INCREASING EFFICIENCY OF FREIGHT CARRIERS THROUGH COLLABORATIVE TRANSPORT PLANNING: CHANCES AND CHALLENGES

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Abstract
Facing the pressure on the transportation market, freight carriers are suggested to exchange customer requests through collaborative transport planning for further increment of their profitability. This paper discusses the chances offered by this kind of horizontal collaboration and proposes challenges to meet its successful utilization.
Keyword: horizontal collaboration, request exchange, profit sharing

1. INTRODUCTION

Freight carriers are confronting increasing pressures to improve profitability, while it is difficult to further reduce operational costs. This problem is even more serious for those who already have almost exhausted their internal potentials by process optimization and by the application of new technologies including modern telecommunication equipments as well as powerful planning software. To further reduce cost and to increase operational efficiency, collaboration is proposed as a promising remedy for small and middle-sized companies. Collaboration partners can be suppliers, customers, or even competitors. Vertical collaboration, such as collaboration between shippers and carriers has been well studied in the last decades. An additional form of collaboration which happens between companies operating at the same level(s) in the market is given by horizontal collaboration. Although this kind of collaboration has attracted great attentions, it has not been thoroughly researched yet. In such a collaboration of freight carriers, which is referred to as a *groupage system* [6], transport planning is not executed by each participant separately but in a collaborative fashion, which is referred as collaborative transport planning (CTP). Such planning will generate extra benefits that cannot be achieved alone. In this paper, we will show how CTP could increase transport efficiency of less-than-truckload (LTL) carriers in detail. The emphasis of this paper is the discussion of the challenges on the research on CTP. We first analyze some basic issues of CTP and the difficulties as well as limitations of its application. Some general guidelines are then drawn for the design of a CTP model, while the challenges on the design of CTP models are discussed later.

This paper is organized as follows. A brief literature review of related works is presented in Section 2. In Section 3 the benefits of CTP are demonstrated. The challenges are then discussed in Section 4. Conclusions are drawn in Section 5.

2. LITERATURE REVIEW

Small and mid-size freight carriers are suggested to use CTP for efficiency increment because of its potential cost-savings that cannot be achieved individually. The achievable cost reduction is commonly estimated to be 5% to 15% [4][8][12]. In [4][8], a decrement of the number of utilized vehicles of 7.3 and 10 percent is also reported. Cruijssen et al. present the results of their large-scale survey on the potential benefits of and impediments for horizontal cooperation in logistics in general [3]. Based on a case study and simulations, Cruijssen and Salomon discuss factors affecting order sharing with its impact on clients, collaborating companies and the society [4]. Kopfer and Kopfer review some difficulties of applying CTP among profit centers of a large freight carrier company, especially the conflicts among parties in the distribution logistics including management, sales, drivers, schedulers and accounting personnel [5]. Bloos and Kopfer give some insights about the evaluation of the efficiency of transport collaboration mechanisms [2].

Another research direction is the design of CTP models. Schönberger develops a CTP model that also considers the usage of coalition external resources [11]. Krajewska and Kopfer propose a model concept including a profit sharing scheme based on game theory and combinatorial auctions. In the auction, each participant has to give bid prices not only for a bundle of requests but also for all single elements in this bundle [7]. Schwind et al. present an exchange mechanism for intra-enterprise order exchange among profit centers with the purpose of reducing total costs of the entire company [12]. They reduce the complexity of the problem enormously by employing a cluster building method while considering time windows and capacity constraints. Berger and Bierwirth develop a framework of request re-assignment where only a small part of requests to be exchanged is processed in each round. The marginal costs of this part are then determined by solving the traveling salesman problem with precedence constraints [1]. Krajewska et al. present another profit sharing scheme based on the Shapley value [8].

3. COST REDUCTION THROUGH COLLABORATIVE TRANSPORT PLANNING

Cost reduction through CTP means to take advantage of both economies of scale and economies of scope. Economies of scale may be achieved by integrating several LTL requests in one tour, while economies of scope are reached by the combination of various tours which might decrease empty miles.

Fig. 1 shows the situation, where transferring requests between two carriers may decrease the number of used vehicles. Without CTP, both carriers A and B would have to serve their requests with two vehicles. Suppose the total demands are less than one truckload, carrier B's two requests can be transferred to carrier A for a certain price less than carrier B's costs but higher than the additional costs for carrier A.

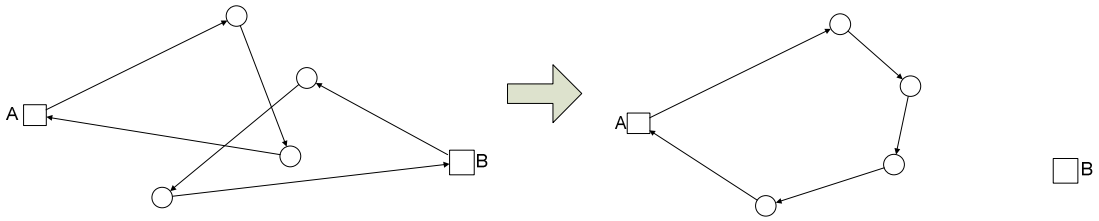

Figure 1. Reduction of used vehicles and empty miles

Fig. 2 illustrates another scenario, where the routes of both carriers A and B overlap. Through CTP they can exchange some requests and reduce the length of both routes. The total cost-savings achieved by performing CTP can then be shared between the two carriers.

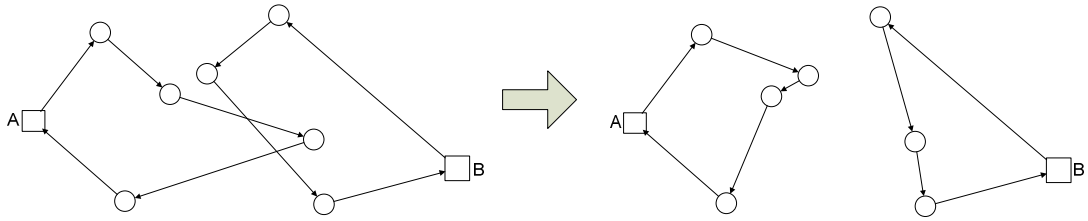

Figure 2. Reduction of extra traveled miles

A more complex possibility is to introduce transshipments. Fig. 3 gives an example of this idea. Carrier A would deliver cargos to D1 and D2 and then pick up goods at P1 and P2 before she goes back to her depot. One route of carrier B with enough capacity lies nearby. Carrier B could pick up the loads at both customers P1 and P2 in her route and pass them at the transshipment point TP.

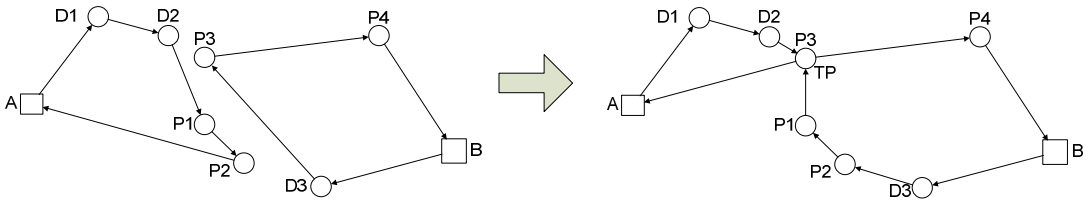

Figure 3. Reduction of extra traveled miles through introducing a transshipment point

4. CHALLENGES ON COLLABORATIVE TRANSPORT PLANNING

Although it is widely acknowledged that CTP could improve transport efficiency, there are still a lot of challenges on building up coalitions and on increasing their sustainability.

4.1 Determine the potential cost-savings

The first challenge is to determine the collaborative benefits for both the whole coalition and each participant. A common way to answer this question for the whole coalition is to calculate the cost difference between the total costs of all participants' plans without request exchange and the total costs of a centralized planning as in merge [4][8][11].

However, the real case could be much more complicated. The first difficulty is to gather all local information and transfer it to a central planer. This means that both requests and private company information including capacities and cost structures are to be exposed. The second difficulty is to develop algorithms that can solve the central planning problem effectively and efficiently. Since the vehicle routing and scheduling problems in the operational transport planning are all NP-hard problems, to get a global "optimal" plan for all participants' requests may be extremely difficult or even impossible.

Another disadvantage is that it disregards participants' autonomy. They may have different company strategies and in turn different objectives of business operations. These operational objectives are not always consistent with that of the whole coalition, which is the maximization of the collaborative benefits. A central planning omitting these individual settings could even be unacceptable for some participants and represents an unfeasible solution of the CTP. Autonomy also enables a better utilization of local knowledge which can be hardly considered centrally. Theoretically, both individual strategic preferences and local information can be formulated as lots of additional restrictions for the aggregated central planning problem. *The best achievable solutions* of the coalition may then have great deviations from the "optimal" solution obtained by models ignoring autonomy. To overcome this shortage, much more complicated algorithms are needed as central solver that can effectively process all local information and individual preferences. However, in a dynamic environment where additional restrictions reflecting environmental changes keep varying, the development of such a super algorithm will be extremely challenging.

The last factor is the transactional costs associated with CTP, which haven't been specifically studied yet. Activities including partner selection, bargaining and execution will cause many collaborative transaction costs. Thus, net benefits of the collaboration are actually less than the best achievable solutions offer.

Even if there is an appropriate expectation about the mutual benefits of the coalition, it is still not clear for individual participants, how much will they profit from the collaboration. This problem seems to be more important since the individual profit is the practical incentive for freight carriers to work together.

4.2 Egoistical rationality

The incentive of applying CTP is to increase participants' profits. However, regardless of the differences of individual planning, a collaborative planning or a

central planning will only give participants a lower bound of their individual profits. Although a central planning considering all specifications of participants would achieve the maximal collaborative profits, some participants may still enlarge their profits by leaving from the central plan and shrinking partners' profits. Obviously this behavior is very "egoistical" and negative for the coalition. Nevertheless, if we assume that individual participants are rational and eager to maximize their own profits regardless of those of others, it seems to be more rational for them to deviate from central "optimum" to maximize own profits.
This dilemma will be even thornier for the following example. Suppose the situation where a participant offers a request for exchange with payment p, while another participant may execute this request with additional cost $c < p$. The latter partner may bid on this request for c, leaving the difference $\Delta = p - c$ as mutual benefits, or ask for p as transfer payment to keep all Δ without harming the exchange, with which both partners would be satisfied. It is admirable to reciprocate for the coalition by sharing Δ with partners but not rational for the own interest of a single partner.
The problem of how to offer individuals more incentives for not being selfish, or at least to reward someone's reciprocity is referred as the incentive compatibility problem [7][12]. A common way used in game theory to achieve this goal is to alternate the corresponding payoffs of egoistical behaviors to make them irrational. But we also have to recognize the limitation. If the compensation for being more cooperative, or more reciprocate are less than the benefits of behaving egoistically, such attempts will never succeed. In CTP context, this happens when the profit increment of mutual benefits is less than the benefits of behaving egotistically. Participants will otherwise get only a part of the additional mutual benefits as compensation for their scarification. This nature of CTP makes it impossible to use any profit sharing scheme to change participants' payoffs, or expectations of payoffs and force them to be more cooperative.
This dilemma causes also problems for the individual participants. Being too egotistic will make the coalition ineffective and will harm both the coalition and the individual partners themselves. It makes the decision quite irrational, since it is clearly dominated by the strategy to being totally reciprocate. It is then sophisticated to find out the best position.

4.3 Design of collaborative transport planning models

The next great challenge is the design of CTP models. A three-phase framework including preprocessing, profit optimization and profit sharing is proposed in [7]. We first discuss some general guidelines and then the three phases later.

4.3.1 General guidelines

The design of CTP models requires thinking holistically about all three phases. Participants may benefit from collaborating by 1) paying less for the execution of their transferred requests than their potential costs, 2) getting more paid for

the fulfillment of partners' requests than their own costs, and 3) getting the shared mutual profits. All three possibilities need to be concretized in different phases considered simultaneously in the design.
The primary incentive to join in a groupage system is to gain more benefits. The goal of keeping the system profitable has two impacts. There must be enough cost-saving potentials and they have to be exhausted as much as possible. The first impact requires complementary request portfolios of participants, so that much synergy effects can be achieved. However, to identify how "complementary" two partners' portfolios are will not be easier than to specify the potential gains of collaboration. A heuristical resolution might be, to encourage partners to offer more requests for exchange. Exhausting the synergy effect means to find the best possible matching between the offered requests and capacities. For this purpose, coalition has to provide participants both sufficient information for their local decision-making processes and enough incentives for cooperative behaviors. Nevertheless, transactional costs of CTP have to be limited.
The second basic rule is "fairness". However, it seems impossible to give a definition of absolute fairness, with which no participant will disagree. Participant may have their own understandings of fairness, especially when it concerns with exposure of private information or transferring of decision competences, as well as with their shares of mutual benefits. The fairness principle can be relaxed that all the rules of a CTP must be enough fair perceived by individual participants to take part in it. Some general interpretations of fairness in CTP are:

- No one has to expose more private information than others.
- No one has to give up more competences than others.
- All contributions to the coalition, especially to a successful exchange leading to a win-win situation, should be awarded.
- The award for participants depends only on their contributions, but not on other characteristics.
- Same contribution has to be equally awarded.

Also, autonomy of partners must be acknowledged within the collaboration. It concerns primarily private information and decision competences. For different grades of autonomy with dissimilar willingness to expose private information and to abdicate decision competences, different models have to be developed.
The last point is simplicity of the processing. A collaborative model should be easy to understand by all participants for their execution. This will not only increase its acceptance but also help reducing transactional costs.

4.3.2 Preprocessing

The major task in this phase is to specify customer requests for exchange within the coalition and to identify the payments for transferring them to partners.
To specify which requests in the own portfolio should be offered for exchange is a pure local decision of autonomic collaboration partners and seems to be irrelative to the design of CTP models. However, in which form should a participant

specify her requests must be given by the coalition and constitutes an important element of the design. Participants may offer requests both as single objects and as request bundles, which supposed to be completely transferred.

Generally, there are two principles for the evaluation of requests or request bundles. The first one is to use the customer payments as transfer price [11]. The challenge is how to encourage participants to report the real customer payments, which is strictly hidden as business secret. Another point that makes this method not realistic is the "egoistic rationality" (see Sec.4.2). For the request offering problem, it can be easily found for request bundles. Consider the situation where some requests can be well bundled together, and the resulting potential costs for this bundle are much less than the sum of customer payments. To offer less as transfer price seems more rational as to offer all customer payments, so long as it will not affect the exchange. This implies that to use customer payment as transfer price in the preprocessing phase doesn't dominate the strategy of behaving somehow more egoistically.

Assume that individuals are aiming to maximize their own profits regardless of their partners' and they believe in exchanges according to their knowledge. It will be more rational to build the transfer price based on the evaluation of requests' potential costs using own disposable resources, keeping in mind that not all strategies are known in advance and their payoffs are hardly to be exactly identified. The advantage is that participants don't have to worry about disclosing secret information. However, to determine the costs for a given request or request bundle may be quite complicated, since it relies on the composition of the whole request portfolio. It is especially intricate for the LTL business, when the request(s) would be executed with some others in a same route.

The payment p for transferring selected requests for exchange depends primarily on the possible execution cost of these requests using own disposable transport resources without collaboration c_0. The opportunity cost c_1 representing the evaluation of own capacities supposed to be engaged in fulfilling those requests also affects the payment amount. Furthermore, a participant may just behave selfishly and lower her offering payment by r. Suppose a certain collaborative result which could be achieved with both payments p_1 and p_2 with $r = p_1 - p_2 > 0$, this selfish behavior means keeping r for herself, which would otherwise be somehow shared with other partners as coalition profit. The last element to be considered is a preference value β for the requests offered. The payment can then be calculated as follows.

$$p = c_0 + c_1 - r + \beta$$

It is important to keep the evaluation of a given request or a request bundle simple and direct. For instance, it is much easier to evaluate the costs of a complete vehicle route with many LTL requests than each of them separately.

The opportunity cost factor may be not important if all capacities released by transferring own requests to partners will be reused for executing requests from other participants within the coalition. However, since capacities could be saved

for new customer requests and would in turn bring more revenues (see Sec. 3), participants would pay more than their potential cost c_0 only.
It is clear that setting r too large will prohibit many exchanges from happing and reduce the possibility of transferring requests, which means a "lose-lose" situation. This gives a challenge on the design of CTP models to offer sufficient incentives to prevent individual participants from being too egoistic.
The preference value β measures how complementary these requests are with others in the own portfolio. The more complementary these requests are the more preferable are they to the participant. Other criteria apart from cost like quality, experiences, company strategy may also be taken into consideration. This measurement β may thus be negative if it is not important to transfer the according requests. It may also be greater than zero if the requests are so inconvenient for a participant so that she would rather pay some more to raise the possibility to transfer them to partners, than to fulfill these requests herself.

4.3.3 Exchange mechanism

It is aimed in the profit optimization phase to find out a mapping of requests offered for exchange and collaborating partners, so that the profit of the entire coalition is maximized [7]. An appropriate exchange mechanism has to be established to ensure an efficient exploration of cost-saving potentials.
A certain exchange mechanism will not work properly if it ignores the given autonomy grade of the collaborating partners. Consider an extreme situation where participants possess no autonomy, which makes the collaboration as a quasi fusion. All information would be processed centrally and the problem of profit optimization would be a routing problem for all vehicles of all participants. In another extreme situation, where all participants solve the request reallocating problem without mediators with accordingly competences, the CTP will work like an electronic transportation market [10]. For these two extreme situations, no mechanism with elaborated profit optimization function is needed. Between these two extreme values of grade of autonomy, participants may commit more or less decision competences to a mediator. Depending on the mediator's competences and available information from participants, the configurations of the exchange mechanisms will vary from each other.
Cost-saving potentials are embodied in the complementarities of single requests and are explored by combining them into bundles. The most intuitive examples of such bundles are vehicle routes. Thus a decisive factor for the success of a CTP model is to assist participants to excavate synergy effect by generating better bundles. However, this may lead to conflicts if some requests are included in more bundles. For the mediator, a simple splitting of certain bundles is definitely not a good solution, since the synergy effect would be destroyed. The situation may be much worse for participants, whose bundles are only partially reassigned. In auctions, the problem of not obtaining a complete set of offered objects in a multi-object auction is called the exposure problem [9]. This trouble

may be so severe that the new portfolio after exchange could be even less profitable for partners, when lots of centrally reallocated bundles are cut down for more mutual profits. This dilemma, to encourage the “troublesome” bundles and to offer enough incentives for inevitable splitting gives another great challenge.
The next great challenge is to ensure the functionality of the mechanism even if some participants play “non-cooperatively”, regardless if partners mean to. Participants may have different business focuses, or still need experiences with CTP. An exchange mechanism must still be working, even if such behaviors appear. The embodied profit optimization module should be able to find collaborative solutions, whereas the possible negative effects will be compensated. A better performance should be expected if the mechanism can eliminate the negative effect, so that no other partner will be “punished” by the “faults” of others. In order to fulfill these requirements, the mechanism should be able to limit such “non-cooperative” behaviors to minimum.
The last element to be concretized is the payment flow of exchanges. It is the basis for the calculation of both to be shared mutual profits of the whole coalition and the results for individual participants without shared profits.

4.3.4 Profit sharing scheme

A profit sharing scheme is the last component of a CTP model. The collaboration mutual profits achieved through exchanging requests in the profit optimization phase will be divided and given back to partners in a fair way.
The first difficulty is then to identify contributions to the coalition that should be awarded in the profit sharing phase. This identification has to be done both for the successful and profitable exchange for the short-run and for the sustainability and stability of the coalition for the long-run. After that, all identified elements must be given an appropriate weight, representing the evaluation of the importance of these identified contributions. Unfortunately, each participant will have their individual opinion on both the identification and weighting of awardable contributions. A pragmatic solution to resolve this conflict is to make an agreement that is fair enough to be accepted by all participants. Thus, the challenge on the design of CTP model is to find out a profit sharing scheme, which is fair enough to attract more possible participants to take part in while the profitability and sustainability of the coalition are strengthened.
The information required for a specific profit sharing scheme must be in accordance with those needed for the other parts of a CTP model. For instance, the idea proposed in [8] to use the Shapley value needs to know the collaborative benefits of all possible sub-coalitions. It is appropriate only if it is possible to employ a central planning or to repeat the same procedure of the first two stages of the models to get out the collaborative benefits for all sub-coalitions.
Profit sharing scheme may induce certain computational workloads as in [8] for both the mediator and the participants in the coalition. It is preferable to reduce these calculations to make the scheme easy for the implementation.

5. CONCLUSION

Request exchange among collaborating partners within CTP offers lots of potentials of cost-saving for freight carriers. Participants of such a groupage system can increase their efficiency while keeping their autonomy. In order to exhaust the potentials of the system, appropriate CTP models have to be developed. According to the willingness of participants to expose private information and to sacrifice decision competences, different compositions of CTP models are required. Based on the discussion about the chances and challenges related to CTP, we present both basic considerations for a better understanding of the complex problem and some challenging topics for future research. The first one is to estimate the collaborative benefits for the whole coalition and for each participant taking participants' autonomy into account. Nevertheless, a robust and efficient model is a crucial prerequisite for the success of CTP.

6. REFERENCES

1. Berger, S., Bierwirth, C. (2010) Solutions to the request reassignment problem in collaborative carrier networks, in: *Transportation Research Part E* 46, 627-638.
2. Bloos, M., Kopfer, H. (2008) Efficiency of Transport Collaboration Mechanisms, in: *Communications of SIWN* 6, 23-28.
3. Cruijssen, F., Cools, M., Dullaert, W. (2007) Horizontal cooperation in logistics: Opportunities and impediments, in: *Transportation Research Part E* 43, 129-142.
4. Cruijssen, F., Salomon, M. (2004) Empirical study: order sharing between transportation companies may result in cost reductions between 5 to 15 percent. CentER Discussion Paper.
5. Kopfer, H. W., Kopfer, H. (2009) Hemmnisse horizontaler Kollaboration in der Speditionsbranche, in: Ivanov, D., Meinberg, U. (Hrsg.): Logistics and Supply Chain Management: Modern Trends in Germany and Russia, Cuvillier Verlag, Göttingen, S. 354-362.
6. Kopfer, H., Pankratz, G. (1999) Das Groupage-Problem kooperierender Verkehrsträger, in: *Operations Research Proceeding 1998*, Springer, Berlin Heidelberg New York.
7. Krajewska, M., Kopfer, H. (2006) Collaborating freight forwarding enterprises - request allocation and profit sharing, in*: OR Spectrum* 28(3), 301-317.
8. Krajewska, M., Kopfer, H.; Laporte, G.; Ropke, S.; Zaccour, G. (2008) Horizontal cooperation of freight carriers: request allocation and profit sharing, in: *Journal of the Operational Research Society (JORS)* 59, 1483-1491.
9. Kwasnica, A. M., Ledyard, J. O., Porter, D., Dellartini, C. (2005) A New and Improved Design for Multiobject Iterative Auctions, in: *Management Science* 51(3), 419-434.
10. Nandiraju, S., Regan, A.C. (2005) Freight Transportation Electronic Marketplaces: A Survey of the Industry and Exploration of Important Research Issues, in: Proceedings 84th Annual Meeting of the Transportation Research Board, Washington D.C.
11. Schönberger, J. (2005) Operational Freight Carrier Planning, Springer, Berlin Heidelberg New York.
12. Schwind, M., Gujo, O., Vykoukal, J. (2009) A combinatorial intra-enterprise exchange for logistics services, in: *Information Systems and E-Business Management* 7, 447-471.