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Design of a combinatorial bidding market for Green Corridor freight

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Abstract

The Green Corridor (GC) initiative, pursued by the Swedish government and the European Commission, is intended to be a platform for innovation for long-distance freight transport aiming for more green and efficient solutions by enhanced use of economies of scale and development of new technologies. However, scale has to be traded off by two other aspects (i) freight transport time and reliability; and (ii) economies of scope. In this paper we present an already existing rail corridor case that highlights the need for tools (and/or markets) for making more efficient tradeoffs between economies of scale and scope in long-distance freight transport. This involves making very complex coordination of shipments that are differentiated with respect to origins-destinations, shipment size, time, time reliability requirements, regularity of shipments and involving both ex ante transport planning and real-time control. A market-based method that in principle could be used to solve such complex coordination is combinatorial auctioning and we briefly review a number of Swedish public tendering cases where this is done in practice. However, this raises questions on whether a fragmented vertically separated European rail industry can mobilize the "soft" market infrastructure needed to support a Green Corridor.

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1. Introduction

The railway industry, more than other transport modes, is marked by national idiosyncrasies. National differences in track width, electrical power systems, signal systems, safety standards, etc. have been until recently severe obstacles to cross-border rail traffic in Europe. Partly for that reason, train freight has a larger share of long-distance freight transport in the U.S. than in many European countries. Given increasing road congestion and awareness of global warming issues, many industrial and political efforts are therefore made to enhance competiveness of the rail mode on the freight markets for export and import of products within Europe.

The European Commission's action plan for sustainable freight transport (KOM/200//0607/final) in 2008 launched the idea of establishing "Green Corridors" (GC) for long distance freight haul in Europe. This initiative origins from previous discussions between government and industry in Sweden and is now a part of the Commission's policy for meeting climate policy challenges in the transport sector. The action plan states that the "concept of transport corridors is marked by a concentration of freight traffic between major hubs and by relatively long distances of transport. Along these corridors industry will be encouraged to rely on co-modality and on advanced technology in order to accommodate rising traffic volumes while promoting environmental sustainability and energy efficiency."

Being a political proposal, the precise definition of GC is open to discussion. Based on a survey to a sample of stake holders, public agencies and academia a draft definition has recently been suggested (Hansen 2011). From this it is clear the GC initiative aims at concentration of national and international freight on specific long-distance transport stretches. By economies of scale in long transport legs, the establishment of GC is supposed to make possible reduction of freight transportation cost, greenhouse gas emissions, and energy use. Each GC will be defined by a basis of measurable indicators. A GC is "green" only if these indicators are better than the European average and there is a continuous improvement over time. Green corridors can be co-modal, with parallel long stretches for road, rail and sea transport, and are expected to be inter-modal; in particular since "first mile" and "last mile" road transport may be needed in combination with rail or sea transport on a long leg. A final feature of the GC concept is that is intended to be "a platform for innovation", for instance for development of new wagon-load systems or more fuel-efficient engines.

Although the Commission´s action plan and other documents thus collect a broad set of actions under the GC hat, it is clear that the focus is on enhancing cost efficiency of freight transport through better use of economies of scale. That can be made for instance by technological, institutional and infrastructural changes that allow use of longer/wider/heavier truck and train configurations. However, scale has to be traded off by two related aspects (i) freight transport time and reliability, and (ii) economies of scope. These are related since consolidation of freight needed to get large shipment sizes (economies of scale) and high capacity use in all parts of the transport network (economies of scope) is time consuming, and even if time and reliability concerns can be met so as to get economies of scale in one part of the transport system (for instance in a long leg) it may be at the price of lost economies of scope. The tradeoffs with respect to economies of scope concern two aspects: One is the load factor in the long leg in both directions; i.e., a high cost/energy/carbon efficiency achieved by use of fully loaded large truck or train set in one direction may be offset by a low load factor in returning (and/or other) transport lanes. The second is the trade off between low cost per kilometre in the GC long leg and the additional kilometres and handling costs needed in medium range transport to and from the GC.

Some observers (Campagna 2009) have noted that establishing a GC is not just a matter of "hard" infrastructure construction but also of "soft" infrastructure, such as solutions for e-marketplaces, access to information, Intelligent Transportation systems, agreed standards to follow between operators, training and policies. In this paper we focus on some components of such a "soft infrastructure" needed for creation of a GC. In particular we ask whether more efficient trade-offs between economies of scale and scope in long-distance train freight transport can be made with combinatorial auction methodology.

For this purpose, we first briefly discuss the basic considerations in the choice of freight transport mode, when the alternatives are rail and road, and then describe an already existing "train corridor" solution; a collaboration between Swedish paper companies for rail freight from Sweden to the European continent. This case demonstrates that technical and infrastructural conditions for establishing a GC is already present; what still is lacking to make the train corridor “green” is an improved market mechanism that can fill the load capacity in all directions. Next, we therefore discuss the basic features of combinatorial auctions. To provide some sense for the practical usefulness of this mechanism we briefly present a few tendering cases in which combinatorial auctions have been made by national and local government agencies in Sweden. Finally, we discuss issues that need to be investigated to design a market for train freight transport capacity, based on bidding in combinatorial auctions.

2. The need for an improved market mechanism to make a GC work

In this section we first discuss the basic cost and time trade-offs in a choice between rail and road freight, to get a feeling for the basic challenges in establishing a market clearing mechanism for green corridor transport capacity. We then briefly present an already existing “corridor”, which is a joint venture by some Swedish paper companies for train freight haulage to the European continent. Both the discussion of the various trade-offs and the case study points to the crucial role, and the complexity of, a combinatory mechanism that can establish a high load factor.

2.1 Factors affecting choice between rail and road in long-distance freight haul

Consider a shipper that sends goods to a remotely located receiver and has a choice between road transportation all the way or short to middle range truck transportation to and from railway terminals and rail transportation in between these terminals. The total shipment cost can be decomposed and compared between the two modes in the following way:

1. Freight travel cost. The direct travel cost is the cost of driving a loaded truck or train between two points. Since the main idea of a rail GC is to take advantage of economies of scale, we assume that the cost per tonne kilometre of a fully loaded train is lower than that of a truck. However, the road alternative may still have a travel cost advantage as the truck can choose a direct route to the final

destination, while the rail alternative may require a longer route including the short range transport to and from terminals.

2. The "generalized" freight travel cost. The total, or "generalized", travel cost is got by adding the cost of travel time and travel time-uncertainty to the direct travel cost. The travel time cost includes the capital cost of the freight during transportation and the waiting cost of the customer. The cost of travel-time uncertainty depends on the just-in-time-demands of the shipment and the access to back-up systems when a good is delayed. Whether a train or a truck is most fast depends to some extent on running speed but more so on the degree of road and rail congestion. In rail, congestion, i.e., conflicts in track-use, are handled in two ways, by a scheduled time table, and by real-time traffic system control. Trucks, in contrast, are not hindered by scheduled delays, except for scheduled breaks for drivers´ resting time and for ferry crossings, but may be vulnerable to more or less occasional traffic jams.
3. Loading, reloading and consolidation cost. These activities are costly and hence add to the total shipment cost. Freight consolidation is the combination of several shipments to a larger and hence more economical load (Cetinkaya and Lee 2002). Consolidation is time consuming and therefore comes at the expense of inventory carrying costs and customer waiting costs. This means that the larger economies of scale of the rail GC can be assumed to have a price by higher costs and time requirements for consolidation.
4. Return travel load. Assuming a full load capacity transport in the direction from the sender to the receiver, the question is what happens in the other direction. If trucks and trains have to return empty, then the unit transport cost will double, compared to when they are fully loaded. It is not clear a priori how less than full capacity return freight affects the cost comparison of the two alternatives. If the cost of the train alternative is lower in the outbound direction, it will also be lower when the cost of the return travel is included. However, the direct truck alternative may possibly have a more flexible routing, which could affect the possibility to take on return freight.

In summary, we see that train freight have several disadvantages in competition with truck freight. More efficient solutions for train transport on long stretches will give the train mode a competitive edge only if the enhanced use of economies of scale is combined with high performance in use of economies of scope (distribution and return transport) and in planning and real-time coordination of the freight consolidation.

2.2 Supply chain management and transport market design

Modern production is often characterized by complex exchange between multiple levels of production. These relationships are called supply chains. There are often strong complementarities between various inputs, i.e. production requires that specific bundles of inputs are available at the same time or in specific sequences. Freight shipment is a supply chain in itself. Freight is distributed in a logistics network with links and hubs, combining different transport modes and requiring complex synchronization of activities. Freight transportations therefore involves making very complex coordination of shipments that are differentiated with respect to origins-destinations, shipment size, time, time reliability requirements, regularity of shipments and involving both ex ante transport planning and real-time control.

This coordination task is normally done by separate, or simultaneous, contracting between shippers and transport operators. However, markets where transactions between suppliers and buyers for multiple goods are negotiated in separate distributed negotiations may fail to result in efficient allocations in such settings (Walsh et al. 2000).

In the next section we will briefly consider an existing train "corridor" case, showing that this way of contracting may not perform sufficiently well.

2.3. A Green Rail Corridor: The case of Scand Fibre Logistics[1]

In a trial conducted by Deutsche Bahn, very long freight train sets are operated between Maschen (Hamburg) and Ringsted at Zealand in Denmark (Nelldal 2009). A possible next step would be to extend these trains over the Öresund bridge to Sweden, for instance to the rail hub at Hallsberg (200 km west of Stockholm). This is the core of a recent suggestion to launch a GC initiative for Hallsberg-

[1] Interviews for this case study were made by Jonna Flodman and Maria Gezici in 2010. Some basic facts are found in *Godset* (2011).

Maschen, possibly as part of an extended North-South European rail corridor from Narvik (in northern Norway) to Naples, Italy. In fact, the Hallsberg-Maschen route is already part of a train corridor operated by freight shuttles. This is the result of a collaborative effort by a group of large paper-exporting companies in Sweden.

Scand Fibre Logistics AB (SFL) thus delivers and develops logistics and rail-based transport services for the Swedish forest industry. Originating from a sea shipping division within Assidomän AB, SFL started train operations in 1999. It is presently owned with equal shares by the five paper companies Korsnäs AB, Billerud AB, SmurfitKappa Kraftliner AB, Mondi Dynäs AB Holmen AB. Only one of the large Swedish paper companies, The Swedish-Finnish Stora Enzo, has not joined SFL. Stora Enzo has developed its own transport system using containers of a non-standard size that therefore are difficult to integrate with the systems used by SFL.

Until recently the SFL system was based on trains with ordinary wagonload systems running from the paper mills located all over Sweden to the rail hub Hallsberg. From Hallsberg, dual-system locomotives took the wagons through Denmark or by ferries to Hamburg (Maschen). In Maschen, these wagons were connected to train sets for final destinations in Germany, the Netherlands, Belgium, Poland, Spain, Italy and the Czech Republic. SFL has however now acquired train systems (called Rail11) that can go directly from the ten papers mills at different places all over Sweden to Germany (Hamburg and Dortmund) and further, or to Swedish harbors in Göteborg and other places. It also operates train systems starting in Southern Sweden (Malmö). The trains go via three regional nodes (Ånge, Gävle and Norrköping) and are then combined to as long and heavy train sets as possible in Malmö. In the homeward direction all wagons are collected in Hamburg and driven in long train sets to Hallsberg, from which they are distributed back to the paper mills.

SFL currently has 5-7 daily outward trains (30-trains a week) and it owns 42 000 wagons. This covers 90 percent of the needs; the rest is covered by purchases on spot markets. The trains are operated by Green Cargo, Hector Rail, and Captrain. The total outward annual shipment is 2.4 million tons

In Sweden, the cargo is loaded by the shippers; all other loading is done by SFL or is contracted. A German wagonload system is used with long wagons that take three containers. However, shippers often have smaller shipments of specific paper assortments that do not fill a whole wagon, sometimes not even one container, which means that the full rent of the wagon has to be paid. An alternative that is currently considered is therefore to build an outbound distribution warehouse serving several customers for consolidation of freight.

SFL transports import goods to Sweden, for instance wine and liquor, waste paper, construction material and components for Volvo Equipment Construction. The shippers have different requirements; some, like exporters of pasta, wine and liquors from Italy have strict time demands, others are willing to pay more and also accept a longer transport time for a "green" transport. All shipments are planned in advance but some are contracted with a short notice.

Shipments on SFL trains are ordered one day in advance; orders must be posted before 9 am the day before the shipment is to be made.

However, while the load capacity is more or less fully utilized in the outward direction, the load factor on return is a mere 40 percent. This is a major weakness of the current system that only to a minor extent is mitigated by the energy efficiency gain accomplished by the longer train sets on the way back to Sweden. This is therefore the main obstacle that has to be overcome if the SFL system is to be part of a "green" corridor.

SFL has operated for a long time and has a well developed marketing department that is supported by some of the largest paper companies in Sweden. Looking for ways to increase the overall load factor, a natural starting point is to consider the general structure of the market, and in particular how transport contracts are made. As we already have indicated, a natural suspect is the separate contract by contract process between shippers and transport operators. A logistics system is a complex network with intrinsic public good features. In the next section we will present a contracting/ market mechanism that possibly may work better than traditional business contracting as a means to raise the overall capacity utilization in the network.

3. The combinatorial auction mechanism

A combinatorial auction is an efficient bidding mechanism that can be applied when multiple contracts are to be awarded in the same tendering process (Vohra and de Vries 2003). The mechanism gives the individual shipper (auction) or supplier (procurement auction) an option to condition his bid on a separate contract upon the outcome of his bids on other contracts in the same tender. Hence, it enables both smaller and larger shipper/suppliers to bid more competitively on more contracts without being exposed to the risk of winning too few or too many contracts. The option to submit bids on bundles of contracts or to express maximum capacity, when multiple contracts are auctioned out (combinatorial bids), has the potential to reduce auctioning/procurement costs, thus value is added to the auctioner/procurer.

Walsh et al. (2000) consider the use of combinatorial auction for supply chain formation. They consider a case where a “market-maker” auctions the most important activities in the market using a one-shot combinatorial auction. If bidders bid their true valuations then this mechanism, unlike separate distributed contracting will yield an efficient allocation. However, with this mechanism, agents may be willing to place more aggressive strategic bids than they would do with separate negotiations. They conclude that there are roles for both distributed separate and combinatorial auctions in supply chain formation.

Roughly, one can distinguish between two types of combinatorial bids. The first type offers a discount if the shipper/supplier is awarded a package of contracts, pre-determined by the purchaser or arbitrary chosen by her. The second type of combinatorial bids expresses that the shipper/supplier has a limited capacity, or additional costs for engaging, to fulfill more than a certain number of contracts. The shipper/supplier submits stand-alone bids on a number of contracts, but in an addendum states that he is only prepared to accept a maximum number of contracts or contracts up to a given maximum contract value, or up to a given maximum physical volume. The shipper/supplier can also submit stand-alone bids on several of the contracts, but will in an addendum stipulate negative discounts; that is to say, if they are awarded more than a certain number of contracts, then all bids should be raised by x percent for each additional contract awarded.

Combinatorial auctions are difficult to implement, mainly for two reasons. Firstly, the mechanism is NP-complete as it requires software that can handle the computational complexity to determine the winner. If the number of items and bids – single bids as well as package bids – are sufficiently large, one might end up with an unsolvable problem where a polynomial-time algorithm to find the optimal allocation is unlikely ever to be found. However, progress in combinatorial algorithms and computer-processing capacity in the last few years has increased the use of the mechanism in industrial procurement, mainly in transportation.

Secondly, combinatorial bidding is strategically very complex for bidders and also very complex to design. Unlike single-item auctions, multiple item environments still lack theoretical guidelines for making general predictions concerning revenue and efficiency ranking for various types of combinatorial auctions. Krishna and Rosenthal (1996) show in a sealed-bid second-price auction, with two objects and a single global supplier, that a simultaneous auction outperforms the combinatorial auction when synergies are present. The reason is that the global supplier engages in "overbidding" where the supplier is bidding above his value, thus facing the possibility of a loss *ex post*.[2] When it comes to the first-price multiple unit auctions, there is to our knowledge, no similar proof derived showing that a simultaneous first-price auction outperforms a first-price combinatorial auction. Also, the number of empirical and experimental studies comparing the outcome from the two auction formats is very limited. If any, there is weak support that the first-price combinatorial mechanism generates, at least, the same low cost as the simultaneous format (e.g. Epstein *et al.*, 2004; Lunander and Nilsson, 2004; Cantillon and Pesendorfer, 2006; Lunander and Lundberg, 2009).

Cantillon and Pesendorfer (2006) refer to the results obtained in McAfee *et al.* (1989) and show that the presence of a combination bid does not necessarily indicate that the bidding firm is facing synergies. The submission of a combination bid can be equally motivated by strategic price discrimination. Cantillon and Pesendorfer conclude that the welfare consequences of first-price combinatorial procurement auctions are an open empirical question. However, the more that the

[2] A similar result is found in Kagel and Levin (2005) in which they derive and analyze bidding behavior in a sealed-bid uniform price auction when synergies are present. They find that a supplier with multi-unit demand has, for some intervals of values, an incentive to submit bids above the valuation. Testing their prediction in an experiment, they find that subjects exhibit no reluctance to overbidding.

bidders' unit costs are negatively correlated in the number of contracts won, the more likely it is that the combination bids reflect synergies across contracts rather than strategic price discrimination.

A number of studies on combinatorial bidding focuses on the inherent winner determination problem and how to express combined bids (e.g. De Vries and Vohra, 2003; Sheffi, 2004; Cramton *et al.*, 2006; Abrache *et al.*, 2007). Also, there is quite a large amount of literature analyzing the strategic implications of combinatorial bidding and how to design combinatorial bidding. A number studies consider the Vickrey-Clarke-Groves (VCG) mechanism (e.g. Krishna and Rosentahl, 1996; Holzman and Monderer, 2004; Yokoo *et al.*, 2004; Ausubel and Milgrom, 2006; Chew and Serizawa, 2007).[3]

Combinatorial auctions are used frequently today in the procurement of transportation services, especially in the U.S. (Sheffi, 2004, Elmaghraby and Keskinocak 2003). In these auctions, the shipper asks the bidding carriers to quote prices on groups or packages of lanes, in addition to individual lanes. The carriers can form their own packages based on their own economic conditions, their existing client base, their drivers' domiciles, and their underlying maintenance networks. The idea is to help carriers form packages that, if granted, will allow them to cut their costs for operating the lanes included in the packages and pass part of the lower costs on to the shipper in the form of lower bids.

Given the theoretical ambiguities, it is clear that the question of the role that combinatorial auctioning can play as a means for improving efficiency in utilization of large-scale transport capacities is on a case where the proof of the pudding is in the eating, i.e., in the practical experience. For this reason we will in next section briefly review recent experience from some combinatorial auctions in Sweden.

5. Experiences from combinatorial auctions in Sweden

In this section, borrowing from Lunander and Lundberg (2011) we briefly describe the procurement of four different public services (road resurfacing, elderly care, cleaning services, and bus services) carried out in Sweden over the period from 2003 to 2010. The tenders were all sealed-bid combinatorial auctions where suppliers had the option to submit bids on bundles of contracts as well

[3] For a criticism on the practical usefulness of the VCG mechanism, see Rothkopf (2007).

as the option to declare limited capacity. In all tenders, suppliers were required to submit a stand-alone bid for every contract being part of a package bid. The suppliers were, with some minor exceptions, free to bid on any bundle of contracts. In some of the tenders, the procurer imposed a constraint upon the maximum number of contracts allowed to be in a package bid, or a constraint upon the maximum size of the offered discount in a package bid. Finally, the awarding of contracts was, in some of the tenders, based on the lowest price only, taking the form of the standard first-price sealed bid auction. In other tenders, contracts were based on multidimensional bids awarded according to a scoring rule where suppliers received a negative or a positive discount on their bids depending on the quality dimension of the bid.

Case 1: Asphalt resurfacing. Asphalt resurfacing in Sweden is characterized by a relatively high degree of homogeneity with different suppliers offering similar quality and performance. Most suppliers operate over the whole of Sweden and submit tenders for contracts in all regions. Contracts are mostly awarded on the basis of price alone. Suppliers do, however, differ significantly in their capacity to produce and lay asphalt and this can vary according to their current workload. Asphalt resurfacing has a high fixed cost and a relatively low marginal cost – the marginal cost being the cost to produce and lay an additional ton of asphalt. At any time, it is likely that there will be a contract size which is most desirable for each supplier, best exploiting their spare capacity and enabling them to bid their most competitive price. In this situation, there is a tendency for collusion between suppliers which, in their eyes, can be 'legitimized' by the fact that it should lead to a reduction in total cost. The inherent problem when suppliers coordinate their bidding behavior is, of course, that they take advantage of the situation to offer prices which are higher than they need be.

In order to try to lower the incentives for collusion, the Swedish Road Administration (*SRA*) since 2002 allow suppliers to submit combinatorial bids when bidding for asphalt resurfacing contracts. Lunander and Lundberg (2011) show that suppliers have been very successful in using package bids to get business. For every year that was studied, more than 70 percent of the contracts were awarded to package bids.

Case 2. Public Procurement of Cleaning Services. In 2006, the Swedish Social Insurance Agency procured cleaning services for all of its local offices in Sweden using a combinatorial bidding process. In total, 42 separate contracts, of which some of them comprised several offices, were auctioned out. The total area to be cleaned was 450,000 square meters. Besides submitting a stand-alone on any of the 42 contracts, bidding suppliers were given the opportunity to submit package bids on any bundle of these contracts. There was no limit as to how many bundles the suppliers could specify. In addition to their stand-alone and package bids, suppliers could also express capacity constraints by specifying the maximum amount of cleaning area they could manage in total in terms of the number of square meters.

Contracts were awarded according to the principle of the most economically advantageous bids. In addition to price, three qualitative criteria were considered when bids were evaluated and contracts assigned winners. Depending on the level of quality the supplier declared for each of the three criteria – which had to be controlled by the procurer – a monetary value per square meter was subtracted from the supplier's offered price for each contract. That is, a bid for a specific contract was lowered with the reduction per square meter times the number of square meters for that contract. A statistical analysis by Lunander and Lundberg (2011) shows that bids were decreasing in the contract size, suggesting that suppliers face synergies in the number of square meters won.

Case 3. Public Procurement of Elderly Care. The Swedish government has, in the last ten years, encouraged its municipalities to contract out their elderly care services. Private suppliers compete for contracts in a tendering process where the suppliers offering the best price and quality combination are awarded contracts. The motives for contracting the elderly care are both to improve the quality of the services and to lower the cost. In general, the size of a contract is determined by the number of elderly people to be taken care of. Although it is quite common that municipalities offer multiple set of contracts in one and the same procurement, combinatorial bidding is seldom applied. However, there are some exceptions. For instance, a combinatorial procurement auction of elderly care was carried out in the city of Östersund in November 2008. Eight separate contracts were available. Four of them concerned nursing homes and four concerned home care service contracts. Suppliers were given the option to submit bids on packages of contracts, as well as stand-alone bids for individual contracts.

Case 4. Public Procurement of Bus Transportation. Sweden's local and regional bus services have been procured on a competitive basis since the late 1980s. In each province, the buyer is an administrative body owned by the local governments within the province and the elected regional assembly. The buyer makes a detailed description of the way in which the services are to be operated, including precise timetables. The buyer also controls the ticket price and the operator hands all ticket revenue over to the buyer; alternatively, this revenue is deducted from the payment made to the operator. The contracts that are available are therefore gross cost contracts with no revenue risk for the operator. Operators provide vehicles, garages, maintenance depots, drivers, and facilities for drivers. The buyer also specifies norms for bus quality, including environmental standards, and minimum requirements for drivers, including such things as the use of standardized uniforms. Finally, the operator has to present a plan for the quality control of the activities to be undertaken. In most regions, contracts are awarded to suppliers with the lowest price. The supply of bus services to the public sector in Sweden are characterized by a high degree of homogeneity between operators in terms of service quality and high fixed costs for operators due to large investments in capital (buses). It is therefore likely that at any time there will be, for each operator, a package of services which closely matches their spare capacity and enables them to bid very competitively.

The main conclusion for our purposes of the review of these four cases in public tendering is that combinatorial bidding is already made in a variety of applications within the Swedish legal and institutional framework. The bumble-bee is indeed flying; combinatorial bidding is not just a theoretical construction but a practically implementable instrument that hence can have a potential also in use for coordination of supply and demand of train freight capacity in cases where multiple items and synergies (economies of scale and scope) are involved.

6. Discussion and conclusions

In this paper we have observed that the basic idea of "Green Corridors", which is to exploit economies of scale, is in inherent conflict with economies of scope. In specific, a transportation system based on a long rail leg raises very complex challenges to transport planners in finding ways to get freight transport demand and supply to meet in all parts of the transportation network, so as to get an overall load factor and high transport efficiency. This would involve very complex coordination of shipments that are differentiated with respect to origins-destinations, shipment size, time, time reliability requirements, regularity of shipments and involving both ex ante transport planning and real-time control. Such a coordination task is normally done by separate distributed contracting between shippers and transport operators, which may lead to less than fully efficient allocations.

Our transport corridor case study, Scand Fibre Logistics' rail freight transport centered on Swedish export of paper products, illustrates that separate contracting may not result in a high load factor. We also observe that in spite of much differentiated time requirements across shippers, the business is mainly organized in a spot market framework where transport next day is ordered (in the morning) the day before. Further, while SFL provides the exporting Swedish paper companies with integrated shipping solutions from each paper-mill site to receivers, shippers in the other end that want to use the transportation capacity in the northbound direction may need to find inter-modal combinations.

A rail corridor must have access to a more efficient multi-market clearing mechanism if it is to become a "green" corridor. From a brief review of some Swedish experience from the use of this mechanism for public tendering, we found that this mechanism is already used in a variety of applications with different kinds of synergies in production and consumption. Our conclusion is therefore that the combinatorial mechanism is a candidate to consider in the search for a market structure that can support Green Corridors.

This conclusion leads to questions on how to organize Green Corridors. The railway industry in Europe was previously nationally separated and dominated by vertically integrated ("steel to steel") national state-owned operators. This is now replaced with a (more) transnational and competition-oriented structure based on vertical separation between management of the rail (etc.) infrastructure and train operations. While physical infrastructure is still in the public sector domain, coordination of supply and demand for freight transport services is to be made by the market. However, it is not obvious that in the new integrated European rail market with its much more fragmented structure it is possible for individual firms or even coalitions of firms to organize the market so that system-wide economies of scale and scope can be exploited. An issue for further analysis is therefore whether a "soft" GC infrastructure, like a market mechanism for GC freight load capacity that allows combinatorial bidding, is possible without some government intervention. The corridor case we have presented is the result of joint action of one group of shippers. This coalition thus involves only one side of the market (shippers) and on that side only firms with a primary interest in operations in one direction (export from Sweden). Moreover, they contract train operations but are not in control of the physical infrastructure, for instance the assignment of track usage slots and time-tables. In fact, the market for GC transport capacity can be seen as a market within a broader market or allocation mechanism that is controlled by government bodies. Further, when a market is organized by a limited group of companies, issues may arise concerning third-party access and other such problems in competition among firms that share a common network. This may limit the efficiency in a societal perspective of market solutions that are not supported by government intervention.

Going to more specific issues for further analysis in designing GC markets, an important aspect is to what extent prices can be differentiated with respect to various aspects of the timing of a shipment (departure, arrival, reliability, etc.), for instance by offering discount for so-called ramp freight (i.e., freight that can wait until there is free transport load capacity). Efficient price differentiation with respect to various timing features is obviously a systems-wide task involving synergies between shipments. This dimension of contracting for rail freight is therefore worth consideration; first because it concerns directly the core trade-off in consolidation between time and size; second because it can be exploited with combinatorial bidding organized already by a "partial" GC such as SFL.

Another essential issue to consider is how contracting for load capacity in a "long train leg" can be integrated with contracting for short and medium range transport to and from the rail hubs. In the SFL case, that would put shippers in both directions of the corridor shuttles on a more equal footing and would therefore be an important step in establishing a GC.

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