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Virtual Transportation Manager: A Decision Support System for Collaborative Forest Transportation

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Abstract. Transportation operations account for a significant part of wood procurement costs. In recent years in Canada, a number of research initiatives have been devoted to forest transportation planning methods as a mean of achieving cost reduction. Moreover, literature on freight transportation identifies inter-firm collaboration in transportation planning as a way to attain further cost-savings. Typically in Canada, many decision makers are involved in forest transportation at a regional level. This article presents a decision support system supporting collaborative transportation among these decision makers. More precisely, collaboration takes place in the routing of forest trucks, i.e. the determination of the set of routes to deliver transportation requests specified by the decision makers. The main components of the system as well as how transportation collaboration is organized with the system are detailed. The routing problem addressed and the solution method proposed are described. An industrial case study in which the system was tested is presented with the results obtained. Details about the actual outcome of the case study complete the discussion.

Keywords: Transportation, collaboration, decision support system, forest products industry.

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1 Introduction

Transportation activities from harvest areas to industries represent an average of 36% of the operational costs to deliver timber to a Canadian mill (Michaelsen, 2012). With an average of 155 million cubic meters harvested annually from 2005-2010 (CCFM, 2012), transportation represents an expense of at least two billion Canadian dollars a year for Canadian forest companies. With all this money spent on transportation, even a small cost reduction can lead to substantial savings (Palmgren et al., 2004). Therefore, in recent years in Canada, a number of research initiatives have been devoted to computer-based transportation planning methods as a mean to achieve cost reduction through enhanced transportation activities efficiency, Gingras et al. (2007); El Hachemi et al. (2009, 2011a,b); Audy et al. (2011b); Rix et al. (2011). Different benefits, including potential/real cost-savings of 0.8-35%, from computer-based planning methods in forest transportation have already been reported in several countries such as Chile, Finland, New Zealand, Sweden and US. Moreover, to allow decision makers (DM) in forest transportation to use computer-based planning methods, decision support systems (DSSs) embedding planning methods have been developed and deployed in the industry.

In the research field on freight transportation planning, collaboration among companies has been identified as a way to attain a further increase in transportation activities efficiency and, in turn, provide additional cost-savings to collaborating companies. We refer interested readers to e.g. le Blanc et al. (2007), Cruijssen et al. (2007b), Ergun et al. (2007), Özener and Ergun (2008), Krajewska et al. (2007), Clifton et al. (2008), Audy et al. (2011a) and Dai and Chen (2012). Case studies with cost-savings through collaborative planning have also been reported in the literature on forest transportation. For instance, Marier et al. (2009) and Lehoux et al. (2009) report a savings of 1.2% and 8.7% with collaborative planning in their respective case studies. These savings from collaboration account for a proportion of 23.8% and 61.3% of the total cost reduction obtained by the computer-based planning method. Therefore, forest companies must be aware that continuing further with collaborative transportation planning could provide significant additional cost-savings.

In Canada, many DMs are typically involved in the management of the wood fiber flow at a regional level. This regional wood fiber flow includes flow from the forest to industries as well as between industries. In this article, we present a DSS to support inter-firm collaboration in forest transportation in Canada. Collaboration occurs through the planning of a Vehicle Routing Problem (VRP): the determination of the delivery routes to be performed by a fleet of forest trucks to transport wood fiber (e.g. logs, sawdust, wood chips) from origin sites (e.g. harvest area, intermediate terminal, industry) to destination sites (e.g. intermediate terminal, industry). By enabling a centralized organization of the delivery routes, the DSS makes possible the collaboration among these DMs. Called VTM (abbreviation of 'Virtual Transportation Manager'), the DSS was jointly developed from 2003-2007 by researchers at FORAC Research Consortium (Université Laval) and FPInnovations (formerly Forest Engineering Research Institute of Canada), and with the cooperation of a number of Canadian forest companies.

The main research contribution of our article is twofold. First, we give a description of a DSS for forest truck routing that is explicitly designed to address an inter-firm collaboration context. Second, through the presentation of an industrial case study where the system use is illustrated, we provide a description of the VRP addressed and the planning method proposed.

The article is organized as follows. In Section 2, we introduce preliminary concepts supporting the article; we introduce transportation planning and the collaboration opportunities in forest transportation, we discuss a number of existing DSSs in forest transportation and finally, we review a number of planning methods for VRP in forest transportation. In Section 3, we introduce the developed DSS and provide an overview of its main components. How transportation collaboration is organized on the system is described in Section 4. This description covers the VRP addressed and the planning method proposed. In Section 5, we detail the industrial case study in which the system was tested and report numerical results. Discussion about the actual outcome of the case study and further initiatives to transfer the system to the Canadian forest industry are given in Section 6. Finally, we make concluding remarks in Section 7.

2 Preliminary concepts

2.1 Planning and collaboration opportunities in forest transportation

Transportation planning in forestry operations involves many decisions commonly managed according to four time-perspective horizons [i.e. strategic (up to five years), tactical (six months to one year), operational (one to 180 days), and real-time (<one day)] where the exact planning horizons used by transportation decision makers are related to their context. We provide a summary of some of them but for a more exhaustive survey, we refer to Rönnqvist (2003), Epstein et al. (2007) and D'Amours et al. (2008).

Decisions at the strategic level are concerned with the construction of transportation infrastructures (e.g. primary road network, terminal) and the selection of transportation modes (e.g. deployment of train, ship or heavy-load truck multimodal system with associated transportation equipments acquiring). Tactical decisions mainly address upgrading of the transportation infrastructures (e.g. road class or terminal storage-capacity increase) and the adjustment of the transportation equipment capacity and aggregated utilization level (e.g. number of wagons in the train route and train route frequency). Operational decisions deal with volume allocation from supply points to demand points, design of truck backhaulage tours, truck routing and scheduling of the transportation equipment/crew. Real-time decisions principally concern truck dispatching with the assignment of the next load (or more) to a truck as the transportation operations occur.

Strategic and tactical transportation-related decisions are often planned simultaneously with other decisions related to wood procurement (e.g. silviculture, harvesting) and mill production. Consequently, companies are generally reluctant to engage in transportation collaboration on these levels even with high expected returns (Audy et al. 2006). This is particularly true for the construction of major transportation infrastructures (e.g. train terminals). In contrast to strategic/tactical decisions, operational decisions provide interesting conditions (i.e. high-moderate expected return, low risk and noncore activity) for collaboration among many companies (Audy et al. 2006). Depending on the operational decisions, the savings with collaboration in transportation planning derive from several collaboration opportunities. We identify three main collaboration opportunities when companies collaborate in their transportation planning at the operational/real-time level: *raw material exchange* (operational level), *common backhaulage tour* (operational level) and *common route* (operational and real-time levels).

In *raw material exchange*, volumes of some supply points are exchanged between companies to reduce the total travelling distance as e.g. in Marier et al. (2009). To reduce the total travelling distance even more, the raw material exchange can be jointly planned with backhaulage tours as e.g. in Forsberg et al. (2005) and Frisk et al. (2010). Backhaulage tours are future potential routes schedules that combine the delivery of two or more truckloads (see the survey by Carlsson and Rönnqvist, 2007). Our second collaboration opportunity, designated as *common backhaulage tours* refers to tours in which the combined truckloads belong to different companies. The third collaboration opportunity, *common routes*, can occur at both the operational and real-time planning levels. At the operational level, it involves the routing of a fleet of trucks in which some route schedules are enhanced by realizing pick-up/delivery operations for several companies rather than only one. At the real-time level, enhanced truck routes by multi-company pick-ups/deliveries will also be obtained but through truck dispatching instead of truck routing. The *common routes* collaboration opportunity also involves sharing of transportation capacity among independent carriers as e.g. in the case study by Mendell et al. (2006). Typically, independent carriers rely on a fixed transportation capacity (e.g. in number of trucks and drivers) for a fluctuating workload. This leads to situations of excess or shortage in capacity depending on the average short (excess) or long (shortage) transportation distance from roadside inventory supply sites (for which they are responsible) to the industries. Sharing transportation capacity allows minimizing such situations by a transfer of capacity from the carriers in excess to the carriers in shortage.

Geographical distribution of the origin and destination sites, as well as a multi-directional and connected road network, has an important influence on the potential in savings from these collaboration opportunities. Moreover, not all the volumes to transport involve a collaboration opportunity. For instance, in aformentionned case study in Marier et al. (2009), only 12% of the total transported volume involves raw material exchange.

Furthermore, the collaboration opportunities as well as the potential in savings are not necessarily equally distributed among the volumes of each company. This means that the volume of some companies provides, either absolutely or relatively, more potential in savings than the volume of other collaborating companies, as found in the case study with eight collaborating companies by Frisk et al. (2010).

The second column in Table 1 reports a number of papers on solutions methods for forest transportation planning at the operational/real-time level. The selected papers focus on timber transportation and thus planning methods for other wood fiber are excluded (e.g. forest fuel transportation in Acuna et al., 2011 and Flisberg et al., 2012). The papers are classified according to the main planning decision addressed by the solution method they propose. For the planning decision on timber truck routing, the solution methods are further classified in two subsets depending on whether they also involve allocation decisions (i.e. subset titled ‘many-to-many structure’) or not (i.e. subset titled ‘one-to-one structure’). More details on this classification are provided in Section 2.3.

Modifications to a method can be required in a context of collaborative planning among forest companies and/or their carriers. These modifications are usually expressed as additional constraints to the models behind the planning methods. For instance, in a case study of raw material exchange, Forsberg et al. (2005) report additional constraints to their allocation model according to different exchange scenarios (e.g. a limit on the total volume that could be exchanged between the companies). In another case study with raw material exchange on a monthly basis, Lehoux et al. (2009) report two constraints: each company must remain the main supplier for its own mills (specified by a minimum percentage), and raw material exchanges must be pairwise equal (i.e. a company must supply each collaborator with the volume equivalent to that received from that specific collaborator). This latter constraint is also mentioned in the case study in Bouchriha et al. (2009) and Marier et al. (2009). By adding constraints, the potential savings of the collaboration is usually reduced. For instance, the two modifications in the aforementioned case in Lehoux et al. (2009) systematically decrease by 1-2% the potential savings of each month, which are in the range of 5-20%. Many of the papers with case studies involving transportation collaboration (papers identified with an asterisk in Table 1) do not report modification to their planning method because of the transportation collaboration. Therefore, this suggests that the solution methods proposed for planning in a context without collaboration could be used without modification for collaborative planning. However, extra care must be taken to ensure that no modification is required to satisfy the collaboration context.

Table 1 : Planning methods and decision support systems classified per collaboration opportunity.

Collaboration opportunity (planning decision)		**Reference on planning method** (papers identified with an asterisk involve case studies with collaboration)	**Decision support system** (reference)
Raw material exchange (Supply and demand points allocation)		Williamson and Nieuwenhuis (1993); Bergdahl et al. (2003); Puodziunas et al. (2004)*; Forsberg et al. (2005)*; Palander and Väätäinen (2005)*; Carlgren et al. (2006)*; Frisk et al. (2010)*	FlowOpt (Forsberg et al., 2005)
Common backhaulage tours (Design of truck backhaulage tours)		Eriksson and Rönnqvist (2003)*; Puodziunas et al. (2004)*; Forsberg et al. (2005)*; Palander and Väätäinen (2005)*; Carlgren et al. (2006)*; Carlsson and Rönnqvist (2007)*; Gingras et al. (2007); Frisk et al. (2010)*	Åkarweb (Eriksson and Rönnqvist, 2003); FlowOpt (Forsberg et al., 2005); MaxTour (Gingras et al., 2007);
Common routes	(Truck routing)	*Many-to-many structure:* Shen and Sessions (1989); Linnainmaa et al. (1995); Weintraub et al. (1996); Murphy (2003)*; Palmgren et al. (2003, 2004); El Hachemi et al. (2009, 2011b); Flisberg et al. (2009)*; Rey et al. (2009); Rummukainen et al. (2009); Audy et al. (2011b); Hirsch (2011) *One-to-one structure:* McDonald et al. (2001a,b)*; Mendell et al. (2006)*; Gronalt and Hirsch (2007); El Hachemi et al. (2011a); McDonald et al. (2010)*; Zazgornik et al. (2012)*	EPO2 (Linnainmaa et al., 1995); ASICAM (Weintraub et al., 1996) ; KUORMA (Savola et al., 2004 ; Rummukainen et al., 2009) ; RuttOpt (Andersson et al., 2008) ; ORTEC (Kokenge, 2011); Blue Ox/FLO (Jacqmin, 2012)
	(Truck dispatching)	Rönnqvist and Ryan (1995); Rönnqvist et al. (1998)	CADIS (Rönnqvist and Ryan, 1995; Rönnqvist, 2012); Blue Ox/FLO (Jacqmin, 2012); ForesTruck (Soriano, 2012)

2.2 Decision support systems in forest transportation

How the transportation planning is done, by whom and to what level of detail varies significantly among companies (Rönnqvist et al., 2003). Some companies perform in-house transportation planning while others outsource it, entirely or partly, to transportation service providers (e.g. independent or associated carriers) or to logistics service providers (LSP). Relying on human expertise and information systems instead of physical assets such as trucks, LSP is a single point-of-contact integrated service provider for a company that coordinates, on her behalf, a set of asset-based transportation service providers (Selviaridis and Spring, 2007). Transportation planning outsourcing may raise a number of issues for a company such as the loss of knowledge on the operations (e.g. useful to evaluate the relevant of transportation rates increase) and a sub-optimal planning at the expense of optimality sought by the transportation/logistics service provider. Thus, there is a gradient in transportation planning from a decentralization approach to a centralized one.

There is a trend for transportation planning to become more centralized and for trucks to increase their working area (Epstein et al., 2007). Such a trend increases the relevance of computer-based planning methods like the ones reported in Table 1. Indeed, on larger and more complex transportation problems involved in centralized planning, they are more cost-effective than manual planning by a DM. Thus, to allow DM in timber transportation to use computer-based planning methods, decision support systems (DSSs) embedding planning methods have been developed and deployed in the industry. To the best of the authors' knowledge, the first mention of DSS in timber transportation is by Robinson (1994) who reports the development of a "mechanical [truck] despatching aid" in the 1960's by a New Zealand company that was still in use at the time of publication. Considerable effort has been expended on transportation-oriented DSSs in other industry sectors as reported by Zak (2010).

The third column in Table 1 reports a number of DSSs in timber transportation. They are classified according to the main planning decision they address. We provide an overview of them and we refer to the review by Audy et al. (2012b) for more detail.

Since its development in the early 1990's by researchers at the Universidad de Chile, ASICAM is used by several forest companies, mainly in South America (Epstein et al., 2007). It produces the daily working schedule for a fleet of more than 250 trucks and many loaders (Rey et al., 2009) and significant benefits are reported in Weintraub et al. (1996) and Epstein et al. (1999). More recently, the system has been redesigned to be used for real-time decisions in truck dispatching (Weintraub, 2012).

EPO2 is the truck routing planning module in EPO, a system developed in the early 1990's by a major Finnish forest company to cover the strategic to operational planning of its procurement activities. It produces the weekly working schedule for a fleet of about 20 trucks (Linnainmaa et al., 1995). Additional savings are anticipated with KUORMA, the second-generation DSS that replaced EPO in 2002 (Savola et al., 2004). KUORMA provides a few days' working schedule for the entire fleet (about 250 trucks) carrying for the forest company. Before its execution, the working schedule is validated by local DMs (Rummukainen, 2012).

CADIS was developed in the mid-1990s for truck dispatching in a New Zealand forest company. This system was successfully implemented to manage a fleet of more than 120 trucks for several years before the company went through a difficult period financially and abandoned the system in its reorganization (Rönnqvist, 2012).

Åkarweb is a web-based system developed by a major Swedish forest company from 1999-2001. It is used with 50 DMs and involves about 80 trucks (Andersson et al., 2008).This system identify, on a daily basis, the best potential backhaulage tours for all the truckloads, each assigned to a specific DM. It is then up to each DM to schedule or not the proposed backhaulage tours and, for a backhaulage tour involving a truckload assigned to a different DM, collaborate or not to achieve it.

A first version of FlowOpt was developed from 2002-2004 by the Forestry Research Institute of Sweden. It makes the allocation decision of large supply areas (i.e. catchment areas) to demand points with the possibility of integrating multi-modal transportation (e.g. truck and train), backhaulage tours and, with collaborative planning, raw material exchanges. The DSS has been successfully used for Swedish and international forest companies (Flisberg et al., 2012) and, in particular, to update the whole transportation planning of a Swedish forest company after its supply areas were hit by a major storm (Broman et al., 2009).

RuttOpt was developed from 2003-2007 by the Forestry Research Institute of Sweden for log truck routing in the Swedish context (Andersson et al., 2008). It produces, for up to five days, the daily working schedule for a fleet of up to 110 trucks. Despite significant potential benefits in several case studies, the system faced implementation issues and until now has mainly been used to perform analyses (Audy et al., 2011c). This system is currently being used to assess the truck routing efficiency for an association of Swedish carriers. In this project, carriers can identify opportunities to exchange loads between them with a data access on their on-board computer to the recent loads delivered by their fellows (Lidén, 2011).

Developed in the mid-2000s, MaxTour is the truck backhauling module within the forestry operations control platform FPInterface, developed by FPInnovations (Lepage, 2012). It provides backhaulage tours with the possibility of using multi-product truck trailers (e.g. timber and pulp chips) in addition to classic (mono-product) truck trailers. Multi-product trailers can increase the number of possibilities in backhaulage tours and, in turn, benefits (see e.g. case study in Gingras et al., 2007). The proposed backhaulage tours have been used by DMs in Canada to support their manual truck routing (Lepage, 2012).

The company ORTEC provides decision support software solutions for different industrial sectors. A tailored version of their truck routing system was implemented by a US Pacific Northwest forest company and provided, from 2005-2007, the daily working schedule for a fleet of up to 100 trucks. Despite significant benefits, the use of the system was suspended, especially because of the difficulty in changing the culture of the parties involved (Kokenge, 2011).

ForesTruck is an information system for the operational planning, control and analysis of the entire wood supply chain activities that include a truck dispatching module. A first version of ForesTruck was developed in 2006 by West Ingeniería Ltda. It is used by Chilean forest companies to manage any size fleets up to reaching limits in technology capacities (e.g. hardware, Internet connection). Implementation of the system provides cost-savings according to two main factors: increased productivity of the equipment and lower fees for administration and required system use (Soriano, 2012).

A first version of FLO (formerly Blue Ox) was developed in 2009 by Trimble Forestry Automation. It is mainly used by US forest companies and transportation contractors to manage fleets of 50 trucks on average but the system is able to manage fleets of several hundred trucks (Jacqmin, 2012). FLO can be configured to be used for truck routing or dispatching and many benefits from real implementations are advertised by the system provider (e.g. truck fleet and mileage reductions, increase in number of deliveries per truck).

2.3 Planning methods for forest truck routing

The presented DSS focuses on one operational planning decision: how to determine the set of routes to be performed by a fleet of trucks to deliver wood fiber (e.g. logs, sawdust, wood chips) from origin sites (e.g. harvest area, intermediate terminal, industry) to destination sites (e.g. intermediate terminal, industry). In the literature, this planning problem is known as the Vehicle Routing Problem (VRP) and is one of the most important and well-studied combinatorial optimization problems (Toth and Vigo, 2002). The VRP in forest transportation is a variant of the pick-up and delivery vehicle routing problem, more commonly designated a pick-up and delivery problem (PDP). In a PDP, entities (e.g. commodities, disabled persons) have to be transported between origin and destination sites by a given fleet of vehicles. Therefore, the PDP consists of constructing a set of vehicle routes according to a given objective and subject to a set of constraints. Often when time constraints are considered in vehicle routing, the problem is called vehicle scheduling (or vehicle routing and scheduling) and the vehicle route is usually called vehicle schedule. For a survey on planning methods for PDPs, we refer to Berbeglia et al. (2007) and Parragh et al. (2008); and for a survey of VRPs and their several variants such as the PDP, we refer to book chapters in Toth and Vigo (2002), Barnhart and Laporte (2007) and Golden et al. (2008).

An important dimension in PDP is the availability of information at planning time (Berbeglia et al., 2007). In *static* problems, all information is assumed to be known a priori, while in *dynamic* problems, information is revealed gradually and/or subject to change over time. Planning methods for both static (see papers on line 'Truck routing' in Table 1) and dynamic (see papers on line 'Truck dispatching' in Table 1) PDP in timber transportation have been proposed in the literature. A critical aspect in the planning method for a dynamic PDP is to be able to quickly adjust a current solution as new and/or updated information is obtained. In practice, a DSS designed to be used in a dynamic mode (i.e. therefore embedding a dynamic PDP) involves higher operational requirements than a DSS designed for use in static mode. For instance, a dynamic DSS requires human resources for continuous monitoring of the transportation operations and deployment of technology for information exchange in quasi real-time with scattered transportation actors (e.g. drivers, delivery facility at destination site). The presented DSS was designed to be used in a static mode (i.e. embedding a static PDP). Future redesign of the system for a dynamic mode remains an option as done by the aforementioned DSS ASICAM.

In their classification scheme for PDPs, Berbeglia et al. (2007) differentiate three structures to describe the number of origins and destinations of the commodities involved in the PDP. In Table 1, papers addressing a static PDP can be classified into two of them: the *many-to-many* structure (i.e. in which any site can serve as a source or as a destination for any commodity) and the *one-to-one* structure (in which a commodity has a given origin and a given destination). This means that in the many-to-many structure, the supply and demand points are unpaired and, therefore, the PDP includes allocation decisions in addition to the routing decisions. Allocation decisions are made before the presented DSS and thus the system addresses a static PDP with a one-to-one structure.

Static PDP in timber transportation has been studied in many countries (e.g. Austria, Canada, Chile, Finland, New Zealand, Sweden and USA). Several planning methods have been proposed in the literature (see Table 1). Typically, planning methods for PDP with a many-to-many structure transform the many-to-many structure of their initial PDP into a one-to-one structure by taking the allocation decisions first and then the routing ones. To take allocation decisions, the well-known *transportation model* in OR could be modified to deal with the notions of assortment and assortment group (see e.g. Epstein et al., 2007). We discuss a number of planning methods for static PDP in timber transportation and we refer to Audy et al. (2012b) for a complete review.

Linnainmaa et al. (1995) propose a three-phase approach using exact mathematical programming methods and heuristics to generate a preliminary weekly truck schedule that is then subject to validation by DMs. Weintraub et al. (1996) propose a simulation-based method with embedded heuristic rules that assigns, on a moving time horizon, one load at a time to available trucks and thus generates a daily truck schedule. McDonald et al. (2001a,b) and Mendell et al. (2006) also propose a simulation-based method to generate a daily route schedule and different rules to assign trucks to supply sites are tested.

A column generation method in which each column corresponds to one feasible route is proposed by Palmgren et al. (2003, 2004) and Rey et al. (2009) to generate a daily truck schedule. McDonald et al. (2010) propose a simulated annealing method in which each new solution (daily routes schedule) generated is evaluated according to four performance metrics.

Gronalt and Hirsch (2007) propose a Tabu Search (TS) method to generate a daily route schedule to deliver a set of requests. The method is based on the *unified tabu search algorithm* (UTSA) for a general VRP with time windows proposed by Cordeau et al. (2001) and two modified TS strategies are introduced. The third phase in the three-phase method by Hirsch (2011) addresses a daily PDP and, based on Gronalt and Hirsch (2007), the author proposes a TS method and two modified TS strategies.

Flisberg et al. (2009) also propose an extended version of the UTSA in the second phase of their method generating routes schedules for up to five days. In the first phase, a two-step procedure generates *transportation nodes* (i.e. comparable to a request with a maximal volume of one full truckload) in which less-than-truckload (LTL) size requests with the same destination are, under some conditions, allowed to be included in one request of full (or nearly) truckload size. With Rummukainen et al. (2009), Flisberg et al. (2009) propose the two planning methods that support the consolidation of less-than-truckload (LTL) size requests in full (or nearly) truckload-size request. Rummukainen et al. (2009) propose a three-phase method embedding a mixed integer programming (MIP) model, a dynamic programming algorithm and two TS heuristics. It is in the first phase that a TS heuristic creates a full (or nearly) truckload-size request by splitting large volume at supply point or by consolidating LTL-size request together.

El Hachemi et al. (2009) and El Hachemi et al. (2011b) propose a two-phase method to solve consecutive daily PDPs from an initial weekly PDP. The first method embeds local search algorithms enhanced with a tabu component and a greedy heuristic. The second method embeds an MIP model and a constraint-based local search model with two solving approaches: an iterated local search algorithm and a hybrid algorithm combining previous iterated local search algorithm and constraint programming (CP). A hybrid method based on a CP model and an integer programming model is proposed by El Hachemi et al. (2011a) to generate a daily route schedule.

3 Decision support system Virtual Transportation Manager

In Canada, many DMs are involved in managing the wood fiber flows at a regional level, i.e. flow from the forest to the industries as well as between industries (e.g. the wood chips produced at a sawmill are used to supply a pulp mill). As reported in other countries (e.g. Sweden, US), the organization of transportation planning in Canada is typically decentralized: i.e., each DM performs his/her own transportation planning with no or limited collaboration with other DMs. However, a growing number of forest companies are aware that a number of their transportation contractors achieved some limited collaboration without disclosing it. Moreover, according to a number of experts and studies (Brown et al., 2003; Gingras et al., 2007), benefits could be achieved in Canadian regions through well-organized collaboration in transportation planning, especially through the use of multi-product truck trailers that generate new opportunities in backhaulage tours. Indeed, cases in the forest industry (Michaelsen, 1996; Webb, 2002; Michaelsen, 2009) demonstrated the benefits of replacing a number of tractor-trailers specialized in hauling only one type of product by multi-product tactor-trailers capable of hauling different type of product (e.g. bulk fiber and timber, bulk fiber and finished wood products). Despite such results, adoption by the Canadian forest industry of multi-product trailers remains limited up to now. One issue is the decentralized organization of transportation planning: the types of product that a multi-product trailer is capable of hauling are typically under the management of distinct DMs with no or limited collaboration.

The DSS presented in this article was developed to capture the third aforementioned collaboration opportunity (i.e. common route) within the wood fiber flow in a region. DMs with transportation activities within the targeted region specified their transportation needs on the DSS through transportation requests. A transportation request is defined by a product type and attribute(s), an origin and a destination site, a volume, a weight and a transportation time window (i.e. an earliest pickup time at the origin and a latest delivery time at the destination). By enabling a centralized organization of the routes to deliver these transportation requests, the DSS allows collaboration among the DMs, i.e. to achieve a number of common routes. The novelty of the developed DSS lies in a number of attributes specifically designed to address an inter-firm collaboration context. More particularly, the DSS is designed to provide a logistics service to distinct DMs (belonging or not to the same company) and to manage transportation planning of different product types with the possibility of using multi-product trailers, while respecting data confidentiality and standardization issues.

3.1 System overview

Object-oriented modeling (OOM) was used to design the VTM. OOM is a modeling paradigm in which the data structure of software application is represented by 'objects' in an object-oriented model. In such a model, each object (e.g. transportation request, site) has potential mandatory or optional attributes (e.g. weight for object 'transportation request'), methods (e.g. 'GetByOriginSite' returns the transportation requests at a given origin site) and relations with other objects (e.g. object 'transportation request' is linked with two objects 'site'). We refer to e.g. Meyer (1997) for more detail on OOM in the design of software application.

The VTM has been developed as a web-based system. In contrast to the desktop DSS, a web-based DSS makes the system accessible via the Internet, typically using a web browser. See Zahedi et al. (2008) for a review on web-based systems. One motivation to have opted a wb-based DSS is the expected business model of the VTM: the Application Service Provider (ASP) model. In such a business model, the software application (here the VTM) is hosted and maintained by an ASP and Internet (or other wide area network) is used to provide online access to it on a rental basis (e.g. users billed on a per-seat basis or monthly/annual membership fee). This business model offers a number of benefits for the users (e.g. no hardware/software to maintain, small investment and risk), particularly for small to medium-size enterprises that are very present in the Canadian forest industry. More detail on ASP model is found in Tao (2001).

A user of the system must have one of the following three roles. First, a central DM role to perform, using the VTM, a centralized organization of the truck routing between the collaborating DMs. Second, a member role for each company with one to many DMs receives the logistics service from the VTM. Third, the ASP has an administrator role to ensure proper system running and management of the user accounts on the VTM (e.g. once a company becomes a member of the VTM, a personalized user account is created for each of his DMs).

The main components involved in the VTM system are illustrated in Figure 1. They include: i) the transportation data from the DMs members of the VTM, ii) the core components constituting the VTM and, iii) the support components connected to the VTM. We describe each of them.

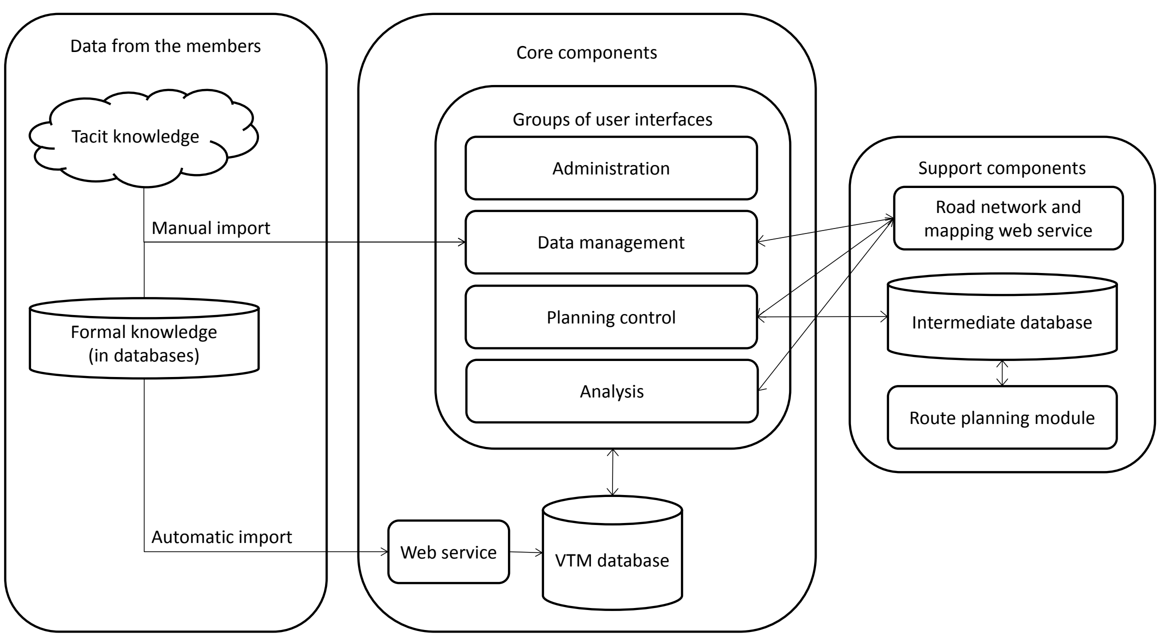

Figure 1 : Main components of the VTM system.

3.1.1 Transportation data from the members

The first component includes all the sources of transportation data available from each DM. These sources can be formal or tacit knowledge. With formal knowledge (i.e. already present in databases) it is possible to set up an automatic import of the transportation data from the database of a DM to the VTM database. This was implemented in the presented case study (see Section 5). This import is done using an Extensible Markup Language (XML) document and a web service. XML is a simple text-based format for representing and sharing structured information between programs, people and computers-people (W3C, 2012). The web service acts as a postal box to receive the XML documents (generated automatically from the DMs' databases) and triggers the update of the VTM database.

When such automatic import is not developed and/or to transfer tacit knowledge, a user interface in the VTM has been developed to allow DMs to manually import their transportation data to the VTM database. This import also uses XML documents that DMs generate on their own from their database (if formal knowledge) or (if tacit knowledge) by 'manually' generating the XML document, e.g. typing information in a provided database (Microsoft Access) embedding an XML document generator. As was done in the presented case study, in practice it is expected that most transfers of tactic knowledge to the VTM database will be handled by the central DM instead of individual DMs. Indeed, using different modes of communication (e.g. telephone, email), the central DM will gather the tacit knowledge from the individual DMs and achieve the required steps to import it in the VTM database.

Finally, we highlight the one-way flow of information from the individual DMs to the VTM database. At each new automatic or manual import, an update process is performed by the VTM to compare information already in the VTM database to the new imported information. For instance, new transportation requests in the import are added to the VTM database and transportation requests present in the VTM database but absent (with new parameters value) in the new import are removed from (modified in) the VTM database. Also, after each automatic or manual import by a user, a message (i.e. report on the import) is automatically generated and sent to the user by the VTM.

3.1.2 Core components

The core components constituting the VTM are: the groups of user interfaces, the VTM database (Microsoft SQL Server) and the aforementioned web service dealing with the automatic imports.

There are four groups of user interfaces grouped together by their main functionality: Administration, Data management, Planning control and Analysis. Access right to each user interface is according to the aforementioned roles (see Table 1). Moreover, some interfaces support the editing of the VTM database: i.e. they allow editing information directly in the interface. This editing right is also according to aforementioned roles (see Table 1). The administrator role has access and editing rights to all user interfaces but typically only uses its editing right on the interfaces related with the management of membership and the user accounts (i.e. interfaces in the group Administration). The central DM role has access and editing rights to all interfaces except the ones in the group Administration. Interfaces in the group Data management support preparation of the data required for the routes planning that are run by the central DM (using interfaces in the group Planning control), as well as the evaluation and implementation of the planned routes (using interfaces in the group Analysis). For the DMs of a member role, the access and editing right is limited to specific interfaces dedicated to data import (group Data management) or viewing (groups Data management and Analysis). In particular, an editing right is temporarily allowed when a DM imports a new site in the VTM database and only the information related to this new site can be edited. Details on a number of interfaces are given in Section 4. Finally, not reported in Table 2, there is an interface dedicated to each user of the VTM for the management of their personal account (e.g. change login password, update contact information).

Information displayed in an accessible user interface is subject to a confidentiality restriction for the member role while the central DM and administrator roles have complete visibility on all members' data. This restriction guarantees the confidentiality of members' private data between them while allowing private data visibility among the DMs of a same member. Data private to a member are the transportation requests imported by its DMs and, if any, specific site(s) requested to be kept private to the member. How the privacy on a site is managed on the VTM is detailed in Section 4.1.3.

Table 2 : Access and editing rights to the VTM interfaces per role.

Set of user interfaces	Interface		Role: Administrator Access	Administrator Editing	Central DM Access	Central DM Editing	Member (1…n DMs) Access	Member (1…n DMs) Editing
Administration	Membership management		Y	Y	-	-	-	-
	User account management		Y	Y	-	-	-	-
Data management	Data import		Y	n.a.	Y	n.a.	Y	n.a.
	Product types		Y	Y	Y	Y	Y	-
	Product attributes		Y	Y	Y	Y	Y	-
	Distance and time matrix		Y	Y	Y	Y	-	-
	Sites	Detail	Y	Y	Y	Y	Y	Y when a new site is imported
		Mapping	Y	Y	Y	Y	Y	Y when a new site is imported
		Resource	Y	Y	Y	Y	Y	Y when a new site is imported
		Calendar	Y	Y	Y	Y	Y	Y when a new site is imported
		Visibility	Y	Y	Y	Y	Y when a new site is imported	Y when a new site is imported
		Approbation	Y	Y	Y	Y	-	-
	Resource types	Detail	Y	Y	Y	Y	Y	Y when a new site is imported
		Calendar	Y	Y	Y	Y	Y	Y when a new site is imported
	Truck types		Y	n.a.	Y	n.a.	-	-
	Truck fleet	Region definition	Y	Y	Y	Y	-	-
		Pseudo-depot mapping	Y	Y	Y	Y	-	-
		Capacity	Y	Y	Y	Y	-	-
		Calendar	Y	Y	Y	Y	-	-
Planning control	Planning	Parameters	Y	Y	Y	Y	-	-
		Start	Y	n.a.	Y	n.a.	-	-
Analysis	Route	Status management	Y	Y	Y	Y	-	-
		Statistics	Y	n.a.	Y	n.a.	-	-
		Segments	Y	n.a.	Y	n.a.	-	-
	Transportation requests	Query	Y	n.a.	Y	n.a.	Y	n.a.
		Map and table	Y	n.a.	Y	n.a.	Y	n.a.

Legend: Yes (Y); No (-); Not applicable (n.a.)

3.1.3 Support components

The support components used by the VTM are: a road network and mapping web service, an intermediate database and a route planning module.

To perform truck routing, travelling time and distance between each pair of sites are required. In some countries, this information is available in specialized national road databases, for example the Forestry National Road Database (SNVDB) in Sweden (Andersson et al., 2008). In Canada, this information is typically obtained from a company's geographic information system (GIS) or governmental or general road databases (e.g. Google Maps web service). The level of accuracy and coverage of the forest road network is variable. Therefore, the selected database(s) will mainly depend on which databases are available in the region(s) where the VTM must be implemented. The presented case study involves several regions and the planning of transportation activities travelling only on the public road network. Thus, a forest roads database was not required and a general one can be used: we selected the Map Point web service. More specifically, using a procedure of information exchange in Simple Object Access Protocol (SOAP), the VTM obtains the travelling time and distance information from the Map Point web service. Moreover, the Map Point web service is also used in a number of user interfaces requiring a roads network-based mapping display.

The two other support components (i.e. an intermediate database and a route planning module) are related with the computer-based planning method supporting the central DM in the organization of the transportation. The solution from the planning method provides a set of routes to deliver the transportation requests and, because the VTM has been designed to support collaboration in transportation planning, a number of these routes are enhanced with the aforementioned third collaboration opportunity (i.e. common route). The planning method was implemented and solved with the modeling environment ILOG OPL Studio 3.7. Information in input/output to/of the planning method is kept in an intermediate database (Microsoft SQL Server) generated from the VTM database/route planning module with queries in Structured Query Language (SQL).

4 Organization of transportation collaboration with the VTM

How the central DM uses the VTM to organize transportation collaboration can be summarized in three basic steps: i) gathering and organizing the transportation data for the planning, ii) performing the planning and iii) analyzing and implementing the solution. These steps are applied in a sequential routine each time the central DM triggers the process of organizing transportation collaboration. In the next subsections, we describe each of these steps followed by the central DM as well as their associated user interfaces. We also detail how (and on which interfaces) the DMs of each member use the VTM. As aformentionned, all the membership and user accounts must first be set by the administrator to allow the central DM and DMs of each member to use the VTM.

4.1 Gathering and organizing the transportation data

As discussed by Andersson et al. (2008), one complex factor when developing a DSS for timber truck routing is the need to obtain the detailed information required in input to the planning of the PDP. The main attributes of a PDP in timber transportation can be summarized by: the objective and planning horizon targeted, the time windows considered, the definition of the transportation requests (for a PDP with a one-to-one structure), the representation of the truck fleet, the driver and the depot (i.e. a site where the truck fleet is based) and, finally, the representation of the loader and its operator (Audy et al., 2012b). We follow a similar framework to describe what information is required in input to the static PDP addressed by the VTM and how this information is acquired in the VTM database.

4.1.1 Objective

The set of routes schedule delivering all requests at the total minimum transportation cost is the objective. We represent a route schedule as an ordered sequence of segments starting at a site and travelling towards another. In each segment, there are four potential operations (i.e. waiting, (un)loading, carrying and resting) and each of them involves a cost. In order to explicitly compute the number of fuel litres consumed by each route schedule, fuel cost is computed separately in the cost of each potential operation. The total transportation cost of a route schedule is the sum, in each segment, of the operation cost and the fuel cost.

The first three operations (i.e. waiting, (un)loading and carrying) involve the same hourly cost depending on the truck type selected. This hourly cost includes the driver's salary and a fraction of the annual expenses of the truck such as depreciation, license and insurance. Waiting time occurs when a truck arrives on a site before the beginning of a mandatory time window (e.g. opening hours of the site). Handling time is estimated according to: the handled volume, if it's for loading (slow) or unloading (fast), if it's performed by a truck type with (slower) or without (faster) a crane and finally, a short fixed time to represent various basic actions for pickup/delivery on a site such as travel within the site and load binding. The productivity values to enable handling time estimation are parameters setting by the central DM in interface 'Planning-Parameters'. Finally, the operation resting involves a fixed cost that corresponds to a compensation for the potential layover that the driver must take. Details on when a resting operation is required are found in Section 4.1.4.

Except during the resting operation (no fuel cost), fuel costs are calculated according to three different truck engine fuel consumption functions: idling, handling and on-road. The idling and handling functions are hourly fuel consumption applied on the duration of the waiting and (un)loading operation, respectively. For truck type without a crane, no additional power is demanded from the engine during the (un)loading operation, consequently the value of the hourly fuel consumption is the same for both idling and handling functions. The on-road function depends on the travelling distance and the total weight of the truck in the carrying operation. The class of route taken is usually another factor in such function. However, virtually all roads belong to one class (i.e. paved route) in the case study, consequently this factor was not included (we use the function for paved route).

The cost and fuel consumption functions have been provided by FPInnovations which, in turn, are based on many studies conducted in the Canadian forest industry. This means that the computed costs on the VTM are not the transportation rates paid by the members of the VTM. There are indisputable issues (e.g. anti-trust law) and well-founded resistance to the sharing of transportation rates among distinct companies. Consequently, the VTM uses a cost function representative of the operational cost of a truck (i.e. without the variable profit (or loss) percentage included in the rates table of a carrier). In the presented case study, computed costs on the VTM were compared with the average transportation rates paid by the different DMs for 8.5 months of deliveries at the main customer-mill. Results showed that the difference was plus or minus 4% for five of the six DMs (Charrouf, 2009). The cost and fuel consumption functions are embedded in the data on each type of truck (see 4.1.4) while the cost by fuel litre is a parameter setting by the central DM in interface ‘Planning-Parameters’.

4.1.2 Time windows

Several time windows are used. A first time window is specified on each transportation request to advise the earliest (latest) pickup (delivery) time of the request at its origin (destination) site. Time windows on the availability of the trucking capacity can also be specified when e.g. no capacity is available during the weekend. How this could be achieved on the VTM is given in Section 4.1.4.

Time windows on a site consist of two forms: opening hours and on-site resource operation hours. The first indicates the site’s opening hours during which a truck can perform a pickup/delivery, while the second indicates the hours during which a given on-site resource is in operation (e.g., on-site loader(s) are available for (un)loading operations, wood scaler on duty). Truck types without a crane must be scheduled inside two time windows: site opening hours and on-site loader(s) operation hours. Waiting time is allowed when a truck arrives on a site before the beginning of the mandatory time window(s). Time windows on a site are managed by the central DM using the interface ‘Sites - Calendar’ for site opening hours and ‘Resource types – Detail/Calendar’ for on-site resource loader(s) operations hours. When a site is a member’s private site (see Section 4.1.3), this member is responsible for providing site information to the central DM.

General practices in place among the carriers involved in the presented case study, require the addition of a daily time window on the allowed starting time of a route. Indeed, as discussed in 5.1, night shifts for a driver are uncommon in the presented case study and thus, a route cannot start during the evening-night. This optional time window is a parameter that can be set by the central DM in interface ‘Planning-Parameters’

4.1.3 Transportation request

As discussed in Section 3.1.1, each DM is a source of transportation data that are automatically and/or manually (using interface ‘Data import’) imported in the VTM database. The crucial data specified by each DM are their transportation requests. To allow the system to perform data consolidation, the members have to agree on a standard in defining their requests. More precisely, there must be a standard on the different product type (e.g. logs, wood chips), their attributes (e.g. firm-spruce chips, pine chips) and their unit (i.e. volume, weight and time). Adhering to this standard is crucial to respect the compatibility/incompatibility matrix associated with each product type and product attribute. Indeed, for each product type (product attribute) there is a set of compatible/ incompatible product types (product attributes) that can/cannot be hauled at the same time. Access right to the interfaces ‘Product types’ and ‘Product attributes’ allows the DMs to consult the standards to follow. Modification to the standards can only be made by the central DM (has an editing right on these two interfaces), for instance when a DM demands the addition of a new product attributes.

To allow the system to perform data consolidation, there is also a standard for the origin and destination site that must be indicated by the DM on each of their transport requests. Access right to the interfaces proving information on each site (i.e. interfaces ‘Site – Detail/Mapping/Resource/Calendar) allows the DMs to consult the standard to follow. However, display of the list of sites among the members is subject to confidentiality restrictions. Indeed, there are two kinds of status for a site: shared or private. Information on a shared site is displayed to all members while information on a private site is only displayed to a subset of the members established when a private status is attributed to a site. Private sites are only for particular business considerations (e.g. high competition between two or more members for a supplier recognizable by an origin site) and consequently, most sites on the VTM are expected to be shared.

The status of a site is attributed by the first DM who, by importing its transportation requests in the VTM database, imports a new site (i.e. not present in the VTM database).

In the message received after each import, the DM will receive the notification to perform a few tasks related to its import of a new site. The purpose of these simple tasks is to collect basic information on the new site to enable its management by the central DM. Cooperation to achieve these tasks promptly is expected by the DM, considering that the collected information is required for organization of the transportation request(s) with this new site.

To complete the mandatory tasks, an editing right (limited to the new site information) is temporarily given to the DM on specific interfaces. The first task is to enter information related to the new site and, if any, on-site resource (using interfaces 'Sites – Detail/Resource/Calendar' and 'Resource types – Detail/Calendar') and then, to localize and validate the geographic position of the new site on a map (using interface 'Site - Mapping'). Finally, the DM attributes a shared or private status of the site and if the status is private, to indicate the member(s) (dis)allowed to see the site.

After the DM has completed these tasks, the central DM must approve the new site before the transportation request(s) with this new site can be planned (using interface 'Sites – Approbation'). Approbation involves a diligent review of the site information and the travelling time/distance between the new site and the sites already in VTM database. As aformentionned, travelling time and distance values are obtained from the Map Point web service through an automatic procedure. Modification, if any, can be realized by the central DM on the interface 'Sites – Distance and time matrix'.

Transportation requests in the VTM database can be viewed in both an interactive map and a table format in the interface 'Transportation requests – Map and table'. The choice of the transportation requests displayed can be limited by product type with or without additional product attributes, origin site and/or destination site (using interface 'Transportation requests – Query'. Moreover, on the interface 'Transportation requests – Map and table', an additional filter may be applied on the transportation request displayed as well as how transportation requests are illustrated on the interactive map. For instance, scaled semi-transparent circles at origin (or destination) sites illustrate the total volume or weight in transportation request(s) to be picked up (delivered) on these sites and transportation flow are illustrated by arrows (see Figure 2). All members' data are completely visible to the central DM and administrator roles while each member can only view their transportation requests and, on the map, each private site is only displayed to the member(s) allowed to see it.

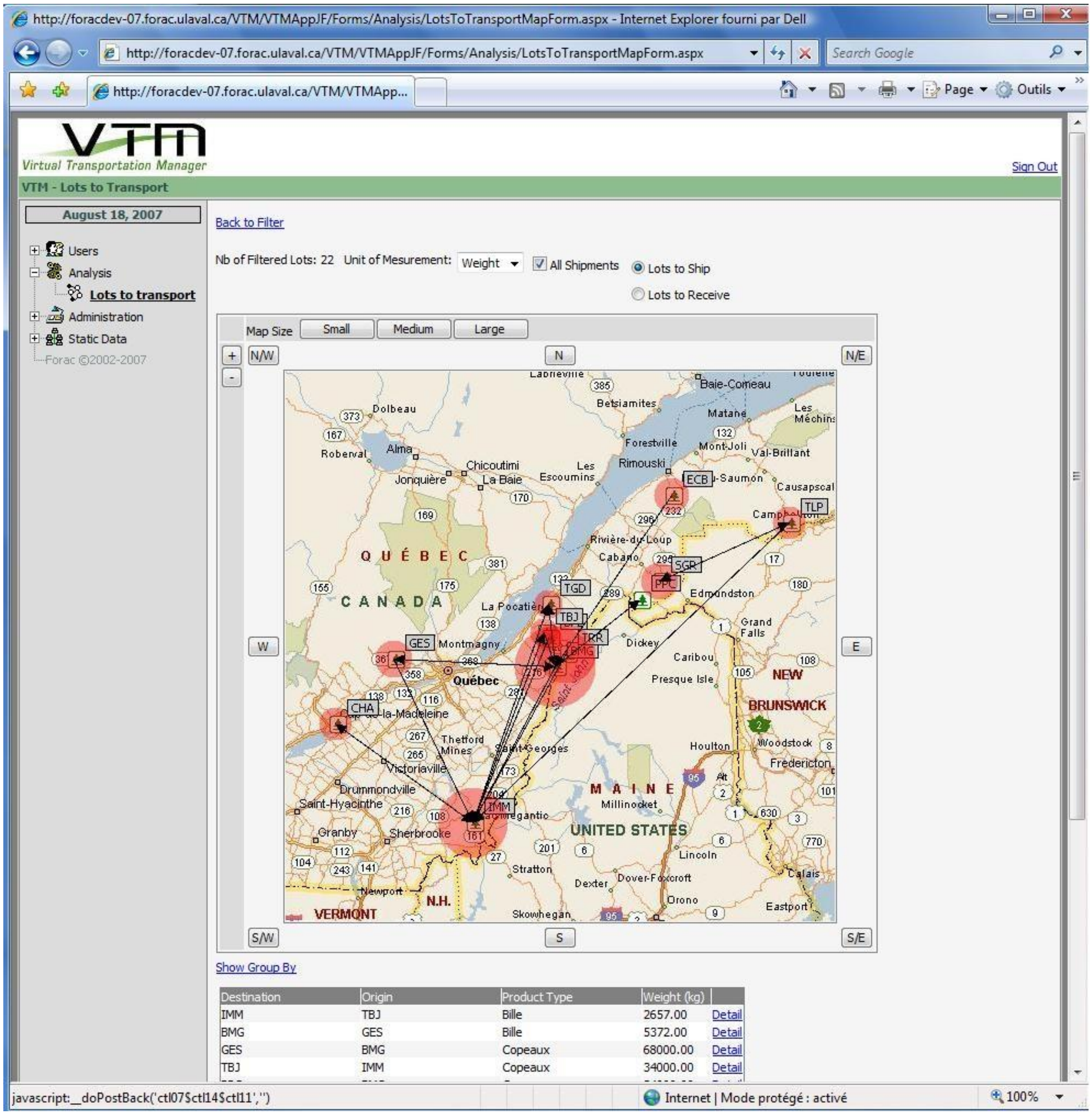

Figure 2 : Screenshot of the interface 'Transportation requests – Map and table' displaying information on queried transportation requests

4.1.4 Truck fleet, driver and depot

Typically, Canadian forest companies do not operate a private truck fleet, but sign one-to-many year(s) contracts and/or maintain not-contracted business (i.e. without official agreement) with assets-based transportation service providers (i.e. independent or associated carriers). Forest truck fleet ownership is highly fragmented in Canada, mostly for timber trucks where approximately 80% of the whole fleet (i.e. about 2530 units) belongs to independent owner-operator truckers (Boutin, 2012). Forest companies usually prefer to do business with a limited number of carriers (that typically sub-contract a number of carriers) but this is not always possible, mainly in vast regions. Therefore, as in the presented case study, DMs have a precise-to-general knowledge of their available truck fleet and thus, there is a significant level of imprecision on the available truck fleet for the VTM. To manage such imprecision, we use an approach based on transportation regions with pseudo-depot instead of the standard representation of the truck fleet in a PDP: i.e., vehicles spread throughout a set of sites (multi-depot) or based in only one site (single depot).

A transportation region is defined by a subset of sites in which given trucking capacities are available. Transportation regions can overlap (i.e. a site can be included in more than one transportation region). Trucking capacity in a transportation region is aggregated by type of truck, each type having a unique set of transportation-relevant characteristics (e.g. volume/weight payload capacity, cost/fuel consumption function, with or without a crane, set of product types allowed to haul). Payload capacity is given in both volume and weight because on some truck types, the first capacity reached depends on the product type(s) hauled. Time windows could be added to the trucking capacity to represent: e.g., the trucks on duty the whole week and the ones on leave during the weekend.

Furthermore, each transportation region is linked with a site designated as its pseudo-depot and localized around the centre of the region. Transportation payment method in the Canadian forest industry is mainly based on a route that starts and finishes at the first pickup site (i.e., a loop). This rule is applied in the route planning module of the VTM with one exception related with our representation of the truck fleet using transportation regions with pseudo-depot. Each route is planned for a given type of truck. This type of truck is available through the aggregated trucking capacity of a transportation region. When no capacity is available in the transportation region(s) where the first pickup site of the route is located, capacity from a neighbouring transportation region should be sought. In this case, the pseudo-depot of the neighbour transportation region becomes the starting and ending site of the route in order to reflect the additional cost incurred by going back and forth to a neighbor transportation region.

This approach based on transportation regions with pseudo-depot also supports a transportation payment method based on a route starting and ending at a carrier's depot (i.e. garage) instead of the first pickup site. In such a case, only the site of the garage must be included in the transportation region and the garage must be defined as the pseudo-depot of the region. Usually, no pickup is realized at a garage. Therefore the first pickup site will be outside the transportation region and this will constrain the planning module to start and end the route at the pseudo-depot, which is the garage.

The definition and up-to-date care by the central DM of the transportation zones (interfaces 'Truck fleet - Region definition'), their pseudo-depot (interfaces 'Truck fleet – Pseudo-depot mapping') and their aggregated trucking capacities (interfaces 'Truck fleet – Capacity/Calendar') are based on regular discussions with the DMs. No regular modification is expected to the existing types of truck in Canada and thus, no editing right has been developed on the interface 'Truck types'. An XML document including average parameters of the most common truck types in Canada is available to the central DM for an import in the VTM database (interface 'Data management-Data import'). The value of the parameters is based on the many studies conducted by FPInnovations in the Canadian forest industry. XML is a text-based format that is human-readable, therefore modification to the types of truck (e.g. addition of a truck type, increase of a cost value) is easily done by manually editing the XML document and importing it back to the VTM database.

Routes must respect different time constraints and a number of them are related to official regulations for drivers as well as general practices in the forest trucking industry. Regulations and general practices that are in place are not homogeneous across Canada and thus, modification to the following ones could be required in other implementations of the VTM.

Regulations on working and driving hours for drivers of commercial carriers embrace many rules and exceptions. Most of them are managed by carriers (i.e. crew scheduling) but three rules may constrain route planning on the VTM: (i) a maximum driving time allowed per working shift; (ii) a maximum working time allowed per working shift (usually two additional hours to prior maximum driving time) and (iii) a minimum daily layover time in which a given number of resting hours must be consecutive. In forest transportation, a typical working shift for a driver involves many sites to visit and, in turn, considerable working time not behind the steering wheel. Therefore, route duration is restricted by the second rule rather than the first one. The minimum daily layover time (third rule) is applied when the second rule is reached on a route. When a route involves more than one working shift, the driver is allowed to go on layover with a truck not fully unloaded (i.e. stay loaded overnight). General practices in the forest trucking industry try to return drivers home every day and, when impossible, to limit the number of nights away from home. Therefore, a maximum number of working shifts on a route is embedded in the data (i.e. XML document) on each type of truck.

4.1.5 Loader and operator

Any available loader on duty at a site is specified by the aforementioned time windows for on-site loader(s).

4.2 Performing routes planning

Procedures conducted in previous steps allow setting in the VTM database the detailed information required to the planning. Before launching the routes planning (using interface ‘Planning-Start’), a number of parameters can be edited by the central DM to control/influence the planning method (using interface ‘Planning-Parameters’). We have already reported the parameters’ fuel cost per litre, productivity values to enable handling time estimation and optional daily time window on the allowed starting time of a route. The other parameters are the duration (in days) and starting date of the planning horizon.

The planning module is a solution method implemented and solved with the modeling environment ILOG OPL Studio 3.7. The method embeds heuristics, a tabu list and three constraint programming (CP) models. The solution methodology is greedy (i.e. only the ‘best’ route is kept at each iteration) and adopts a two-phase approach to generate each route (i.e. perform the routing first and then the scheduling).

The main concept behind the methodology is to use a sequence of origin and destination sites as a support to perform the routing. This sequence is called ‘itinerary’. Relaxing time constraints, a route is built by a heuristic adding transportation request on the itinerary. Then, using a CP model, the route is scheduled to test its feasibility. A number of itineraries per iteration are used to build a set of routes. From this set if routes, the best feasible one (i.e. scoring the higher performance metric) is kept in the solution base and a new iteration is started. But just before the new iteration, the ‘best’ route is duplicated as many times as possible in the solution base. When no feasible route is found in iteration, specific transportation request(s) is (are) sent to a tabu list to prevent looping in the solution methodology.

The methodology starts with a set *S1* of pre-determined itineraries. *S1* is composed of backhaulage tours: i.e., a sequence of sites that combines delivery of two or more loads to reduce the total empty travelling distance. This set is generated by solving one of the backhauling planning method reported in Table 1 on the medium-long-term forecast in wood flow and/or historical wood flow. It is also possible for the central DM to add its own hand-made itineraries. The methodology will use *S1* until all transportation requests are planned or all unplanned requests are in the tabu list. In the former, the tabu list is emptied and at each iteration, two new itineraries to be tested against unplanned request are generated with the resolution of two sequential CP models.

The solution methodology is summarized in seven steps:

1. If all requests are planned, stop. If all unplanned request(s) are in the tabu list, empty tabu list and go to 4). Else, select itineraries from *S1*.

2. For each itinerary, generate testing pairs of ‘itinerary, truck type’ and, on each of them, run a route building heuristic and then a route scheduling model.

3. If a feasible route is found in 2), keep the ‘best’ route, try to duplicate it as many times as possible, and go to 1). Else, add specific request in tabu list and go to 1).

4. If all requests are planned, stop. If all unplanned request(s) are in the tabu list, empty tabu list and go to 7). Else, generate two new itineraries with two sequential CP models.

5. If no itinerary is found in 4), empty tabu list and go to 7). Else, for each itinerary, generate testing pairs of ‘itinerary, truck type’ and, on each of them, run a route building heuristic and then a route scheduling model.

6. If a feasible route is found in 5), keep the ‘best’ route; try to duplicate it as many times as possible, and go to 4). Else, add specific request in tabu list and go to 4).

7. Stop.

In the next subsections, we detailed each step. Steps 2 and 5 as well as steps 3 and 6 are described together because they are identical from a methodological point of view.

4.2.1 Step 1: selection of the itineraries to test

Selection of the itineraries to test is made according to the following heuristic: rank by their weight all transportation requests not in the tabu list, pick the heaviest one (denoted *r’*) and select all itineraries in *S1* that visit both, and in precedence, the origin and destination sites of request *r’*.

4.2.2 Steps 2 and 5: generation of testing pairs, and route building heuristic and scheduling model

For each itinerary to test, generate a testing pair (<itinerary>, <truck type>) for each different type of truck with available capacity in the transportation region(s) of the starting site of the itinerary.

Then, on each testing pair, a route is built according to the following heuristic:

I- on a list, rank by their weight all transportation requests that could be delivered using the itinerary (i.e. must visit both, and with precedence, the origin and destination sites of the request) and the type of truck (e.g. truck type must be allowed to haul the product type of the request, origin and destination site of the request must have on-site loaders for truck types without a crane);

II- on the list, pick the heaviest one (denoted *r'*) and, on each segment of the itinerary from the origin to the destination site of request *r'*:

- compute the available payload capacity;

- if truck type can haul several types of product (i.e. multi-product trailer):

  - validate there is no incompatibility between the product attribute of request *r'* and the product attribute of all requests already on the route segment;

  (if there is incompatibility, remove request *r'* from the list and return to step II)

Else:

  - validate that the type of product for request *r'* is the same (thus, no incompatibility) for all requests already on the route segment;

  (if there is incompatibility, remove request *r'* from the list and return to step II)

iii- if the available payload capacity is over 5% on each segment of the itinerary from the origin to the destination site of request *r'*:

- add request r' to the route with a pickup of the minimum quantity between the lower available payload capacity and the unplanned quantity of request r';

Else:

- to avoid splitting the request into a very small quantity, do not add request r' on that itinerary and go to step IV);

IV- remove request *r'* from the list and return to step II until no more requests are on the list.

In building heuristics, time constraints are relaxed, therefore feasibility of the route is verified by solving a CP model to schedule the route. The objective of the CP model is twofold: minimize the duration of the route and start the route as early as possible on the planning horizon. In the objective function, a multiplier is applied on the route duration to make it three times more important than the starting time of the route. That feasibility verification is fast as only scheduling decisions are made and previous routing decisions are input parameters (i.e., sequence of the sites to visit, pickup quantity of each request on the route, the type of truck in a transportation region that is used).

4.2.3 Steps 3 and 6: selection of the best route, duplication and tabu list

In the presented case study, requests are mainly less-than-truckload (LTL) size. In such a context, a relevant metric to evaluate the performance of a route is the cost paid per quantity delivered per distance traveled. This metric is computed on each feasible route and the 'best' one has the lower metric. The 'best' route is kept in the solution base and the input data for a new iteration are adjusted (e.g., quantity delivered on the 'best' route, trucking capacity use on the 'best' route).

Furthermore, before launching a new iteration, the 'best' route is duplicated as many times as possible. More precisely, to duplicate a route, there must remain an unplanned quantity to pick up in each request on the route and availability in the regional trucking capacity used.

When no feasible route has been found, specific request(s) are added to the tabu list to prevent looping in the solution methodology. In step 3, transportation request denoted *r'* in step 1 is added to the tabu list while in step 6, all transportation requests added on a route in step 5 are added to the tabu list.

4.2.4 Step 4: generate new itineraries with two CP models

At this stage of the methodology, the main part of the transportation requests has been planned using the itineraries in set *S1* (i.e. backhaulage tours). The purpose of this step is to generate new itineraries personalized to the current unplanned requests by including a number of their origin and destination sites. To do so, two sequential CP models are used. The origin sites' precedence over the destination sites are constraints considered in both models.

Before the resolution of the first CP model, the pair (<origin site>, <destination site>) of all unplanned transportation requests not in the tabu list is listed. The objective of the first CP model is to select a number of pairs and assemble them in an itinerary that maximizes the gain in travelling distance. The gain is computed by assuming that in the worst scenario, each of the pairs is traveled twice (i.e. back-and-forth) in an individual route.

If a solution is found, the second CP model is applied. The objective of the second CP model is also to assemble an itinerary that maximizes the gain in travelling distance. However, here the pair (<origin site>, <destination site>) to visit is imposed (i.e. the ones selected by the first CP model) but more than one origin can be visited before visiting a destination. This structure of how the sites can be visited on the itinerary can provide more efficient routes with many LTL-size requests to plan, as in the presented case study.

Moreover, this structure provides the building heuristic (4.2.2) with a higher level of flexibility in the routing of LTL-size requests compared to other planning methods in timber transportation that consider LTL-size requests (Flisberg et al., 2009; Rummukainen et al., 2009). In the former, only one to several pickups followed by one to several full deliveries (i.e. unloading of all loaded requests) is allowed. In the building heuristic, new pickup(s) are allowed after a partial delivery (i.e. truck not completely empty) has been made. Figure 5-B illustrates an example of this flexibility in the routing. The many loading compartments design of timber-trailer allow such routing flexibility while trailers in general LTL freight transport are usually constrained by a ‘First In, Last Out’ constraint (i.e. the sequence of deliveries is the reverse sequence of pickups/loading).

4.2.5 Step 7: Stop

The remaining requests are sent back unplanned to the VTM assuming that, in the worst scenario they will be delivered in a back-and-forth route. In a better scenario, their deliveries can be delayed until new requests are imported on the VTM and they are planned on a route with (some of) these new requests the next time the central DM launches the routes planning module.

4.3 Analyzing and implementing the routes

Once the planning module is done, the central DM achieves an evaluation of each route proposed. Two interfaces support the central DM in its evaluation. First, interface ‘Route-Statistics’, which is composed of two sections: a first section reporting a number of time, costs, travelling distance and payload statistics for the route; and a second section reporting a number of key indicators for the route (e.g., cost per kilometre, percentage of kilometres in load). The second interface 'Route-Segments' illustrates on an interactive map all the segments and visited sites of the routes and, on each visited site, a table provides information on the pickup/delivery to perform (e.g. arrival time on the site, transportation request to load/unload) as well as a short selection of previous statistics but on the segment instead of the whole route (Figure 3). Layout of the interface 'Route-Segments' includes work instructions for the truck driver.

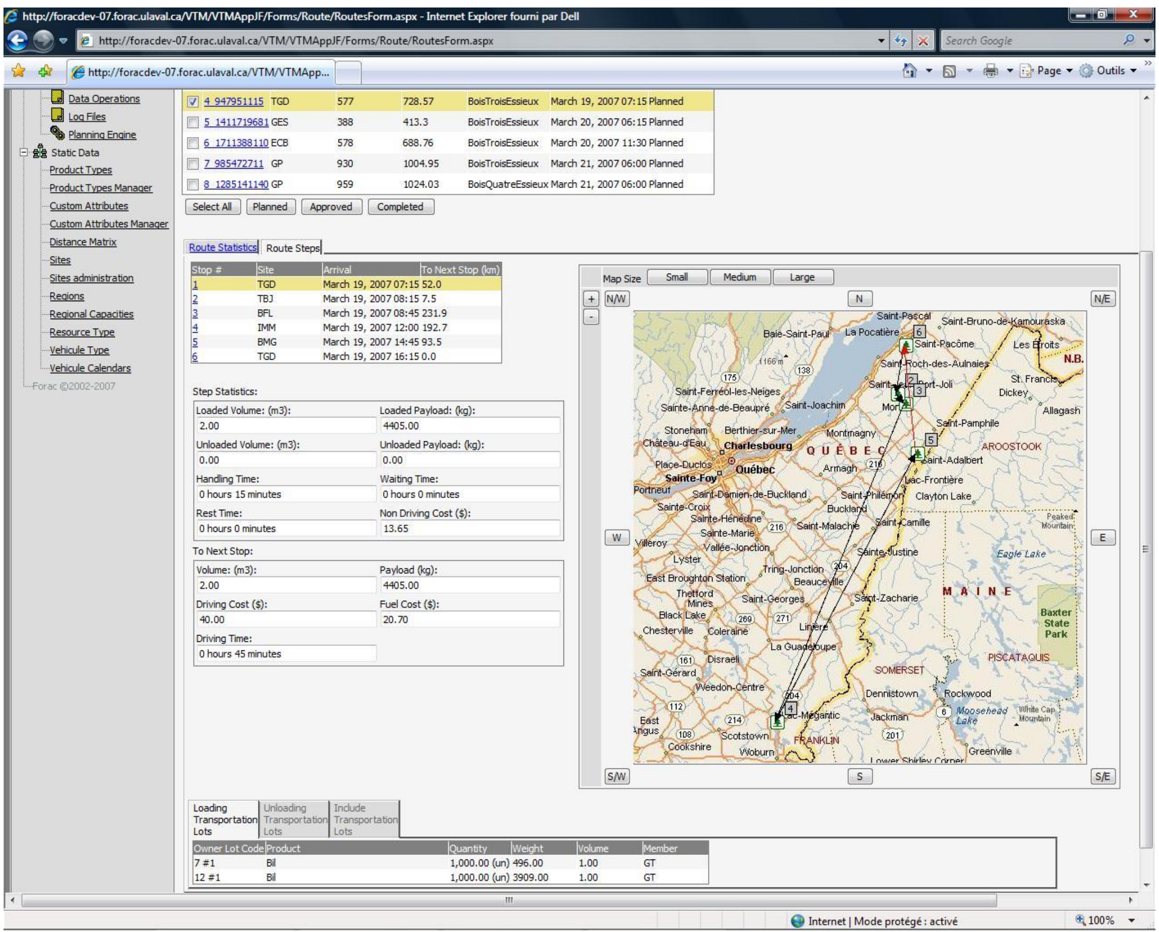

Figure 3 : Screenshot of the interface 'Route –Segments' detailing one route's segment

Each route has a status: 1) planned, 2) approved or 3) completed. The status planned is the default status of a route: i.e., the status attributed to each route in output of the planning module. When the evaluation of a route satisfies the central DM, the status approved is attributed to the route (using interface 'Route – Status management'). A route with a status different than planned allows keeping the route in the VTM database when a new planning is being performed. On the other hand, a route with a status planned is removed from the VTM database and therefore, the transportation requests that were planned on this route could be planned on new routes. The status approved is also used when the central DM has proposed the route to a carrier or if a carrier has accepted the route (reservation). If the carrier refuses the proposed route or later on cancels its reservation, the status approved (as the other status) can be modified with no restriction. Finally, the status completed is attributed to a route that was carried out by a carrier.

Tendering of the routes to carriers could be done in several ways (e.g. auction, area-based assignation). The same apply to the control of their execution. Therefore, processes specific to members of the VTM are expected to be developed and integrated to the VTM. In the presented case study, a number of routes were analyzed with the participating company and evaluated as satisfying enough to be executed by their carriers. Therefore, the implementation of the planned route was not considered in the presented case study.

5 Case study

The VTM system was implemented in a case study to simulate its utilization over almost one year of historic transportation data. This section provides a description of the case study and then the results of the simulation. A discussion about the actual outcome of the case study and the issues faced in further initiatives to transfer the system to the Canadian forest industry complete the section.

5.1 Description of the case study

The case study involves a wood supplier specialized in high-value logs, Groupe Transforêt (GT). This company buys logs from thousands of occasional-to-regular suppliers, classifies them, and finally, resells them in a network of around 20 customer-mills. Its business activities take place in eastern Ontario, southern Quebec and northern New Brunswick in Canada. This wide territory is separated into regions, each being the responsibility of one coordinator in charge of purchasing the logs and organizing their transportation. Figure 4 illustrates the coordinators' regions and business network (i.e. intermediate sites, supplier-mills and customer-mills) of the company.

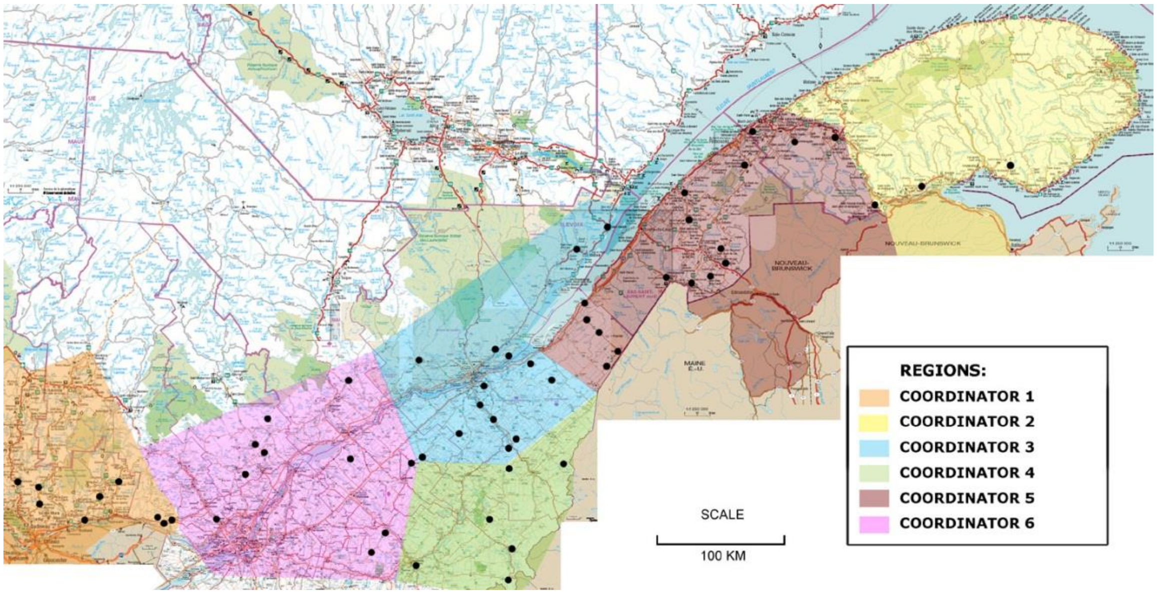

Figure 4 : Coordinators' regions and business network of Groupe Transforêt

GT signs supply agreements with customer-mills based on log 'species and grades' pairs. When a coordinator purchases a log, these supply agreements require the measuring and classification of the log according to a specific 'species-grade' pair. All regional coordinators are licenced wood scaler members of a professional association. Sixteen species are purchased, all hardwood species except three. For one species, up to nine grades are possible among many lengths and diameter classes. For example, for yellow birch, there exist nine possible grades in nine lengths and eight classes of diameter. Purchase and resale prices are different between the species (or a group of species) and also between the grades of one species. For example, the slicing grade of yellow birch can reach up to three times the price of its low veneer grade, five times the price of its medium saw grade and 10 times the price of its poor saw grade. All supply agreements can be roughly divided into two categories:

- supply agreement on the higher value species-grades which are signed with only one or two customer-mills in the whole business network of GT. Logs belonging to this category are thus almost always delivered outside the region of the coordinator who purchases it. This leads to high one-way delivery distances (i.e. can be up to 700 km) compared to the 140-150 km average one-way delivery in Canada (Michaelsen, 2012).

- supply agreements on all other values species-grades which are signed with several customer-mills under the general rule of one species-grade customer-mill inside each or two coordinator regions. Thus, the one-way delivery distances are much lower than in the previous agreements (usually 50 km up to 250 km).

The supply agreements guide the coordinators in the allocation to a customer-mill of each purchase log. A specific color of plastic log tag - including a unique barcode and identification number per tag - is associated to each major customer-mill of GT. Code-based identification information in spray paint is used for the other customer-mills. Such visual information on each log is useful to the truck drivers (e.g., pickup/delivery of the right 'color' of logs) and customer-mills (e.g., perform random quality control on purchased logs). When at purchasing time the coordinator hammers the colored plastic tag (or spray-paints the identification code) on a log, the allocation decision is made and cannot be changed.

Each coordinator uses a hand-held computer to register all purchased logs directly in the field, print an invoice and give a copy to the supplier. A company's web-based system is used to transfer purchasing information from each coordinator to the finance department. Typically, coordinators perform the transfer on a daily basis to allow a very fast payment to the suppliers (i.e. a few business days). In the system, the finance department has a complete view of all purchased volume but each coordinator views only his/her own purchased volume. The information is shown in a query-table without any map support.

Coordinators purchase logs from among a network of thousands of wood producers and dozens of supplier-mills. Volume purchased from a wood producer can represent as few as a dozen logs, while volume purchased at supplier-mills are larger, sometimes over a full truckload size. Coordinators organize their transportation using a hub and spoke network where intermediate site(s) between the origins (supplier sites) and destinations (customer-mills) sites receive the logs, sort them, consolidate them and ship them to the customer-mills. Therefore, most logs are carried twice (i.e. upstream to an intermediate site and downstream to an intermediate site). In some situations (e.g. when logs are purchased at a supplier-mill where an intermediate site is located), upstream transport is avoided. Potential time in inventory at an intermediate site is limited by different factors (e.g. wood deterioration with hot weather, customer demand to satisfy, internal cash flow). Despite this effort for consolidation, most transportation requests are less-than-truckload size. Therefore, coordinators will typically plan a route starting at an intermediate site (with many pickups of transportation request) and then deliver transportation requests to more than one customer-mill (see the route of coordinator 2 or 5 in forthcoming Figure 5-A).

Each coordinator is responsible for organizing the transportation of the logs he/she purchased. To do so, in almost all regions coordinators can use five different types of truck with 13.5, 31.5, 34.5, 37.5 and 41 t capacities on average. The two smaller truck types are equipped with a crane. GT has no exclusivity agreement with any carrier but each coordinator has preferred carriers with regular business. Typical carriers are small companies with one to three trucks. In accordance with current practice with these carriers, they are on leave during the weekend (i.e. Monday-to-Friday working time windows) and drivers can be away from home two nights maximum (except for 13.5 t capacity trucks restricted to one working shift). Also, night shifts for a driver are uncommon and thus a route cannot start during the evening-night. The transportation regions were equivalent to the coordinator's regions with a pseudo-depot located around the centre of the region and the aggregated trucking capacity was estimated with GT.

Overall profitability of GT can be roughly summarized by the resale price of a log minus its purchase price and the operation costs to deliver the log to the customer-mill. Transportation costs account for a significant proportion of these operation costs. In current governing mode, transportation is organized regionally with no or rare collaboration between the coordinators while a large proportion of the purchased logs is delivered outside their purchasing region. Collaboration between the coordinators would lead to increased truck routing efficiency which, in turn, reduces transportation costs and increases overall profitability of GT. Figure 5 illustrates an example of the collaboration opportunity 'common route' in the case study. Collaboration between coordinators 2, 4 and 5 modifies three individual routes (Figure 5-A) in one common route (Figure 5-B) that results in shorter travelling distance to deliver the same volume.

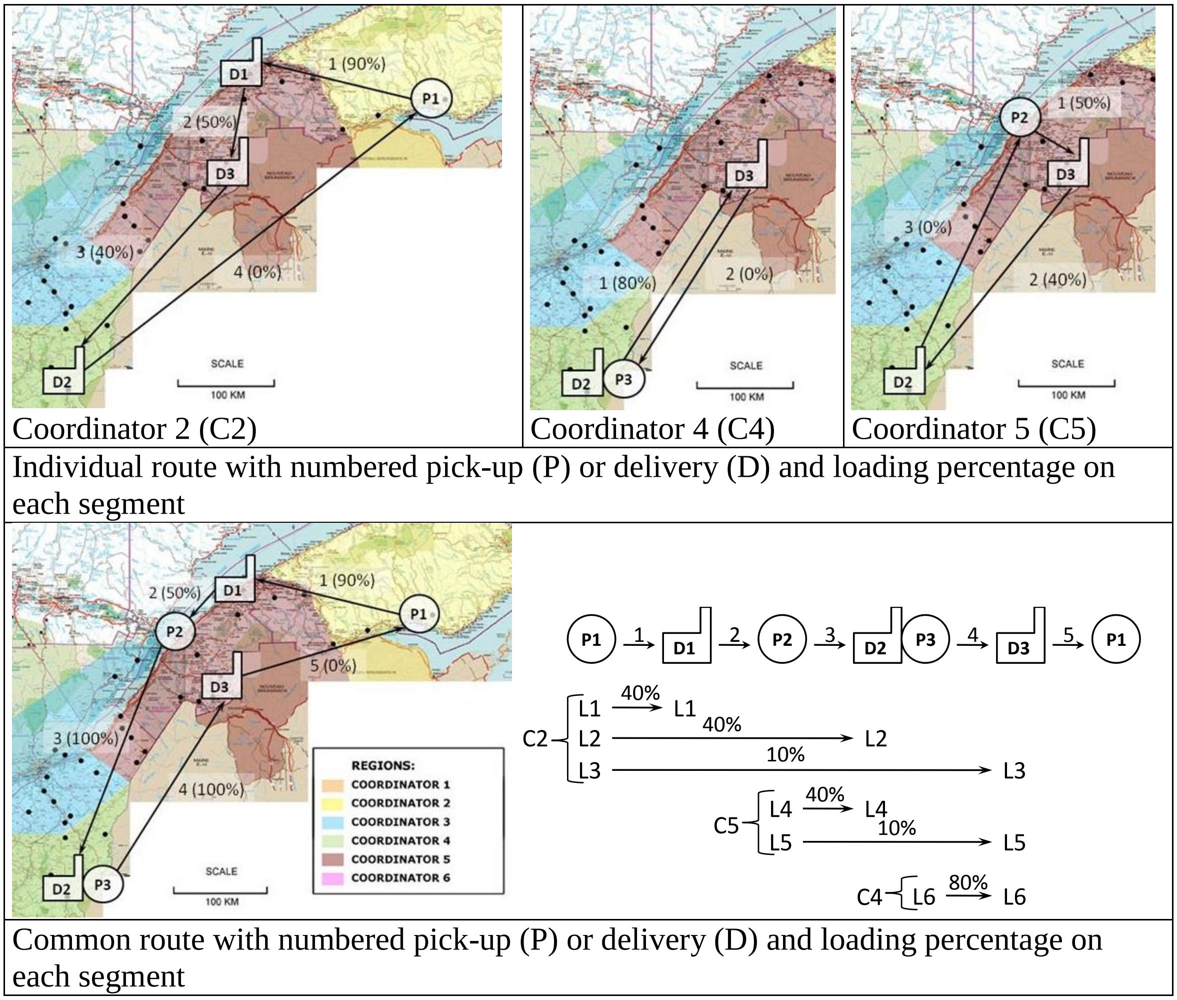

Figure 5 : Individual (A) and common (B) route.

5.2 Numerical results

To assess the potential savings of the collaboration opportunity 'common route', the VTM system was implemented at GT and its utilization was simulated during 10 months of historical transportation data (from July 2006 to April 2007). The VTM system was responsible for organizing the transportation activities downstream the intermediate site while transportation organization upstream the intermediate sites remained in the hands of the coordinators. To handle the VTM system, new employee will be hired by GT. This new way to organize transportation was the one planned by the company in case of system deployment. Among the different analyses conducted on the historical transportation data of GT, one of the findings was the over-average weighted transportation cost (i.e. transportation rate paid by delivered volume and traveled distance) of some coordinators (Charrouf, 2009). Poor transportation planning skill was one of the main reasons identified. This new organization avoids a large part of this concern by focusing the job of the coordinators on the purchase of logs rather than on their transportation planning.

In the literature on freight transportation, several case studies exist where companies obtain savings with collaboration in road transport planning (le Blanc et al. 2007; Cruijssen et al. 2007b; Ergun et al. 2007; Özener and Ergun 2008; Krajewska et al. 2007; Clifton et al. 2008; Audy et al. 2011a). In these case studies, the potential savings (additional profit) of the collaboration are defined as the difference between the cost (profit) of the collaborative transportation plan (i.e. transportation planning of all companies together) compared to the sum of the cost (profit) of each individual transportation plan (i.e. transportation planning of each company alone). This is also the approach used in some case studies in forest transportation in Table 1 (e.g. Forsberg et al., 2005; Frisk et al., 2010). It was impossible to retrace with confidence the routes achieved during the simulation period. Therefore, as in the aforementioned case studies, we defined the potential savings as the difference between the cost of the collaborative routing plan with the volume of all coordinators compared to the sum of the cost of the individual routing plan of the volume of each coordinator.

Logs are stored individually in the inventory system of GT because a number of operations (e.g. purchasing, selling) are performed at this level. However, with thousands of logs to deliver, a procedure to consolidate logs in transportation requests was required for transportation planning. Consolidation was done with the following procedure: logs located at the same origin and that should be deliveries to the same destination are grouped together in the same transportation request. For the volume and estimated weigh (a volume to weight conversion factor by species is used) associated to the transportation request, these parameters on each log are summed up. For the time window associated to the transportation request, the more restrictive one are selected: latest pickup time and earlier delivery time among the grouped logs.

We generate the set *S1* by running the aforementioned DSS MaxTour on aggregated wood flow of the transportation requests in the testing period. Description of the planning method in MaxTour is found in Gingras et al. (2007). Backhaulage tours found with MaxTour can only provide an itinerary including a sequence of pairs of origin and destination sites. As discussed in 4.2.3, in a context involving many LTL-size requests, an itinerary with one to several origin(s) followed by one to several destination(s) can provide a more efficient route. Therefore, on each backhaulage tour obtained from MaxTour, a procedure was applied to allow the addition of new site(s) that imply a minimal detour between two consecutive sites visited on the backhaulage tour.

Considering the limited number of transportation requests to deliver, planning was performed every two weeks during the simulation period. With carriers on leave during the weekend, a Monday to Friday planning horizon was set. At each instance, the VTM provided seven routing plans (i.e., one collaborative plan and six individual plans for each of the six coordinators). A number of routing plans were analyzed with GT and evaluated as satisfying enough to be accepted by their carriers. However, one minor issue was found on a limited number of routes; it involved over three pickup stops before a delivery stop. Drivers typically prefer routes with a small number of sites to visit. In other words, they prefer driving rather than visiting sites for loading. GT points out that payment of compensation for each additional pickup stop will be required. The impact of this additional cost on the whole transportation cost is insignificant and was thus not considered in the simulation.

Harvesting operations and, in turn, purchasing and transportation activities, are subject to seasonality where the business activities of GT take place. A question that arose was to see if this seasonality has an impact on the results. Therefore, three periods have been identified by GT. Including 5 (7) instances and an average of 17 (20) transportation requests to deliver, period 1 (period 2) occurs during the higher (lower) level of purchasing and transportation activities at GT. Period 3 is the buffer and includes 9 instances and an average of 20 transportation requests to deliver.

Table 3 presents average results (with the standard deviation) per period. For each period, the average results (with the standard deviation) reported are from the solutions (i.e. seven routing plans) obtained in each instance included in the period. The illustrated results are the average solution time and average percentage of reduction in cost, fuel consumption and travelling distance.

Table 3 : Results from the case study

Period	**Solution time (second)**	**Reduction**		
		Cost ($)	**Fuel (L)**	**Distance (km)**
1	543.6 ± 233.5	9.8% ± 4.7%	7.1% ± 3.5%	13.0% ± 5.6%
2	647.3 ± 234.0	7.3% ± 3.8%	4.3% ± 4.6%	11.1% ± 4.6%
3	620.4 ± 149.2	10.5% ± 4.2%	8.3% ± 3.1%	12.1% ± 4.3%

Average cost-saving opportunities in the range of 7.3-10.5% exist in the collaboration of the six coordinators. Seasonality has a mitigating effect on the results. At least, we can observe that the period with the lower level of business activity in general shows a few percentage points less in cost reduction.

6 Outcomes and discussion

Since the start of the system development and its utilization simulation at GT, the hardwood processing industry has entered a major crisis in the province of Quebec. The production of hardwood lumber fell by 40% between 2004 and 2008 (MRNF, 2009). A large number of hardwood industries shut down temporarily or permanently, including wood customers of GT. Therefore, in less than two years, GT lost a major part of its business volume built up over nearly a decade. The annual transportation cost dropped to under 1 million Canadian dollars when the decision to move forward with the deployment of the system could be made. With this low level of transportation expense, this meant for GT that the expected annual savings with the system use was nearly equal to the estimated system operation fees (e.g., salary of an employee dedicated to the system, plus IT fee to host the system). Consequently, despite the expected benefits of the VTM, the system deployment decision was postponed until better business conditions would prevail. Another reason for avoiding important changes to the key process of transportation was to maintain GT staff priority on keeping the company in operation. Less than a year later, faced with a continuing negative business perspective, GT first suspended its operation temporarily and then, permanently.

Different benefits from DSS in timber transportation are reported in the literature, including potential/real cost-savings of 0.8-35%. Despite such results, the adoption of DSS by forest companies worldwide has been limited up to now, with one notable exception (i.e., mostly in Chile with aforementioned DSSs ASICAM and ForesTruck). Different issues relevant to their adoption are reported by Audy et al. (2011c), Kokenge (2011) and Rönnqvist (2012). For instance there are problems associated with planning based on inaccurate/erroneous information, unreliable communication, myopic planning, complexity of the set-up parameters that influence the planning method, resistance to sharing of sensitive information, lack of trust between the transport stakeholders, opportunistic behaviour, software non-interoperability, and paying for the DSS and sharing the savings. Further initiatives to transfer the developed DSS to the Canadian forest industry also face similar issues.

Typically, Canadian forest companies outsource their timber truck routing decisions to assets-based transportation service providers (i.e. independent or associated carriers). Implementing the VTM among a set of forest companies modifies current transportation organizations. The central DM plays the role of a logistics service provider (LSP) that realizes, on behalf of the forest companies, the collaborative routing decisions that are then executed by their transportation service providers. Although widely common in several other industries, to the best of the authors' knowledge, LSPs are fairly rare in forestry. One example of LSP in forestry is Asset Forestry Logistics that provides a transportation planning and execution control service for several forestry companies in New Zealand (Ludbrook, 2011). Introducing an LSP represents a major change to the traditional business model of the Canadian forest industry which, as in many countries, has a culture usually known to be conservative. Implementation of the VTM by other actors already involved in forest transportation may represent a more suitable alternative for the Canadian industry. Audy et al. (2012a) identify four alternatives with examples in the international forest industry. Moreover, there are also a number of practical aspects to be addressed in the implementation of transportation collaboration: see e.g. discussion by

Frisk et al. (2006) and Audy et al. (2012a) for a case study involving eight forest companies and the literature review on collaboration in logistics and transportation by Cruijssen et al. (2007b).

Results of recent research projects aiming the VTM simulation among five forest companies tend to suggest that Canadian forest companies are reluctant to engage in inter-firm collaboration in transportation. Indeed, the project obtains mixed results after the low and hesitant participation of most of them (Marier, 2012). However, all participating forest companies show great interest in improving the planning of their transportation activities through the use of a DSS embedding an advanced planning method. This interest also exists in another on-going project to simulate VTM utilization in a wood procurement organization (see Dorval et al., 2012) and, for transportation-oriented DSSs in general, in a large number of Canadian forest companies. For instance, during recent years, a number of analyses with the aforementioned DSS MaxTour have been conducted on historical transportation data of Canadian forest companies and, in the six most exhaustive cases, potential cost savings (travelling time reduction) between 4-7% (5-9%) have been identified (Lepage, 2012).

Despite the potential cost savings revealed through historical data analysis, the adoption by the Canadian forest industry of truck routing DSSs, such as the VTM, has not been successful up to now. As discussed by Andersson et al. (2008) for the Swedish forest industry, one complex aspect when developing a DSS for timber truck routing is the need to obtain the detailed information required in input to the planning problem. Typically in Canadian forest companies, such detailed information is diffused among several databases held by different transportation actors and databases have variable levels of accuracy and unstandardized formats (e.g. different units of measure). In comparison, part of the required information is already in centralized databases in some countries: e.g., the Forestry National Road Database in Sweden (Andersson et al., 2008). Moreover, typically in Canadian forest companies, part of the required information is tacit knowledge: i.e., not recorded in any database and only available through discussion with DMs. Therefore, considerable effort must be dedicated to gathering this detailed information and removing error in the data. Furthermore, additional effort will be required to maintain the detailed information up-to-date while transportation is taking place.

Another issue faced in the initiatives to transfer the developed DSS into the Canadian forest industry was the specialization of the developed planning method to the transportation problem encountered in the case study. Typical transportation problems in the Canadian forest industry involve large volumes composed of dozens of full-truckloads instead of small volumes of less-than-truckload. A joint project between FORAC Research Consortium at Université Laval and FPInnovations, is ongoing to develop a more generic planning method and preliminary results on real instances from the Canadian forest industry were obtained (Marier, 2012).

7 Conclusion

In this paper, we presented a DSS supporting inter-firm collaboration in forest transportation. Collaboration occurs through a centralized organization of the routes to deliver transportation requests specified by DMs. The main components of the system are described and are: i) the transportation data, in formal or tacit knowledge, from the DMs; ii) the core components of the system made up of user interfaces, a database and a web service for automatic data import; and iii) the support components connected to the VTM that include a road network and mapping web service, an intermediate database and a route planning module. Users of the system belong to one of the three roles (i.e. central DM, member and administrator), and access/editing rights to the user interfaces are accorded to them.

How the system enables the organization of transportation collaboration is detailed in three steps, in which the forest truck routing problem addressed and the planning method developed are highlighted. By capturing a number of collaboration opportunities for ‘common routes’, the system allows transportation efficiency enhancements and, in turn, benefits for the collaborating DMs. An industrial case study is presented and simulation over almost one year of the system usage results in potential cost-savings of 7.3-10.5%. Details about the actual outcome of the case study and further initiatives to transfer the system to the Canadian forest industry complete the discussion.

There are many research directions that can be pursued in the future on DSS in forest transportation in Canada and other forested countries such as such as Chile, Finland, New Zealand, Sweden and US. We mention a number of them in addition to the ones raised in the discussion (Section 6). One research direction concerns truck waiting time (i.e. queuing), mainly at the destination sites. Reserved short-time slot for pickup/delivery or enhanced coordination between the truck routing and the scheduling of on-site resources are possibilities to study for queuing time reduction. To better tackle stochastic events intrinsic to forest transportation (e.g. mill reception closure, equipment breakage), insights from the "(…) increasing body of research on dynamic VRPs" (Berbeglia et al., 2010; Pillac et al., 2011) must be investigated. Another research direction concerns revision of the transportation payment methods currently used by the industry that mostly do not foster organization of transportation efficiencies among the transportation actors. Recently, a method has been proposed by Frisk et al. (2010) but other payment methods providing all transportation actors with a fair and sustainable financial incentive to realize transportation efficiencies could be developed.

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