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Groupage Systems – Collaborative Request Fulfillment in Road Haulage: A Procedural View

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1 Introduction

With fierce competition in the market and increased demand for 'green planning' carriers in the road haulage sector increasingly seek new and improved methods of transportation planning. One possible solution is offered by horizontal cooperation in so called 'groupage systems' [Kopfer and Pankratz:1999]. Cooperation is an option especially suitable for small and medium sized companies that try to improve their operations, increase their market share and ensure successful future business operation.

Most freight forwarding companies (short: carriers) have to cope with strongly fluctuating demand on the transportation market which varies considerably over time. Aside from these long-term fluctuations they have to manage the daily variations of their demand. Each day a varying number of orders is received from customers on short call [Kopfer and Wang:2009]. Additionally, some of the orders that have to be fulfilled will not suit well to the portfolio of the orders to be fulfilled during the same time horizon. The efficiency of transportation demand fulfillment can be increased through extending the problem of vehicle routing and scheduling by the possibility of exchanging requests among partners within a coalition. This problem extension transforms the usual vehicle routing and scheduling problems to more general collaborative planning problems for groupage systems [Kopfer and Pankratz:1999]. The horizontal cooperation between carriers within a groupage system provides the possibility that each carrier of the groupage system offers a part of his or her transportation requests to the coalition while each partner of the coalition can make a bid on all offered requests. The request will be forwarded to that partner who submits the best bid; i.e. to the partner who announces that he or she can fulfill the request in the cheapest way [Krajewska et.al.:2008].

An alternative to groupage systems are electronic freight exchange systems. In contrast to these systems, groupage systems are closed systems with a limited and well-known number of participants or established only between profit centers of one company [Kopfer and Krajewska:2007; Krajewska et.al.:2008]. Further, the groupage system aims at improving the planning solution for the entire system. Thereby a common underlying objective is assumed, whereas freight exchange systems often focus only on bilateral exchanges to enhance individual situations. As such, collaborative planning considers the overall planning situation of all carriers whereas freight exchange systems focus on "selling" individual shipments.

Our contribution here is to provide a procedural description of the planners' decision tasks for transportation planning with the option of horizontal cooperation. We will thereby discuss several decision procedures in detail which have not been discussed in such depth beforehand. Specifically, we attempt to analyze the changes at different levels of the transportation planning due to the horizontal cooperation. The first part then focuses on the changes to carriers. The demand planning and especially the demand processing at carriers and the concept of groupage systems are introduced in chapter 2. Then, chapter 3 provides a generic overview of operational transportation planning at carriers. We provide a procedure for traditional transportation planning without cooperation and then suggest an extended planning procedure that is capable of incorporating request exchanges within the groupage system. Groupage systems are formed by several carriers and as such, a coordination instance between those carriers is required. The management tasks and procedures of this coordination instance are discussed in chapters 4 and 5, respectively. The interaction between the coordination instance and individual carriers is in the focus of the last chapter. In this chapter (6) we show that interfaces between the planning systems of the coordination instance and of the individual carriers are required and discuss the information to be exchanged.

2 The carriers' demand planning

Transportation planning refers to all tasks related to the coordination of the physical movement of goods. The planning aims at establishing efficient processes in terms of cost and other performance criteria such as service times. According to Pfohl [2004] transportation planning can then be classified as a problem of operational management. Further, the tasks of inter- and intra-company transportation planning can be distinguished. Our attention is on inter-company transportation which is a task often outsourced to either logistic service providers or carriers. There, planning is usually performed by dispatchers.

2.1 Demand processing tasks

The *transportation demands* that carriers receive from the market can be for transports of varying extent – ranging from the delivery of parcels to a repeated delivery of several containers – meaning that demands can often not be fulfilled by individual trucks or as a one-off service. Transportation demand may also include additional services such as (re-) packing or storage. As such, demand processing has to take place in order to create executable orders within the company. The demand processing is illustrated in Figure 1.After receiving demands from the market, orders are created for all functions that are required for the fulfillment of the transportation demand. One or more of the created orders are *transportation orders.* A transportation order is a demand for a certain function within the carrier's service – such as the transportation of a specific cargo from destinations A to B.

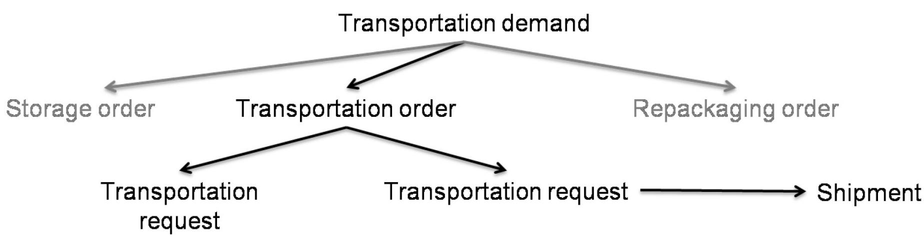

Figure 1: The demand processing of carriers

When splitting demands into orders only the required internal functions –transportation in our case – are considered. In a next step the potentially available capacity of resources is additionally considered. As such, the transportation orders are further split into smaller units, so called *transportation requests*. For the example of the transportation of cargo from A to B, several transportation requests have to be created if the cargo has a size larger than the capacity of one truck.
When planning the fulfillment of transportation requests we consider the additional options of subcontracting and collaborative planning. In both cases, transportation requests are forwarded to third parties for completion. Requests that are forwarded to a third party are then referred to as *shipments.*

2.2 Usage of groupage systems

Groupage systems take the viewpoint of carriers. The carriers interact in a market where they receive demands for transportation from customers. Groupage systems focus on the operational planning of transportation request fulfillment – the *extended vehicle routing and scheduling* for own fleet, subcontractors and collaborative planning – and the discussion here is limited to the function of road haulage transportation.
Groupage systems are a form of horizontal cooperation in the transportation sector [Kopfer and Pankratz:1999; Krajewska and Kopfer: 2006]. This horizontal cooperation provides the framework for the joint operational planning of shipments. The general idea of joint operational planning is a partial exchange of shipments as it is illustrated in Figure 2. The figure depicts an example of five carriers each with its transportation requests (represented by single dark dots) for the respective planning period. In our example each of the carriers is a company of the same size however, the number of transportation requests for a planning period may vary for each carrier (e.g. Carrier 1 has three and Carrier 2 four transportation requests). Different degrees of collaborative planning are then marked by the black rectangles. All transportation requests within a rectangle are potential shipments that may be exchanged with the partners. As such, the largest rectangle depicts the case of merging all requests of all carriers. Then, collaborative transportation planning would mean that all requests are shipments and a planning problem including the assignment of shipments to carriers has to be solved and the solution to the resulting transportation problem for each carrier has to be found. However, a certain reluctance of carriers to revealing details of all their customer requests is found in practice. As such, smaller numbers of requests will be selected as shipments as is exemplarily depicted by the two smaller rectangles. This variation in the number of shipments is also referred to as the modification of the *degree of collaboration*. It may vary from planning period to planning period. This idea of joint operational planning is underlying to the approaches of [Krajewska and Kopfer:2006; Gujo et.al.:2007; Berger and Bierwirth:2008].
Groupage systems have first been introduced by [Kopfer and Pankratz:1999] with a focus on the cooperative framework of the system. Later approaches then discussed procedures for the exchange of shipments. These exchanges were either conducted for individual shipments based on

Vickrey auctions, or for bundled shipments based on combinatorial auctions. An approach referring to individual item Vickrey auctions is found in [Berger and Bierwirth:2008]. Since a common assumption is that profits can further be increased by bundling orders, most approaches consider the effects of exchanges based on combinatorial auctions: [Schönberger:2005; Krajewska and Kopfer:2006; Gujo et.al.:2007] are examples for the pickup and delivery problem with less than truckload freights. All approaches consider at least three fulfillment options for requests: self-fulfillment, subcontracting and forwarding to one of the partners. Additionally, monetary transfer schemes for sharing the costs of collaborative fulfillment and sharing any collaborative profit are introduced in [Krajewska and Kopfer:2006; Krajewska et.al.:2008].

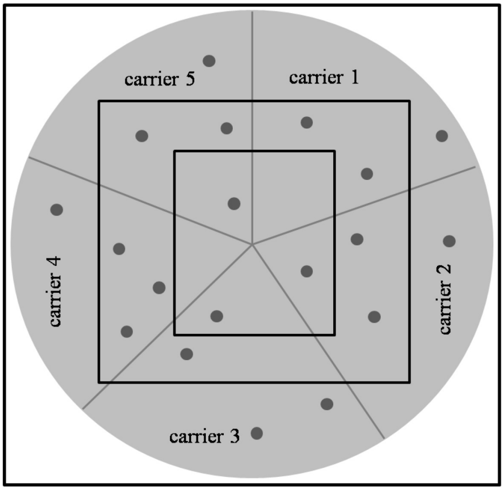

Figure 2: Degrees of request and shipment planning at five carriers

3 The carriers' request fulfillment tasks including collaborative planning

Operational transportation planning is traditionally carried out for a short planning horizon. At the carriers' a sales department or a dispatcher decides on the acceptance of the customers' transportation demands. This demand is divided into transportation orders and then planned in for either own trucks or subcontractors. In addition to these two options, transportation requests may be offered to partners or acquired from the partners in groupage systems. From the carrier's viewpoint, changes to the planning procedures for request fulfillment have to be made.

3.1 Fulfillment preparations

At time t, carrier C_i faces incoming demand $D_i(t)$. A customer demand is typically expressed as the demand to cover the need at certain network nodes (sinks) with offers from other nodes (sources) in a value creation network. Temporal requirements (time windows, latest allowed completion times,…) accompany the demand for the physical movement of goods. The first demand processing step is then the evaluation of each incoming demand expression in order to decide whether the customer's demand will be accepted for fulfillment or not. The 'accepting' decision is based on the current planning situation which can be approximated by so called performance criteria Ω_i. These criteria describe the current utilization of the vehicles, current costs, performance related to time windows and other criteria relevant to the carrier. Thus, carrier C_i has to divide $D_i(t)$ into the subsets $D_i^+(t)$ and $D_i^-(t)$ of which the latter is returned to the market.

The accepted demand contained in $D_i^+(t)$ is further processed and orders for the respective functions within the carrier's operation (e.g. packaging, storage, transportation) are created. The demand in $D_i^+(t)$ must be covered by the created orders. A transportation order represents the tasks to move some goods from some nodes to other nodes in the carrier's network. Cost minimal movements through the network are determined by solving a so-called network flow problem [Williams:1999]. The flow of goods through the network can be realized by using one or several transport resources that move the goods from one node to another node. A request describes the task for moving goods between two nodes in the network using a certain transportation resource. We collect all requests of carrier C_i in the request portfolio $R_i(t)$. Figure 1 exhibits the hierarchy among demand, orders and requests.

The mode assignment for request fulfillment traditionally refers to the decision between the options of self-fulfillment and subcontracting. The first option means that a request is executed by a truck operated by C_i and the second option means that C_i hires another carrier who receives the task of completing the shipment. The hired carrier is referred to as subcontractor and he or she is paid according to pre-concerted tariff. Depending on the available resources at carrier C_i, the costs for the request fulfillment, and the regulations in the customer contracts the dispatcher of carrier C_i selects the fulfillment mode [Krajewska:2008; Schönberger:2005; Pankratz:2002]. For self-fulfillment vehicle routing and scheduling plans have to be created [Golden et.al.:2008; Mitrović-Minić:1998] in order to keep the travel costs of the own fleet as low as possible. Subcontracted requests have to be grouped into shipments [Schönberger and Kopfer:2004] and must be assigned to specific subcontractors with potentially different cost functions [Krajewska and Kopfer:2009]. The transportation plan is formed by the derived routes and shipments [Crainic and Laporte:1997].

3.2 Basic request fulfillment planning process

A basic planning procedure describing the decision making process of an independently operating carrier is described in the pseudo-code of. The carrier and its properties (available number of vehicles, capacity, cost structures, etc.) are denoted by C. Initially, the request portfolio R is empty (a). Requests are collected consecutively until the request fulfillment processes must be started. The request fulfillment process is described by steps (b) to (h). Whenever new requests arrive these requests are initially stored in R^{temp}. The requests in R^{temp} are then filtered in the next step (c). In this step (c), an acceptance check takes place which means, carrier C evaluates for each request $r \in R^{temp}$ whether it matches the carrier's specifications and whether the request can then possibly be fulfilled at the conditions that it comes along with. Those requests that are accepted are then stored in R^+. Only these accepted requests are further processed (d). The remains of R^{temp} are collected in R^- which specifies those requests that are returned to the market (e).

In (f), the request portfolio is updated by the lately accepted requests. Next, this updated portfolio R of carrier C is evaluated with regards to potential fulfillment modes and all requests are assigned to one of those fulfillment modes (g). The requests are now divided into the subsets of requests for self-fulfillment (SE), for subcontracting (SC) and for postponement (PP). A plan generation cycle is completed by the generation of a transportation plan (h). In this procedure step, routes and schedules for the own fleet are compiled from the requests contained in SE and shipments are forwarded as tasks to subcontractors.

As long as the plan may be updated (e.g. as long as the execution has not begun), further requests may arrive. That means, the loop is running until the termination condition is met. In this case, the procedure does not iterate the existing portfolio anymore and returns the currently maintained plan P(i).

Sometimes the steps (e-h) are not executed consecutively but simultaneously. Then an integrated model and a transportation planning algorithm decide simultaneously about the acceptance, the fulfillment modes, the routes and the shipment consolidation [Krajewksa and Kopfer:2009; Pankratz:2002; Schönberger:2005]. Nevertheless, the general iterative procedural structure remains the same.

procedure carrier_planning(C)
(a) R:={}
(b) **Repeat**
(c) R^{temp} := waiting_for_additional_requests()
(d) R^+:= acceptance-check(R,R^{temp},C)
(e) R := $R \cup R^+$
(f) [SE, SC, PP] :=evaluate_portfolio(R,C)
(g) P := generate_plan(P, [SE,SC])
(h) **until** no_further_modifications_possible
(i) **return**(P)

Figure 3: Pseudo-code of the carrier's planning procedure

3.3 Extension to planning in groupage systems

The integration and union of carriers in groupage systems requires significant changes and modifications to the carriers' internal planning. The planning steps described in 3.2 need modification in order to incorporate the possibility of exchanging requests within the groupage system. The exchange of requests requires at least three additional planning and decision making steps.

- First, those requests that will be offered to the partners for the exchange in the groupage system have to be selected.

- Second, the requests in the groupage system's exchange pool have to be evaluated. These evaluations are then expressed as bids on requests.
- Third, after the exchange in the groupage system has taken place, the planning procedure has to run again in order to incorporate any requests won in the auction into the transportation plan.

In order to integrate these three decision tasks into the planning routine of the carrier, we propose to extend the procedure as depicted in Figure 4. The extended procedure is shown in the pseudo-code already used in Figure 3. It consists of three phases: the tentative portfolio iteration and pre-plan generation phase (short: pre-planning), the exchange phase, and the final portfolio evaluation and plan generation phase (short: final planning).

procedure carrier_planning_in_groupage(C)

```
(a)  R:={}
(b)  Repeat
(c)    Repeat
(d)      R^temp := collect_additional_requests()
(e)      R^+:= acceptance_check(R,R^temp,C)
(f)      R := R∪R^+
(g)      [SE, SC, PP, GP] :=evaluate_portfolio_with_groupage(R,C)
(h)      P  := generate_plan(P, [SE,SC])
(i)      update_exported_requests(GP)
(j)    until groupage collection_termination
(k)    view_pool_publication()
(l)    Bid_generation()
(m)    R^temp := exchange_result()
(n)    R := R∪R^temp
(o)    [SE, SC, PP] :=evaluate_portfolio(R,C)
(p)    P  := generate_plan(P, [SE,SC])
(q)  until no_further_modifications_possible
(r)  return(P)
```

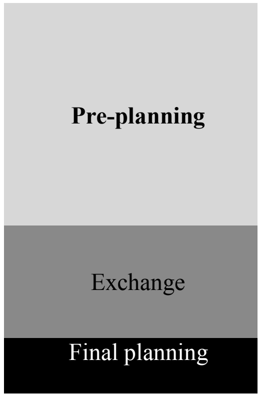

Figure 4: Pseudo-code of the carrier's planning procedure exchanging requests with the groupage system

In the pre-planning phase, the request portfolio is built up successively by integrating either the newly arrived requests from customer demand or the requests from the groupage pool. Initially, the request portfolio R is empty (a). Again, an existing plan is improved as long as the plan is not executed (b-q). In the pre-planning phase, additionally arriving requests trigger a plan revision (c-k). This planning procedure is idle unless additional requests arrive (d). The additional requests are again undergoing an acceptance check (e) with not accepted requests being returned to the market (f) and the existing request portfolio is extended by the accepted requests (g).

The portfolio evaluation and mode selection is carried out by calling the procedure *evaluate_portfolio()*. Again, the mode selection is made delivering the request fulfillment mode. Now, the possibility to submit requests into the groupage pool (GP) enables a fourth classification op-

portunity. Consequently, the evaluation procedure call returns a quadruple consisting of the sets of requests grouped by the fulfillment modes (h). A tentative transportation plan is set up from the sets SE and SC again (i).
The carrier then updates the subset of requests GP and submits it to the groupage system's planning (j). The groupage system accepts the submission of additional requests into the groupage pool until a certain termination criterion is met which is often a certain time limit (k). The groupage pool is then presented to all carriers and they can identify interesting additional requests (l). In a next step, each carrier creates bids on some or all of the interesting requests and submits them to the groupage coordinator (m). The groupage coordinator in turn returns the resulting allocation of the groupage system's execution by transferring the auctioned tasks of carrier C to carrier C(n). The auctioned tasks are additional requests that are integrated into the existing portfolio (o). Then, the final evaluation is carried out (p) and a new transportation plan is set up (q). It is possible to enter a new round with groupage involvement (r). However, after no more groupage rounds are possible, the currently maintained transportation plan is returned and executed (s).

4 Managing the groupage system

The exchange of requests between the carriers has to be managed by a coordination instance. This coordination instance is responsible for the support of the auction process and the allocation of requests to carriers. Therefore, it collects and displays all requests for exchange, considers all bids made by carriers and arranges an allocation of requests and transfer payments. Those transfer payments then function as cost compensation since the transfer of requests creates cost at the accepting carrier [Bloos and Kopfer:2009].

4.1 Steps of the request exchange

The considered groupage system is formed by N carriers C_1, …, C_N who are economically and legally independent. Each carrier has a sales department which receives and accepts customer demand. This demand is later on transformed internally into executable requests. At time t, the requests for which carrier C_i has overtaken the fulfillment responsibility are collected into the set $R_i(t)$. An exemplary groupage system formed by three carriers is shown in Figure 5 depicting the pre-planning phase, the exchange phase, and the final planning phase as introduced in 3.3. Each carrier participating in the groupage system processes its private requests in the same fashion using a procedure like the one shown in Figure 4.
A groupage execution round consists of five steps. In the first step (initial portfolio evaluation) carrier C_i has to evaluate its portfolio and to assign a fulfillment mode to each request in its own portfolio. Based on the results of this evaluation, tentative pre-plans are set up by each carrier in the second step (pre-planning). These two steps form the pre-exchange phase as mentioned in chapter 3.

Requests contained in the fourth category (GP) can neither be postponed nor have they been assigned to one of the first two categories. These requests are waiting for the execution of the groupage system and enter the third step. At this step, the responsibility for their fulfillment can be transferred to another carrier in the exchange phase. Typically, mode selection is a sophisticated task which is executed in several iteration rounds and in every iteration round the tentative classifications are evaluated [Schönberger:2005].

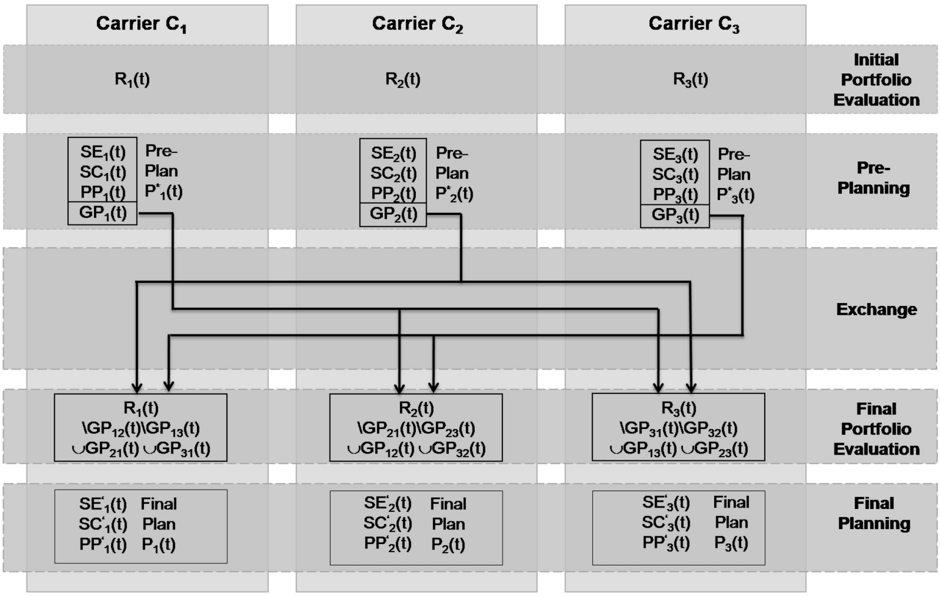

Figure 5: Request exchange iterations in a groupage system

The groupage scenario depicted in Figure 5 has three symmetric carriers. Therefore the five planning steps are only described from the viewpoint of carrier C_1. However, the number of requests contained in the sets may vary. In the pre-planning step, carrier C_1 has assigned requests to be transferred to the set $GP_1(t)$ which carrier C_1 offers to carriers C_2 and C_3. In the depicted scenario, all carriers C_i succeed in transferring their requests $GP_i(t)$ to the other carriers. In the final portfolio evaluation step, requests transferred from carrier C_i to C_j are then contained in the subsets $GP_{ij}(t)$ with $GP_{ij}(t) \subset GP_i(t)$. As such, carrier C_1 updates its portfolio to $R_1'(t)=R_i(t)\backslash GP_{12}(t)\backslash GP_{12}(t)\cup GP_{21}(t)\cup GP_{31}(t)$. In other cases, a carrier might not succeed in transferring all requests to its partners. In that case, the elements that were not exchanged remain at this carrier.

Although not depicted in Figure 5, cases are thinkable, for which the exchange takes place repeatedly. Then, each carrier updates its request classification and assigns each request from $R_1'(t)$ into one of the four categories (SE, SC, PP, GP) again. If no further exchange among the carriers in the groupage system is possible then the requests can only be assigned to the first three categories (SE, SC and PP) in the remaining planning time. An additional request exchange round might become necessary if it turns out that the requests in the updated portfolios can neither be postponed nor can these requests be profitably assigned to the SE or SC modes. In the fifth and final step (final planning) each carrier sets up the transportation plan to be executed.

4.2 The request exchange problem

The decision about the exchange of requests in the sets $GP_1, \ldots, GP_N$ requires the consideration of each individual carrier's situation. Since the profitability of a request depends on its ability to be combined with other requests into profitable routes (SE) or shipments (SC) it is necessary to evaluate candidate requests in $GP_1, \ldots, GP_N$ with respect to their compatibility with requests contained in the SE_i, SC_i and PP_i for each carrier C_i.

A typical request exchange round consists of four phases that are executed consecutively. Referring again to the three carrier scenario of Figure 5 the four phases for this example are depicted in Figure 6. In the pool filling phase, a carrier C_i specifies those requests that do not match the remaining requests well. The identified requests are collected in the set GP_i. A request pool is set up as the set union $GP_1 \cup \ldots \cup GP_N$. After each carrier has announced its corresponding contribution to the pool by specifying GP_i, the pool is made visible to all members of the groupage. Since the complete pool is published at once and at the same time to all carriers a fair and unbiased treatment of all groupage members is achieved.

Each groupage member evaluates the pool by checking whether and which requests match the existing own portfolio of requests. In the bid generation phase, the groupage members decide which requests they want to obtain from the pool. A bid nominates a bundle of requests and a price the carrier demands for fulfilling the bundle. The bundles may contain more than one request. If a carrier receives a certain bundle from the exchange, the carrier is responsible for the fulfillment of this bundle. Each carrier C_i is allowed to specify several bids and these bids are collected in the set $BIDS_i$. It is important to notice that the groupage member only accepts to take over a complete bid. Parts of a bid cannot be integrated profitably into the request portfolio of the member. The self-controlled specification of the bids ensures that each carrier makes a pre-selection of requests that indeed match the planning situation well. All bids are finally collected in the bid pool, which is defined as $BIDS_1 \cup \ldots \cup BIDS_N$.

In the third phase, the requests from the request pool are re-assigned to the carriers. Thereby, the specified bids contained in the bid pool are considered. Conflicts occur if two or more carriers want to integrate the same request(s) into their own processes. The major challenge in the request re-assignment phase is the solving of conflicts arising from non-disjoint bids. Requests that are not assigned to a carrier are returned to the carrier that has originally submitted it to the pool or, depending on the groupage rules, are given away to a logistic service provider for fulfillment [Krajewska and Kopfer:2006; Schönberger:2005] .

The request exchange terminates with the determination and execution of transfer payments among the groupage partners during the profit sharing phase. These transfer payments should cover the additional expenditures of a receiving carrier and they should motivate a spending carrier to put requests into the pool. Typically, the determination of the transfer payments is compromised by the fact that the carriers do not want to publish their cost structures. Thus, the payment determination requires estimations and approximations of the real additional expenditures associated with the fulfillment of the requests in the pool.

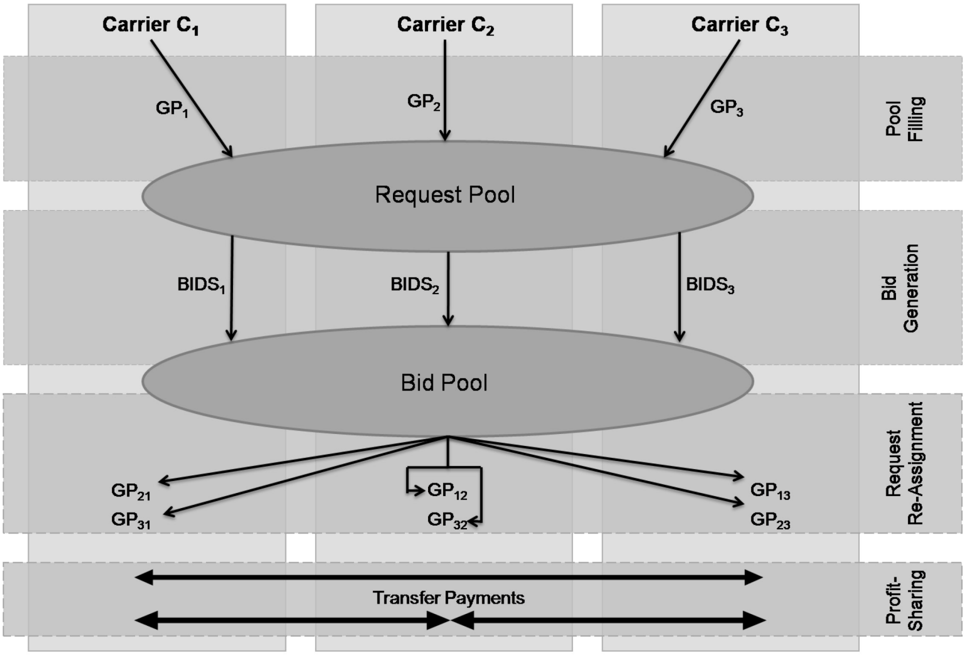

Figure 6: A groupage round

5 Procedures for controlling the groupage system

The coordination instance of the groupage system has to support all phases of the request exchange as well as to calculate the new allocation of requests to carriers. The instance itself has to act in a predictable manner that has been agreed upon in the cooperation's contracts [Bloos et.al.:2009]. As such, it can be a software device operated by a third party host similar to electronic markets. The exact procedures for this device then depend on the agreements made. However, on a generic level in order to adjust the operational transportation planning, the coordination instance has to fulfill certain fixed tasks. From these tasks control procedures can be derived that are valid for all forms of groupage systems.

5.1 Global groupage control procedure

To control the request exchange described in chapter 4.1, we propose the procedure presented in Figure 7. It is necessary to specify the set C of carriers and the vector $R(t):=(R_1(t),\ldots,R_N(t))$ of the request portfolios. The procedure consists of the loop (a-o) and the post-exchange request classification (p-r) in which the mode assignment is made for all requests.
In the iterations within planning period t, at first, a tentative mode selection is made by each carrier (steps b-d of the procedure). Thereby, each carrier specifies the set $GP_i(t)$ of requests that may be exchanged. The sets $GP_i(t)$ are then collected (e) in the vector G(t) and the exchange procedure groupage_round(C,G) is called (f). This procedure returns the matrix $[GP_{ij}(t)]$ of sets describing the pairwise request exchanges among the carriers in the groupage C. Furthermore, a transfer payment TP_{ij} accompanying the transfer of requests is agreed upon. For each carrier C_i the sets of received requests are compiled in the vector $G_i^+(t)$ (h) and the sets of requests emitted by C_i are put in the vector $G_i^-(t)$ (i). The new portfolio $R_i(t)$ of carrier C_i is compiled from the old portfolio plus the additionally received requests reduced by the emitted requests (j). An iteration terminates with the calculation of the benefit $U_i(t)$ of each carrier that results from the last exchange round (l-n).
After a predefined termination criterion has been fulfilled, the iteration stops (o). Now, each carrier determines its final request classification (p-r). Then, the total request exchange procedure stops (s) and the necessary request fulfillment processes are set up.

procedure groupage(C,R(t))
(a) **repeat**
(b) **for all** i=1,…,N
(c) $(SE_i(t),SC_i(t),PP_i(t),GP_i(t))$ = make_mode_assigments($R_i(t)$)
(d) **next** i
(e) G := $(GP_1(t),\ldots,GP_N(t))$
(f) $([GP_{ij}(t)],[TP_{ij}])$:= groupage_round(C,G)
(g) **for all** i=1,…,N
(h) $G_i^+ = (GP_{1i}(t),\ldots,GP_{Ni}(t))$
(i) $G_i^- = (GP_{i1}(t),\ldots,GP_{iN}(t))$
(j) $R_i(t)$:= update_portfolio($R_i(t),G_i^+,G_i^-$)
(k) **next** i
(l) **for all** i=1,…,N
(m) $U_i(t)$:= calculate_benefit_for_carrier($R_i(t),G_i, TP_i$)
(n) **next** i
(o) **until**(no further exchange round to be executed)
(p) **for all** i=1,…,N
(q) $(SE_i(t),SC_i(t),PP_i(t),GP_i(t))$ = make_mode_assigments($R_i(t)$)
(r) **next** i
(s) **stop**

Figure 7: Pseudo-code of the groupage control procedure

5.2 Request exchange control procedure

In order to control the request exchange step in a groupage system (cf. section 4.2) we propose the generic procedure groupage_round(C,G), of which the pseudo code is presented in Figure 8. The call of this procedure requires the specification of the set C of carriers and the set G of sets of requests emitted to the REQUESTPOOL by the carriers. At first (a), the REQUESTPOOL is initialized. Then, it is successively (b-d) filled with the requests taken from the sets G_i as have been specified by the carriers. The REQUESTPOOL is published to the groupage members as soon as it is ready (e). Next (f), the BIDPOOL is initialized. In the next part, the sets of bids that have been named by the carriers are collected from them (h) and all those bids are merged to the BIDPOOL (i). Now, the assignment of requests from the BIDPOOL to the carriers is made by calling the function decide_about_bids() in step (k). The BIDPOOL is used as input parameter. The decided assignment is coded into the matrix $[ASSIGN_{ij}]$. The entry $ASSIGN_{ij}$ contains the set of requests transferred from carrier C_i to any carrier C_j (GP_{ij}). Based on the sets of transferred requests the transfer payments are calculated (l). Finally, the sets of transferred requests and the transfer payments are returned to the global groupage control procedure (m).

```
procedure groupage_round(C,G)
(a)   REQUESTPOOL := {}
(b)   for all i=1,…,N                                Groupage pool compilation
(c)     REQUESTPOOL := REQUESTPOOL ∪ G_i
(d)   next i
(e)   publish_pool(REQUESTPOOL)
(f)   BIDPOOL := {}
(g)   for all i=1,…,N
(h)     BIDS_i = get_bids_from_carrier(C_i, REQUESTPOOL)
(i)     BIDPOOL := BIDPOOL ∪ BIDS_i
(j)   next i
(k)   [ASSIGN_ij] := decide_about_bids(BIDPOOL)
(l)   [TRANSFERPAYMENTS_ij] := determine_transfer_payments(C,G,[ASSIGN_ij])
(m)   return([ASSIGN_ij], [TRANSFERPAYMENTS_ij])
```

Figure 8: Pseudo-code of the groupage control procedure

6 Interfaces of the planning processes

We have analyzed the operational request processing in a groupage system from the perspective of a participant (chapters 2, 3) as well as from the viewpoint of the groupage management (chapters 4, 5). Common to both viewpoints is the structure consisting of pre-exchange, request exchange and post-exchange phase. However, the links between both viewpoints and the interactions between a single participant and the groupage system have not been analyzed so far. The following discussion therefore focuses on interaction and data exchange interfaces. We want to identify those steps of the planning process of the groupage management and of the carriers in which the two planning schemes are coupled because they need information from each other.

In Figure 9 we contrast the generic figure of a groupage system planning cycle (left column) with a carrier planning cycle (right column). We can see that five steps of the groupage system planning cycle are involved in an interaction with the carrier planning cycle. The resulting information interfaces are labeled by (A) to (E). As can be seen, the direction of the information submission goes back and forth. The five horizontal arcs represent the directed flow of information among the involved process steps. A receiving process step has to wait for the information provided by the emitting process step. The highest information interchange necessity is observed during the exchange phase. In the pre-exchange phase information exchange is necessary only once for each carrier. In the post-exchange phase, no information exchange is necessary for the termination of the groupage system as well as of the carrier planning cycle.

We first consider interface (A). The groupage pool compilation requires the submission of the set GP from all carriers involved in the groupage system. In order to enable the highest variety of requests to be interchanged among the participants it is necessary that the groupage planning cycle remains idle until all carriers have exported their corresponding requests into the groupage pool.

Immediately after the completion of the groupage system request pool, the pool is published in the groupage system using interface (B). Now, the carriers have to keep their planning process idle until the groupage system's planning cycle releases the required information.

Each carrier compiles bids from the request pool and submits the corresponding information via interface (C) to the groupage planning cycle. The groupage planning cycle is idle until all carriers have submitted their bids or until a certain time limit is met.

The groupage system's management selects and accepts bids from carriers considering all submitted bids in accordance with the groupage system's rules and guidelines. As soon as the management has finalized the bid accpetance, each carrier is informed about the requests the carrier receives from the groupage system for import into its portfolio. This information is transmitted via interface (D). Again, a carrier has to wait for the arrival of the information about the requests that have to be imported into its portfolio.

In the final step, the groupage system's management derives the related transfer payments to the exchange. This information is transferred to the carriers via interface (E). The information is crucial to the carriers for calculating their potential profits and losses for the current planning period.

From the discussion above we learn that the private internal planning processes of the carriers and that of the groupage system's management are coupled. The mutual need for information requires a fast and reliable processing of each planning step independent of whether the step is a carrier planning step or a groupage system planning step.

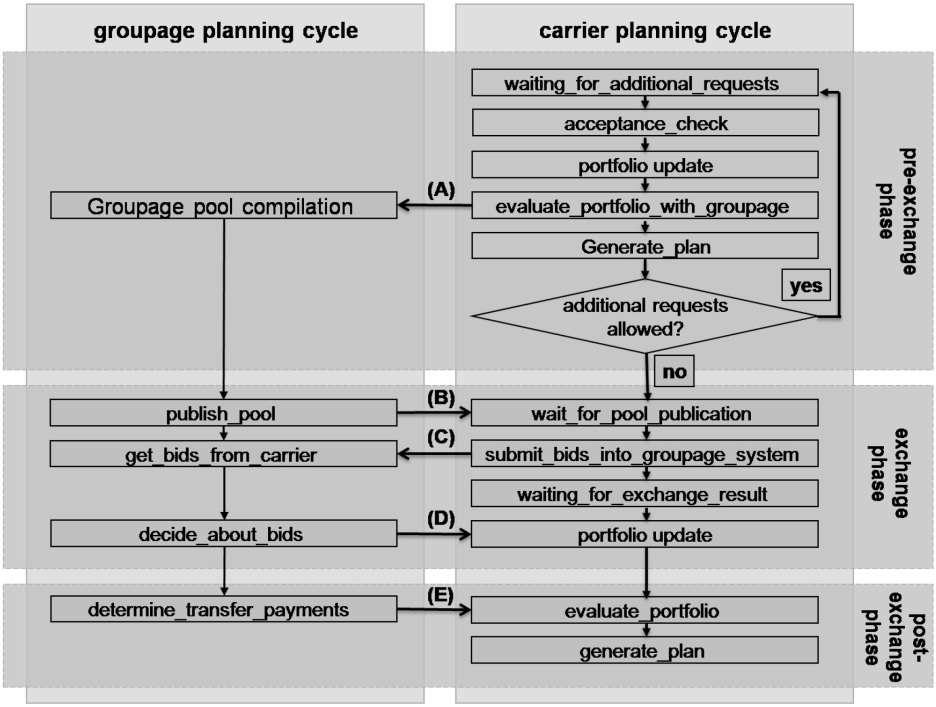

Figure 9: Interaction between the groupage system and the carrier planning process

7 Conclusions

Our contribution has analyzed the changes to operational transportation planning that result from adding the option of horizontal cooperation between carriers. We argued that the request portfolio of a carrier might be updated by removing and inserting requests after an initial mode assignment has been made. As such, the planning procedures at the carrier have to be extended to incorporate the required steps of request submission and bid generation for participation in the exchange. The described procedures remained on a generic level so that they are valid for all carriers in a groupage system independent of the actual planning system used. The groupage system is further amended by a coordinating instance that functions as planning and communication device to the carriers. As such, the carriers do not negotiate directly with each other but follow fixed and predictable structures for their collaborative planning. This coordination instance has to support the five steps of collaborative planning (Figure 5) and especially the request exchange. For both problems we have provided procedural descriptions. Further, we have linked the planning of the carriers to the coordination instance by specifying the required communication interfaces.

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