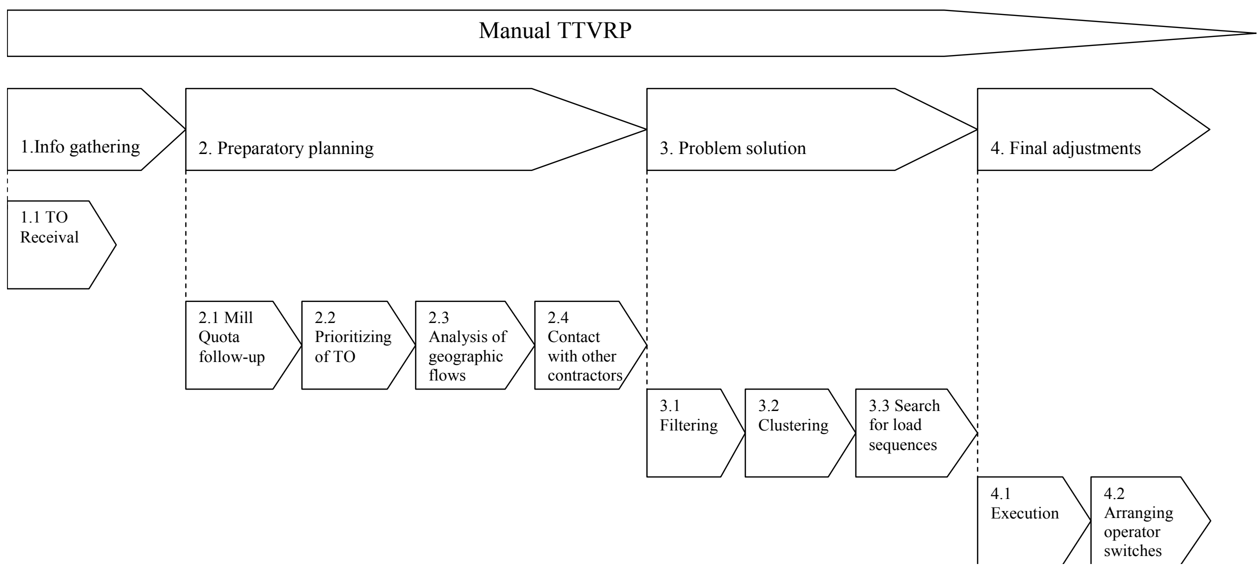

Figure 1: A process model for routing of self-loading logging trucks with 4 sub-processes and 10 activities. The model consists of the activities that the majority of hauling contractors use in their vehicle routing.

Service and profitability for different variants of the routing process

Seven contractors of the 15 studied used another variant of the basic model than described in figure 1. These had a simplified preparatory planning sub-process (2) where follow-up of mill quotas (2.1) was not included in their way of working. Two contractors of the 15 studied used a simplification of the problem solution sub-process (3) where clustering of small volumes (3.2) and the explicit search for optimal load sequences (3.3) was not included in their way of working.

Figure 2 shows that for those contractors working with either the basic model or the variant with simplified preparatory planning (2) profitability decreased (from 15 % to 1 % net operating margin) with increasing levels of supplier service (from 89.5 to 97 % of orders completed within 5 weeks). Within this gradient, those using the complete basic process model had an average net operating margin of 4.1 % while these not limited by quota follow-up (2.1) had an average margin of 9.2 %. Those contractors working with the complete model had higher supplier service levels in all three regions (Fig. 3). Figure 4 shows that profitability decreased with increasing annual operating hours per truck, regardless of which process model the contractor used. However, the contractors with a simplified problem solution sub-process had a higher number of operating hours than other contractors for the same level of profitability.

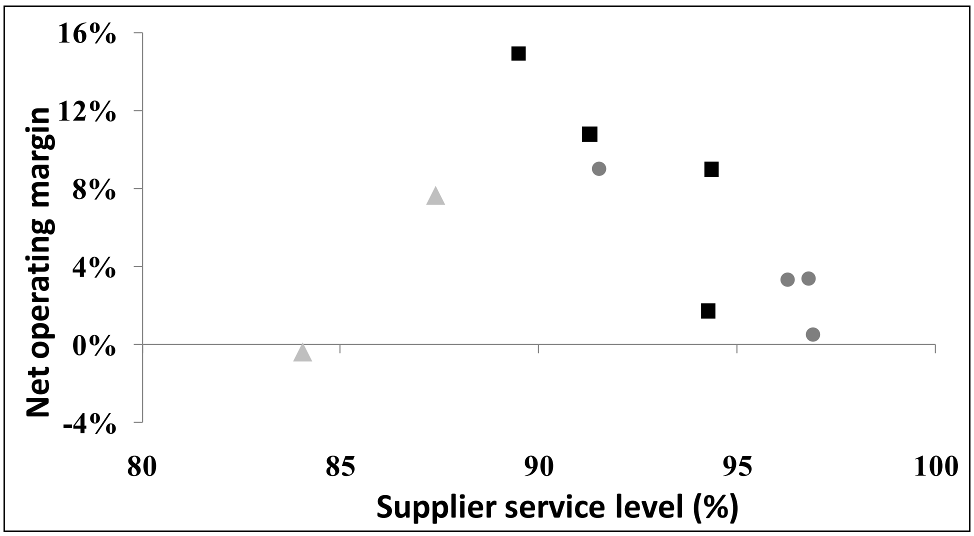

Figure 2: Scatter plot between net operating margin and supplier service levels for 10 trucking companies (circles = hauling contractors with the complete basic process model, squares = hauling contractors with simplified preparatory planning, triangles = hauling contractors that have a simplified solution sub-process.

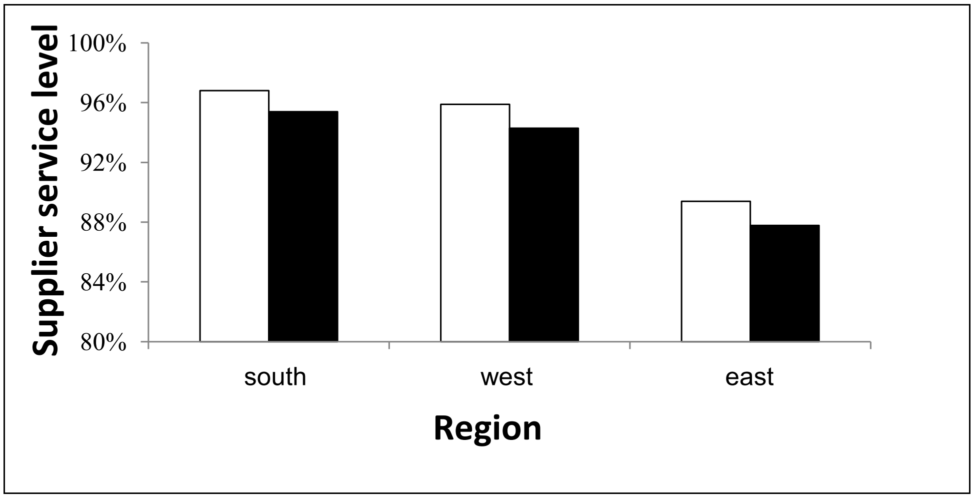

Figure 3: Mean supplier service level for hauling-contractors in each region grouped into whether they had a simplified preparatory planning sub-process or not (black columns = simplified sub-process, white columns = complete sub-process).

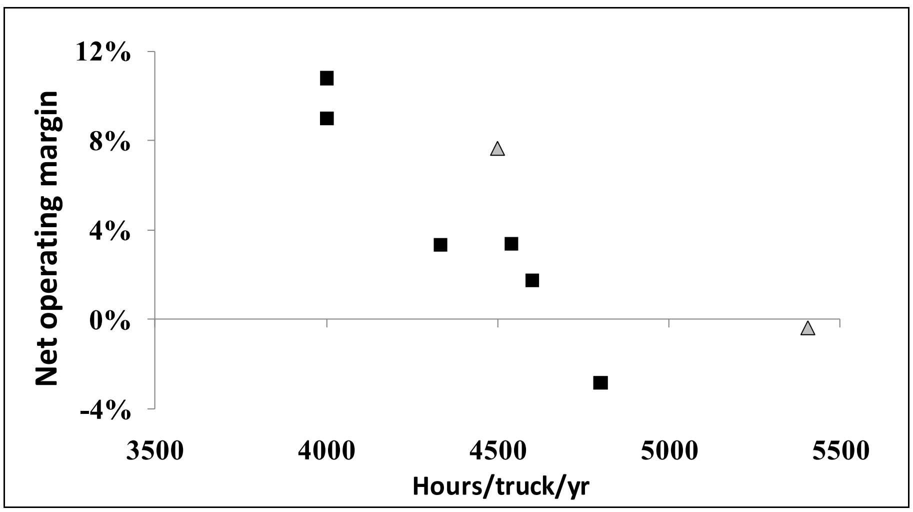

Figure 4: Scatter plot between hauling contractors' net operating margin and the number of annual operating hours per trucks (squares = hauling contractors with a complete solution sub-process, triangles = hauling contractors with a simplified solution sub-process).

DISCUSSION

Karanta et al. (2000) characterizes the logging truck routing problem (otherwise known as the TTVRP) one of the most difficult problems to solve within the world of operations research (OR). Given this, it seems a paradox that roundwood transport works as smoothly as it does. However, the main difference between mathematical OR formulations and practical transport management is the division of potentially large problems into smaller geographic sub-problems. While this poses the risk of geographic sub-optimization, it makes the problems possible to solve manually without advanced decision support systems. Karanta (2000) mentions two particular challenges of solving this problem with traditional OR methods; first, an unusually high number of constraints which must be taken into consideration and second, the difficulty of specifying a general formulation of the goal function. Regarding the first challenge, we can note that the theory of problem solving interprets the preparatory planning sub-process as focusing on the most critical factors of the task environment. In this respect the basic process model presented in figure 1 already at the start of the problem has the opportunity to exclude consideration to certain wood flows and focuses on the most critical constraints.. Regarding the second challenge, a major difficulty in specifying a general goal function is conflicting perspectives between different parts of the system (e.g. supplier vs. contractor. vs. mill). Again, the preparatory planning sub-process of the basic process model captures potentially opposing goals before beginning to address specific sequences or solutions or exclude a high number of potential alternatives (if service priorities can motivate this). Given problems of poor information quality referred to by Ekstrand and Skutin (2004) the solution process used by most contractors also reduces the required flow of supporting info to control constraints and focuses the need for further information gathering on where it supports the most pressing or relevant alternatives.

To summarize, the sequence of activities used by the studied contractors in this study effectively strips down the problem space to its most critical areas. In an extreme case a few priority mills might require immediate deliveries which are only possible to fill from a few priority landings where the critical latest date is near. This limits the number of potential pick-up and delivery points for each truck within the respective contractor's "home territory" to a relatively low number. The contractors can then easily find an acceptable sequence of loads for the day using only knowledge of average trip times. Under these conditions, the possibility for trucks to circulate between the same landing and a few mills can make the routing problem for logging trucks potentially easier to solve than other vehicle routing problems. The consideration of backhaul potentials in logging truck routing, however makes it complex again. Because wood flow patterns for a Nordic hauling contractor are often between competing wood supply organizations the responsibility for exploitation of backhaul potential is normally delegated to the individual contractor who then arranges these in collaboration with other contractors (Audy et al. 2010). Frisk (2002) examined decision support systems for helping to locate potential backhaul flows and Karlsson et al. (2006) mapped the inter-organizational processes for arranging backhauling between contractors. The operational feasibility of realizing these backhaul potentials have been examined in both simulation studies (Fjeld 2004) and empirical studies (Auselius 2009) where the levels of roadside stocks were shown to be one of the most critical aspects for high efficiency. It is in this context when backhauling becomes dependent on a long sequence of deliveries that manual routing begins to resemble an advanced board game.

Effects of the process configuration on contractor profitability

Seen in a theoretical perspective – the typical contractors routing process is about moving through a problem space towards a solution which places the whole system in the goal condition. At each node of the problem space the solver can choose an operator (decision rule) and apply it to get to a new node (state of knowledge) which is hopefully closer to his ultimate goal (in this case, profitability within service restrictions). The series of activities mapped in this study have been interpreted as a process which extracts information about the structure of the task environment and uses this for highly selective heuristic search of the problem space for solutions. The particular advantage of the method is that it makes a potentially complex problem simple. The disadvantage is that it may restrict the problem space too much, thus reducing the degrees of freedom required to find the best sequences of deliveries from a profitability perspective. In this context, both mill quotas and supplier service limits have the same effect – they reduce the number of "legal moves" (degrees of freedom) which can be tested on the way to the next node in the problem space. As a result, the combination of high service demands and a simplified search and solution sub-process clearly reduces the possibility to reach the highest level of utilization and efficiency. In this study the two respondents with the simplified solution sub-process (3.3) worked more hours than the other contractors (with corresponding profitability). These observations are consistent with the logic above. However, there may be a number of explanations for the absence of explicit solution sub-process (3.3) such as a) this decision may be made by others (higher up in the hierarchy) b) there are few degrees of freedom in the task environment or c) the contractor does not have the capacity for further information processing. In general the trend for poorer profitability at high utilization has also been reported by Mäkinen (2001) and has been commonly observed among transport managers. If the above conditions a, b or c are present, increasing transport volumes more cannot compensate for poor planning and may even make the situation worse.

Final comments

This study has used a process-perspective to map the typical contractors methods for logging truck routing in a Nordic context. The process perspective was found to be a suitable for identifying common activities in vehicle routing and illustrating main variants of the process. The sequence of activities, however, varies between contractors and other task environments will result in other models.

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