A Roadmap for Sustainable Freight Transport

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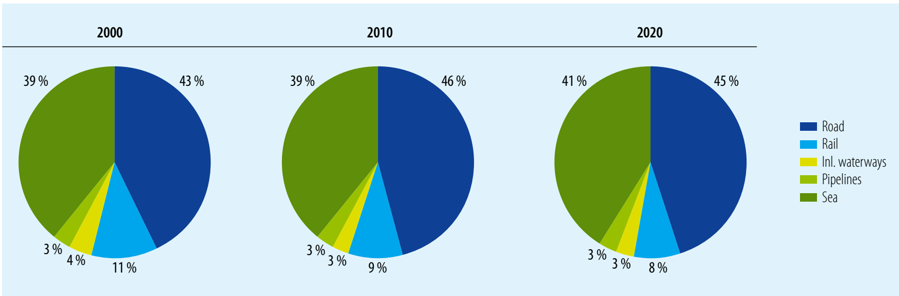
Summary. It is expected that freight transport in the European Union will grow significantly and road transport will account for a major part of this growth. By 2020 almost 30% of CO_2 emissions in the European Union will be caused by transportation. It is obvious that our present patterns of transport growth are unsustainable. One way toward more sustainable transport is to explicitly take greenhouse gas emissions into account in logistics decisions and to get freight traffic to switch from roads to alternative transport modes. This contribution discusses drivers and opportunities for intermodal transport planning. Related literature is surveyed and fields for future research are identified.

1 Introduction

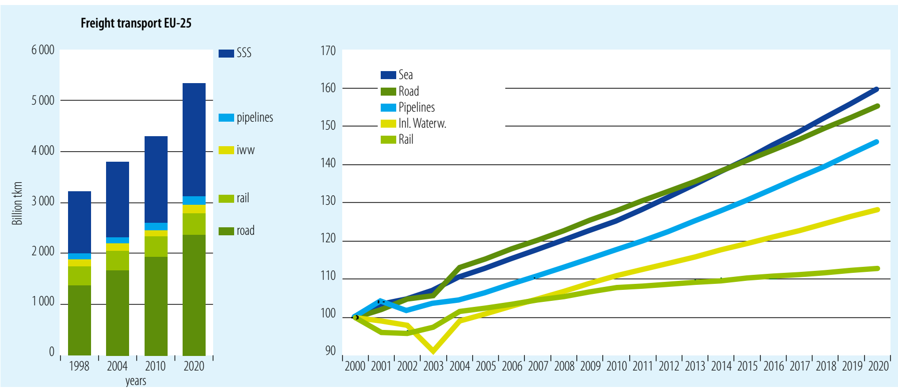
Human contribution to global warming can no longer be neglected. The global costs triggered by climate warming will result in a fall in world GDP of between 5% and 20% per annum if we do not drastically reduce greenhouse gas emissions [23]. Carbon dioxide (CO_2) is seen as the most important anthropogenic greenhouse gas and the primary source of the increased atmospheric concentration of carbon dioxide is fossil fuel use [18]. The share of transport in total CO_2 emissions in the European Union increases continuously and will account for almost 30% of total CO_2 emissions in the year 2030 [7]. By far, the largest share of CO_2 emissions related to freight transport results from road transport which, in the year 2000, accounted for 43% of EU freight transport (see Figure 1). Until 2020 freight transport in the European Union will continue to grow rapidly and road transport will account for a major part of this growth (see Figures 1 and 2).

These figures show that our present patterns of transport growth are unsustainable. One way toward more sustainable transport is to get freight traffic to switch from roads to alternative transport modes, especially rail, but also short-sea and inland waterways.



Source: [5]

Fig. 1. Evolution of modal split



Source: [5]

Fig. 2. Development of freight transport

2 Intermodal freight transport

Intermodal freight transport is the movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes [8]. While classically transport planning mostly focused on one specific mode of transport, intermodal freight transport has developed into a significant sector of the transport industry in its own right [3]. Due to this development, intermodal freight transportation research is emerging as a new transport research application field. [15] survey intermodal transportation research and categorise it using two criteria: the type of decision maker and the time horizon of the decisions. Different decision makers in intermodal transport face different planning problems. Drayage operators organise the planning and scheduling of trucks between terminals and shippers and receivers. Terminal operators manage transhipment operations from road to rail or barge, or vice versa. Network operators are responsible for infrastructure planning and organisation of rail or barge transport. Finally, intermodal operators can be considered as users of the intermodal infrastructure and services. They select the most appropriate route for shipments through the whole intermodal network. The time horizon of the decisions is divided into a) long-term: strategic decisions that often require large capital investments into resources, b) medium-term: tactical decisions aiming to ensure an efficient allocation of existing resources, and c) short-term: operational decisions influencing the execution of transportation processes.

While [15] lists various research works focusing on drayage, terminal, and network operators for strategic, tactical, and operational decision making, it appears that there are only few works focusing on short-term planning problems of intermodal operators. Among them are [2], [1], [16] and [27] who present methods for determining the optimal route through an intermodal transportation network for a single shipment. More recently [4] and [17] include timetables of transportation modes into models for routing shipments through intermodal transportation networks.

3 Increasing sustainability

In order to facilitate a shift in the modal split it is indispensable to understand the reasons for the prevailing dominant role of road freight transportation. As a result of global competition many companies increasingly apply just-in-time practices in order to cut down inventory levels. Just-in-time practices necessitate punctual, reliable, and flexible transportation, as with reduced inventory buffers any mismatch between supply and demand can result into significant disturbances of supply chain performance. The road haulage sector offers its customers fast and flexible door-to-door services providing one face to the customer. This is particularly important as one element of just-in-time practices is the reduction of order sizes and more frequent requests for deliveries with respect to the current demand and inventory levels [22]. Rail, short-sea and inland waterway transport, however, cannot satisfy the resulting requirements as effectively [21]. On the other hand, road transport is the least environmentally friendly mode of transport.

Transportation services that are punctual, reliable, and flexible as well as sustainable can only be provided if the specific strengths of each mode of transport are combined according to the specific customer requirements. Transportation service providers currently focusing on road transportation can only provide more sustainable services if they include intermodal services into their portfolio. Without this integration of intermodal services they are at risk of loosing customers when shippers are becoming increasingly concerned with environmental issues.

Today's planning tools for road transportation are mainly based on the vehicle routing problem and its variants, see e.g. [25]. Most cassical models for vehicle routing, however, cannot consider intermodal services. The general vehicle routing problem (GVRP) presented by [12] differs from these models as it allows specifying transportation requests by a sequence of locations that must be visited in a predefined order. Time window constraints imposed on these locations allow for considering transportation requests in which a part of the transportation between origin and destination must be realised by a specific roll-on/roll-off train or ferry. Although the GVRP has certain capabilities of considering accompanied intermodal transport, it can neither decide on whether intermodal transport shall be chosen or not, nor which specific train or ferry shall be used.

Multiple time windows, as considered by [26], could be included in the GVRP to consider timetables of specific train or ferry connections. Mode choice decision methods for a single shipment (as those cited in the previous section) can be included to furthermore decide on which roll-on/roll-off link shall be used or whether the entire trip shall be performed on road. Considering roll-on/roll-off transport within vehicle routing models would not only give opportunities for improving environmental performance. In the presence of drivers' working hour regulations as imposed by the European Union, roll-on/roll-off transport can reduce total transit times including driving time, breaks, and rest periods. According to EU legislation drivers can take compulsory daily rest periods while travelling on train or ferry. Methods for scheduling driving times, breaks, and rest periods as presented in [10] can be extended to consider the respective provisions. Planning methods that are capable of considering drivers' working hours in intermodal transport can bring significant advantages as trucks keep moving while drivers take their daily rest.

As efficiency, punctuality, reliability, and sustainability can be conflicting objectives, sustainable transportation planning must consider multiple criteria. Multi-criteria decision making (MCDM) has received increasing attention due to the fact that in many real world decision making problems, decision makers have to deal with several conflicting objectives. Interestingly, multi-objective combinatorial optimization problems have not been studied widely [6]. Even less mature is the research in the domain of multi-objective vehicle routing problems which are surveyed in [13].

Depending on when the decision maker introduces his/her preferences, three approaches to multi-criteria decision making can be distinguished: a priori, a posteriori, and interactive decision making. A priori approaches reduce the multi-objective problem to a single-objective problem by optimising a utility function composed of the weighted sum of the different goals. This concept, however, may be difficult to use as the decision maker may not be able to state his/her preferences in the required way. A posteriori approaches first identify the set of pareto optimal solutions, and then allow the decision maker to select a most-preferred solution. This approach requires the calculation of a potentially very large number of pareto optimal solutions as well as the verification and acceptance of the most desirable solution by the human decision maker. The method by [24] follows this approach. Interactive approaches allow the gradual articulation of preferences by the decision maker and compute a sequence of solutions based on his/her individual statements. Such an interactive approach for multi-objective vehicle routing is presented by [9].

For intermodal transport planning, approaches for multi-objective vehicle routing must be extended in order to consider the additional complexities of the GVRP and it's extensions proposed above. Existing approaches for multi-objective vehicle routing often focus on global criteria such as total costs and total tardiness. For real-life applications, however, the decision on the trade-off between costs, on-time delivery performance and environmental impact depends on the requirements of the specific customers. Thus, a large number of preferences must be articulated by the human decision maker.

Another challenging complexity arising in real-life transportation problems is that computer representations of planning problems are imperfect and problem data are incomplete [19]. Consider, for example, that a shipper asks that a load shall be picked up in the morning before noon, when his dock is not as busy. Consequently, the load is entered as being required to be picked up in the morning. The computer model now treats an afternoon pickup as a service failure, when in fact all the shipper was trying to do was express a preference. Because of the cost of getting information into the computer, a significant amount of relevant information that is available to the human decision makers may not be able to the computer. Therefore, solutions obtained by algorithmic approaches cannot always be fully implemented. According to [20], several motor carriers report that average usage of model recommendations is below 60%, and good performance is considered around 70%. In order to deal with this issue, [14] present a framework for interactive problem solving. The concept is founded in posting a problem to a planning method in order to let it generate a solution. The returned solution usually does not satisfy all real-life requirements. Therefore, dispatchers may add, modify, or remove certain constraints in the analytical model. The modified problem is again posted to the planning method, and after a solution is found, further modifications to the model can be made. A similar approach is presented by [11]. This approach differs from the previous as it allows several dispatchers and the computer to simultaneously and concurrently optimise the problem.

In order to effectively handle customer dependent preferences and the inevitable impreciseness of models for intermodal transportation planning, further research in multi-objective and interactive optimisation is required.

4 Conclusions

Freight transportation accounts for a significant part of total CO_2 emissions in the European Union. In order to improve sustainability a modal shift from road transport to other modes of transport is required. New ways of planning freight transport must be developed, taking into account that today and in the near future, most freight is transported on roads. Transportation service providers must provide more sustainable transportation services taking into account specific requirements of the shippers. Instead of burdening the shipper with the mode choice decision, transportation providers can integrate vehicle routing and mode choice decision within their planning methods. Such an integrated planning tool can not only improve environmental impact of transportation services, it can also generate operational benefits by reducing total transit times. Congested motor ways can be bypassed and transportation services can be planned in such a way that drivers can take their compulsory daily rest periods while travelling on a train or ferry. Towards such an integrated planning tool, future research is required to extend and combine existing approaches for rich vehicle routing, intermodal mode choice, multi-objective and interactive optimisation. Although some of the research challenges discussed in this contribution may be resolved fairly easily on its own, tackling all of these challenges simultaneously will be a difficult challenge that future research will have to tackle in order to develop an effective intermodal planning tool.

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