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***Abstract* — In this paper, we propose a framework to describe collaboration in transportation. Then, we discuss the strategic, tactical, operational and real-time transportation planning decisions and raise issues about implementing collaborative decision processes. Also, we provide a literature review of transport decision-support systems that use collaborative planning in the wood fiber flow chain in forestry. Finally, we propose a typology of different business models associated with collaboration in transport**

***Keywords* — Collaboration, transportation, decision-support system, business model, forest product industry**

I. INTRODUCTION

Transportation planning is an important part of the wood fibre flow chain in forestry. Large volumes and relatively long transport distances together with increasing fuel prices and environmental concerns make it more and more urgent to improve transportation planning.

There are often several forest companies operating in the same region. Harvest areas supply the mills that by processing round wood will produce end-products (e.g. lumber, veneer) but also co-products (e.g. chips, sawdust) which will be used to supply other mills. Co-ordination between two or more companies is however rare, even if supply, demand and companies are geographically evenly dispersed in the region. In Figure 1 we illustrate the simplest example of transportation inefficiency due to a low level of interaction between two companies: the total unloaded traveling distance (i.e. broken line) is higher when companies do their truck routing independently (Fig. 1-A) compared to when they are doing them together (Fig. 1-B).

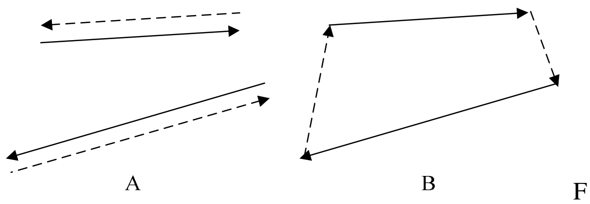

FIGURE 1

IMPROVEMENTS IN UNLOADED DISTANCE (BROKEN LINE) WITH COLLABORATIVE PLANNING

Lately, there has been increased interest in collaborative transportation planning to support the coordination of the wood fibre flow as the potential savings are large. In many of the case studies the collaborative transportation work is compared with the actual transportation work carried out. It is then possible to compute the savings with collaborative transportation planning.

In this paper, we propose a framework to describe collaboration in transportation. Then, we discuss the strategic, tactical, operational and real-time transportation planning decisions and raise issues about implementing collaborative decision processes. Also, we provide a literature review of transport decision-support systems that use collaborative planning in the wood fiber flow chain in forestry. Finally, we propose a typology of different business models associated with collaboration in transport.

II. TRANSPORTATION COLLABORATION FRAMEWORK

There are four main actors involved in transportation collaboration and four master processes. The actors are the customer, the carrier, the pickup/delivery site and the transportation planner. The customer, which in the forest industry, could be a saw mill, a pulp and paper mill or a panel mill, expresses transportation needs. Typically, a transportation need would specify a specific volume of a specific goods to be picked-up at a location (i.e. pick-up site) and delivered to another location (i.e. delivery site), within a specific time window. The carrier provides the transportation services. The carrying can be done by trucks with different capacities, equipped or not with a crane for loading and unloading. It can also be done by train or barge as well as by different combinations of these transportation means. The sites also play a role in the transportation problem since they may impose different constraints to the routing problem. Finally, the transportation planner is responsible for proposing a transportation solution that takes into account transportation needs, carrier capacity and logistics constraints coming from the customer, the carrier and the sites.

To effectively execute the transportation activities, four major processes need to be mastered. They are planning, expediting, carrying and receiving. Note that each actor can be involved in one or many of these processes, which are defined as follows. Planning involves defining the best allocation of transportation needs to carriers and constructing the best routing solution for the carriers. The routes may be composed of one or many pickups and deliveries and need to respect all demand, time window and capacity constraints. The planning process can be defined as (i) intra-organizational, meaning that all actors involved in the planning process belong to the same company; or as (ii) inter-organizational, meaning that actors from different companies are involved in the planning process. The next three processes are associated to execution of the main transportation operations. Expediting refers to the process of making the volume available and ready for pickup. Carrying refers to the transportation of the volume and finally, receiving refers to the reception of a carried volume of products.

III. Collaboration on Transportation Planning Decisions

Collaboration in transportation planning means that a coalition has been defined. This coalition brings together a specific set of actors and involves them in an intra or an inter-organizational planning process. Planning rules have been accepted between the participants of the coalition, permitting a stable collaborating organization where all participants have no incentive to quit the coalition.

In theory, transportation planning provides a great deal of collaboration opportunity. The way the decisions need to be taken will govern the possibility of building the different coalition in time. In some cases, the coalitions may be different for different decisions while in other cases, the coalition needs to remain because of the high interrelation between the decisions to be taken. Collaborative planning on a decision could result in an obligation to future collaborative planning within the same coalition (or a subset of these participants) on shorter term decisions. This "obligation" could come from a common long term agreement and high operational expected returns.

The selection of the participants in the coalition is another fundamental question. In, for instance, a region with many forest companies, if planning is done as though they were a single company, they would obtain the best benefit achievable through collaboration. In practice, there are always some restrictions imposed by one or several participants. These restrictions become additional constraints to be taken into account when planning. By planning with and without these restrictions, it is possible to quantify the financial impact of these business constraints. Some interesting questions are raised such as: *knowing how these constraints impact the benefit of the collaboration, who should be part of the coalition?*

Moreover, the benefit of the collaboration would need to be shared among the participants. How should it be done? [1] suggest using a cost allocation method. They have proposed a series of methods to share the cost that are, partly, based on co-operative game theory. They also illustrated how the different methods can propose different sharing solutions. This raises the question: *will the participants remain in the coalition if one or the other of these methods is chosen?*

The collaborative plan as well as the sharing solution can provide tools to redesign the coalition, showing which participant is providing more benefit to the coalition and which one is gaining more from it. It may happen that only a sub-set of the initial coalition remains at the end. Moreover, the solution may lead a company to divide its participation into a subset of its supply and demand points in order to integrate different coalitions in order to reach the best possible returns.

This creates a new problem for one company: *for each decision, with which coalition collaborates and on which supply/demand points?* As far as we know, this problem as never been studied.

IV. Transportation Planning Decisions

The problem of transportation planning of the wood fibre flow chain in forestry is definitely not a simple one. Planning such transportation activities involves many decisions which are commonly managed according to four perspectives of time horizon: strategic, tactical, operational and online. In Table 1, we reported these decisions. Several of these are discussed in [2] and [3].

TABLE 1
STRATEGIC, TACTICAL, OPERATIONAL AND REAL-TIME TRANSPORTATION DECISIONS

Strategic (>5 years)	- Road building and maintenance - Deployment of train and heavy load truck systems - Fleet capacity and composition management
Tactical (1/2 to 5 years)	- Road upgrade - Equipment - Train system scheduling
Operational (1 to 180 days)	- Supply allocation to demand points - Truck back-haulage tours - Truck routing
Real-time (< 1 day)	- Truck dispatching

Strategic decisions concern the construction and the maintenance of transportation infrastructures and the transportation fleet management. Decisions on the infrastructures include the layout of the forest road network to access the harvests areas, the location and capacity of storage terminals required for transshipment, the deployment of train and heavy load truck[1] systems as well as potential improvements on the existing forest road network to deploy heavy load truck system. Transportation fleet management deals with the capacity and the composition (i.e., number and type of locomotive, wagon, truck and barge) of the fleet (e.g. private, dedicated, etc) to

[1] Heavy load trucks (HLT) are specialized logging trucks hauling loads of two to more than three times greater than conventional logging trucks but which are limited to travel only on the forest road network. HLT system consists of using them to carry round wood from the harvest areas to a terminal (or directly to the mill if it is reachable by the forest road network) in order to complete the delivery by train or conventional truck.

meet the transportation requirement forecasts. This exercise is realized jointly with the current and potential train and carrier service providers (including the company's private fleet if any) and it spreads out over several years taking into account the economic lifespan of the various equipments in the fleet.

Tactical decisions concern forest road path standard upgrade (e.g., speed increase, accessibility during thawing period or during heavy rains) and equipment. Also, decisions on the scheduling of train systems previously deployed that consist in adjusting the capacity of the train routes (i.e. number of wagons in the train route and the train route frequency) in each train system.

Strategic and tactical transportation related decisions are often planned simultaneously with other decisions related to wood fibre procurement (i.e. forest management and harvest operations) and mill production. Consequently, companies are generally reluctant to engage in collaborative planning on these levels even if collaborative planning can be achieved and provide high expected returns. This is particularly true when the coalition is built to share major infrastructures. Typically in such cases, the infrastructure costs are split among participants and the operating and maintenance costs are charged in terms of usage. When the coalition is stable the logic remains, however, as some participants pull out of the coalition the operating and maintenance costs of the infrastructure can become too high for the remaining participants. The risk associated with strategic level collaboration becomes higher. The "strategic" coalition therefore needs to provide higher potential returns and the participants must be bounded by a high level of trust.

Operational decisions are taken for a short term horizon and deal with specific resources and needs. The first operational decision concerns the allocation of supply points to demand points that consists in the establishment of i) the catchment areas for each mill with a demand in round wood and ii) the suppliers' mills for each mill with a demand in fibre bulk. The decision defines the volume of each catchment area and supplier mills allocated to satisfy mill demand. Another operational decision concerns the design of potential truck back-haulages tours. A back-haulage tour delivers several loads instead of only one in order to reduce empty traveling distance and thus transport cost. The simplest case of a back-haulage tour is illustrated in Figure 1: after carrying a load between a supply and a demand point, the truck doesn't return empty to the supply point as usual but carries another load from/around the demand point to/around the first supply points. Finally, another operational decision deals with truck routing where the whole route of each truck is scheduled.

Real-time decision concerns the scheduling of the route of a specific truck, but instead of making up the schedule in advance (e.g. the day before), the schedule is created in real time with the present situation instead of the predicted situation.

The operational and online transportation activities provide an interesting context for collaboration. In contrast with the strategic and tactical decisions, the planning of operational and online transportation is less integrated with procurement and production as they are often planned in sequence after procurement and production decisions are made. Price and service level are the key performance indicators associated with the operational decision level.

Transportation activities represent almost 25% of total costs in the wood products industry. In Sweden and Canada, transportation activities represent one third of the total cost of raw material, round wood, for the industry. Furthermore, they are not a core activity for the wood processing mills which reduces the level of risk associated with the collaboration. As explained by [4], these conditions: high return, low risk, non core activity, provide a good environment for building a strong coalition. The next sections present industrial applications supporting collaborative planning.

V. Industrial Applications

In the next section, we discuss five industrial applications that were developed by university researchers to support collaborative planning in wood fibre transportation. These applications address one or several of the operational decisions (i.e. supply allocation to demand points, truck back-haulage tours and truck routing). These applications can be used in a context without collaboration by a single company but we concentrate on their collaborative potential.

Collaborative planning in transportation raises the need to manage a large set of data coming from different actors involved in the different processes. Information and decision support technologies are therefore necessary to support the collaboration. This section mainly deals with the technical problems and solution approaches while the following section will discuss potential business models that can support such collaborative planning.

A. *FlowOpt*

FlowOpt [3] is an application developed to support strategic and tactical transportation planning for the round wood supply of mills. Taking into account this context of use, the supply allocation decision has been adapted to handle wood fibre exchange between participants. Thus, all the supply and demands points of each participant in the coalition are managed as a common resource. Wood fibre exchange appears when some volume belonging to the supply points of a participant is allocated to satisfy the demand points of another participant.

The exchanges are generally viewed over a period of a year and require a high level of trust between the participants. They aim to reduce the transportation costs of the participants by bringing the supply points closer to the demand points but also in identifying back-haulage tours between the participants when possible. The overall solution approach of FlowOpt is based on column generation. However, the allocation with exchange possibilities is planned with an adaptation of the LP multicommodity transportation problem in order to keep track of the participant "owner" of the supply, and handle exchange restrictions.

Recently, research in Sweden and in Canada reported study on potential logs and chips exchanges between forest companies, see e.g. [5]. In a case study with two forest companies, barter pulp logs on FlowOpt, [3] report a potential cost reduction estimated at about five percent even if some companies impose restrictions on the collaboration such as limiting the total volume in bartering and allowing no barter for deliveries to specific destinations.

In Figure 2, the potential benefits of wood fibre bartering between two companies is illustrated [3]. Four mills (two mills per company) and a set of supply points are considered in this case. In the left part of the illustration, each company operates by itself. The catchment areas are relatively large as compared to the right part where the companies use all supply points as a common resource. The absence of cross-over flows in the right part indicates a better allocation of the supply between the two companies. Finally, let us mention that to obtain an understandable figure for the benefit, no back-haulage tours were allowed but higher benefit could be achievable when back-haulage tours are allowed.

FIGURE 2
ILLUSTRATION OF WOOD BARTERING: IN THE LEFT PART EACH COMPANY OPERATES BY ITSELF AND IN THE RIGHT PART BOTH COMPANIES USE ALL SUPPLY POINTS AS A COMMON RESOURCE.

B. *ÅkarWeb*

Åkar Web [6] is an application developed to support collaboration in the planning of logging truck routing decisions by transportation planner(s). The application proposes a set of back-haulage tours and the tours which will be used as support for future truck routing. When back-haulage tours are designed, no wood fibre exchanges are allowed. However, all the exclusive allocations of each participant are coordinated together since the set of back-hauling tours must minimize the total transportation cost.

Since 2001, a large forest company has been using the application with its associated carriers and also with a second forest company, but not directly. Indeed, the second forest company pre-assigns its transportation needs to its carrier. At this moment, the allocation decision has already been made and definitive. Some of these carriers send their transportation needs assignation to the large company who uses the application to realize the allocation of its own supply and demand points by considering back-haulage tours with the pre-allocated transportation needs. At this point, further truck routing planning can be managed in a centralized or a decentralized way but the latter is in use. The large forest company assigns its supply points to its associated carriers with a list of potential back-haulage tours for each and also informs the second forest company carriers of the potential back-haulage tours for each of their transportation needs assignation. This means that back-haulage tours may appear within the carrier assignations or between several including carriers not associated with the same forest company. Given the potential back-haulage tours it is then up to the transportation planners of each carrier to use them to collaborate. Reduction of 15 percent of the empty trucking distance and 6 to 7 percent of the transportation cost was identified with the use of the application.

C. *MaxTour*

The MaxTour [7] application deals with the design of truck back-haulage tours. Thus, the volume allocation decision is already made and must be respected. In contrast with the two previously applications, MaxTour allows the planning of a back-haulage tour including round wood and bulk fibre deliveries instead of just deliveries of one of them. The use of multi-use truck trailers[2] makes it possible.

In a case study using MaxTour with round wood and bulk fibre fixed deliveries between many business units, [7] report an annual potential reduction of 8 percent in empty hauling time and a cost-saving of 1.1 percent only related to back-haulage tours with multi-use truck trailers.

The solution approach is an adaptation and an enhancement of the saving heuristic of [8]. Currently, the application is mainly utilized a posteriori with historic transportation data to evaluate potential saving with back-haulage tours and also to support economic study on the viability to add a specific number of multi-use truck trailers to the truck fleet.

D. *RuttOpt*

RuttOpt is an application developed to schedule a route for each logging truck in a fleet spread throughout a set of depots. Decisions on the supply allocation to demands points are also supported as well as managing driver changeover during the route.

The solution approach is based on a two-phase method. First, the LP multicommodity transportation problem is solved for the supply allocation then subdivision of future route (i.e. a sequence of supply points(s) followed by a demand point) is conducted following heuristic rules. Second, the customized tabu search algorithm of [9] is used to assemble the route subdivisions in order to construct new routes.

E. *Virtual Transportation Manager*

VTM is an application presently in development to handle the scheduling of routes to satisfy a set of transportation

[2] Multi-use trailers, currently utilized in few Canadian forestry operations, give the operational flexibility of hauling either round wood or bulk fibre loads, which contrasts with specialized round wood or bulk fibre trailers.

requests with an estimated fleet of trucks spread throughout many territories instead of known depots. The participants send their transportation requests to the application specifying a volume of a specific wood fibre type to be hauled from an origin to a destination site within a specific time window. Routes are scheduled and then a central transportation manager proposes the routes to carriers.

The solution approach is based on a constraint programming resolution with heuristic rules. Currently, the application is tested for a set of regional log suppliers. Tests on a low and a high activity period show a cost reduction of 4,5 and 7,7 percent respectively.

VI. BUSINESS MODELS FOR COLLABORATION

Developing the information technology and solution methods is a first step toward the collaboration. The next step is to design a business model for the coalition. The model aims to build a coalition in which the equilibrium is maintainable, i.e. all participants have no incentive to quit the coalition.

We can identify six theoretical business models:

- A customer leads the coalition
- A carrier leads the coalition (or a third party logistics provider, 3PL)
- A fourth party logistics provider, 4PL, leads the coalition
- Carriers share the leadership of the coalition
- Customers share the leadership of the coalition
- Carrier(s) and customer(s) share the leadership of the coalition

For each model, the following business perspectives will be discussed:

- Who is responsible for conducting the transportation planning and what objective(s) is it following?
- How is added/removed a participant in/of the coalition?

To support the discussion, let denote:

B^c	the benefit of the coalition *c*
B^c_p	the benefit on the coalition *c* provide by participant *p*
I^c_p	the incentive to remain on the coalition *c* for a participant *p*
$W^c_{p,p'}$	the contribution of participant *p* to the incentive of the participant *p'* on the coalition *c*

To obtain B^c_p and $W^c_{p,p'}$, we must plan a coalition *c* with the participant *p* to obtain B^c and I^c_p, then plan a coalition *c'* without the participant *p* to obtain $B^{c'}$ and $I^{c'}_p$, and, finally, compute:

$$B^c_p = B^c - B^{c'}$$

$$W^c_{p,p'} = I^c_p - I^{c'}_p$$

Also, in the figures, the circle represents a customer, the rhombus the transportation planner and the rectangle a carrier. The broken line represents a transportation needs and the line a route.

A. *A customer leads the coalition*

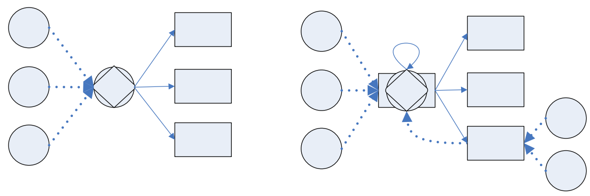

FIGURE 3
BUSINESS MODEL IF A CUSTOMER LEADS THE COALITION: IN THE LEFT PART THE BASIC MODEL AND IN THE RIGHT THE VARIANTS

In the left part of Figure 3, we illustrate the basic business model if a customer leads the coalition. The transportation planner is a customer, TP-customer. It is planning its own transportation needs but also the transportations needs received from other customers. After the planning, the TP-customer allocates the routes to a set of carriers.

The TP-customer objective is the satisfaction of its own transportation needs at the minimum cost.

It is the TP-customer who adds and removes participants in its coalition of customers.

A participant *p* will be added to the coalition *c* if:

$$W^c_{p,p'} > 0 \text{ where } p' \text{ is the TP-customer}$$

A participant *p* will be removed of the coalition *c* if:

$$B^c_p = 0$$

or

$$B^c_p > 0$$

and

$$W^c_{p,p'} = 0 \text{ where } p' \text{ is the TP-Customer}$$

and

$$I^c_{p''} - W^c_{p,p''} > 0 \text{ for each other participant } p'' \text{ in coalition } c$$

In the right part of Figure 3 some variants of the business model are illustrated. The TP-customer can have its private fleet and use external carrier to complete its needs in transportation capacity. Also, TP-customer can indirectly integrate in its planning the transportation needs of other customers through the carrier of these customers. The last variant is the business model of the application ÅkarWeb in the presented case study.

B. *A carrier leads the coalition*

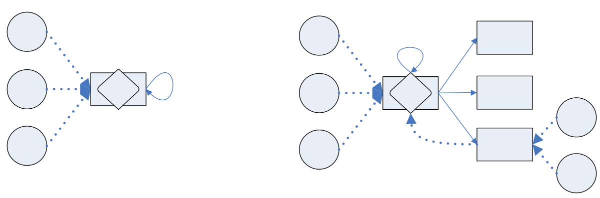

FIGURE 4
BUSINESS MODEL IF A CARRIER LEADS THE COALITION: IN THE LEFT PART THE BASIC MODEL AND IN THE RIGHT THE VARIANTS

In the left part of Figure 4, we illustrate the basic business model if a carrier or a third party logistics provider leads the coalition. The transportation planner is a carrier, TP-carrier, planning the transportation needs of a set of his own customers in using only its transportation capacity.

The TP-carrier objective is the maximisation of its profit by planning its customers' transportation needs using only its transportation capacity.

It is the TP-carrier who adds and removes participants of its coalition of customers. The TP-carrier follows the same rules, but at its advantage, of the TP-customer to add or remove participants.

In the right part of the Figure 4, we illustrate some variants of the business model. In addition to its transport capacity, the TP-carrier can use external carrier to complete its needs in transport capacity. Also, the TP-carrier can indirectly integrate in its planning the transportation needs of other customers through the carrier of these customers.

C. *A fourth party logistics provider leads the coalition*

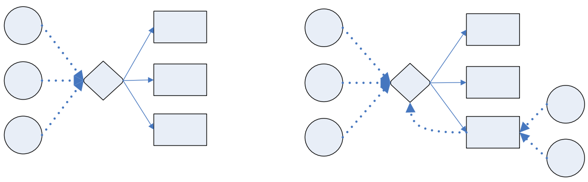

FIGURE 5
BUSINESS MODEL IF A 4PL LEADS THE COALITION: IN THE LEFT PART THE BASIC MODEL AND IN THE RIGHT THE VARIANT

In the left part of Figure 5, we illustrate the basic business model if a fourth party logistics provider leads the coalition. The transportation planner, TP, is neutral in the sense that he isn't a customer or a carrier. It plans the transportation needs of a set of customers under a capacitated set of carriers.

The TP objective is the maximization of its own profit through an optimized match of customers' needs and subcontracted carrying capacity.

It is TP who adds and removes participants in its coalition of customers and carriers. The TP follows the same rules, but at its advantage, of the TP-customer and the TP-carrier to add or remove participants.

In the right part of Figure 5, we illustrate a variant of the business model. The TP can indirectly integrate in its planning the transportation needs of other customers through the carrier of these customers.

D. *Carriers share the leadership of the coalition*

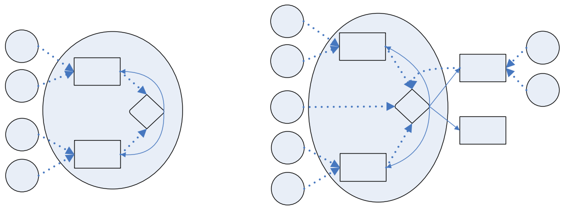

FIGURE 6
BUSINESS MODEL IF CARRIERS SHARE THE LEADERSHIP OF THE COALITION: IN THE LEFT PART THE BASIC MODEL AND IN THE RIGHT THE VARIANTS

In the left part of the Figure 6, we illustrate the basic business model if a set of carriers share the leadership of the coalition. The transportation planner, TP, is named by the carriers' coalition to plan the transportation needs of their respective customers using the transportation capacity of all the carriers. After the planning, the transportation planner allocates the route to the carriers according to their respective transportation capacity.

The TP objective is the minimization of the transportation cost or maximization of the profit of the carriers using their transportation capacities.

Coordinated by the TP, the carriers decide together to add and remove participants in the carriers' coalition.

A participant p will be added to the coalition c if:

$$B_p^c > 0$$

A participant p will be removed from the coalition c if:

$$B_p^c = 0$$

In the right part of Figure 6, we illustrate some variants of the business model. In addition to their own capacity, the coalition can use external carriers to complete their needs in transportation capacity. Also, the TP can integrate in its planning the transportation needs of other customers through the carrier of these customers or directly with the customer.

E. *Customers share the leadership of the coalition*

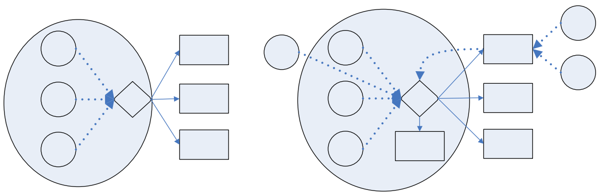

FIGURE 7
BUSINESS MODEL IF CUSTOMERS SHARE THE LEADERSHIP OF THE COALITION: IN THE LEFT PART THE BASIC MODEL AND IN THE RIGHT THE VARIANTS

In the left part of the Figure 7, we illustrate the basic business model if a set of customers share the leadership of the coalition. The transportation planner, TP, is named by the customers' coalition to plan their transportation needs. After the planning, the transportation planner allocates the routes to a set of carriers. This is the business model in the VTM application.

The TP objective is the minimization of the total cost for all the customers.

The building of the coalition can be done in various ways but generally, a customer initiate the coalition by inviting other customers who contribute to its benefit. Coordinated by the TP, the customers decide together to add and remove participants in the customers' coalition by following the same rules of the previous carriers' coalition.

In the right part of the Figure 7, we illustrate some variants of the business model. The customers' coalition can sign contract(s) with carrier(s) to have a dedicated fleet (a carrier could be the private fleet of a customer on the coalition) to use in combination or not with external carrier to complete the needs in transportation capacity. The TP can integrate in its planning the transportation needs of other customers through the carrier of these customers or directly with the customer.

F. Carriers and customers share the leadership of the coalition

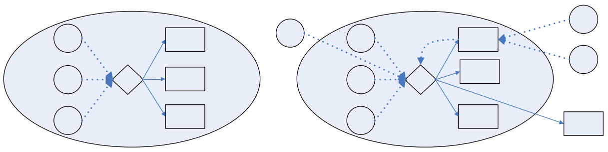

FIGURE 8
BUSINESS MODEL IF CARRIERS AND CUSTOMERS SHARED LEADING COALITION: IN THE LEFT PART THE BASIC MODEL AND IN THE RIGHT THE VARIANTS

In the left part of the Figure 8, we illustrate the basic business model if a set of customers and carriers share the leadership of the coalition. The transportation planner, TP, is named by the customers and the carriers to plan the customers' transportation needs using the carriers' transportation capacity.

The TP objective is the minimization of the transportation costs of the customers using the transportation capacities of the carriers.

Coordinated by the TP, the customers and the carriers decide together to add and remove participants in the coalition by following the same rules of the previous carriers' coalition.

In the right part of the Figure 8, we illustrate some variants of the business model. In addition to the carriers' transportation capacity, the coalition can use external carriers to complete the coalition needs in transportation capacity. Also, the TP can integrate in its planning the transportation needs of other customers through external carrier or directly with the customer.

VII. CONCLUSION

In this paper, we reported some applications which were developed to support collaboration in transportation. We explained their purposes and proposed a series of business models which can permit their implementation in different industrial context.

These contexts are characterized by the composition of the coalition as well as by which actor(s) is assuming the leadership.

Significant cost-savings can be achieved through transportation collaboration. However, the collaboration raises many business challenges and questions. Future work should address those questions and experiment with different cost allocation strategies or benefit sharing strategies in order to provide the means to sustain the different coalitions.

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