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A dynamically controlled network for European truckload cargo industry

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Abstract. Production of full truck load (FTL) services has no characteristics of industrialisation yet. Main reason for this is a tight coupling between the working time of ONE driver and the vehicle operating time. Therefore, the value-added share of the truck is - due to statutory driving and rest periods, and the applicable law on working hours for the driver – lower than 30%. Due to a sequential multiple occupancy of vehicles used in truckload traffic, a significant increase of their temporal utilization can be achieved. It provides first methodological approaches to the implementation of developed new production forms within newly conceived freight transport networks, especially for truck load traffic. This paper is about the quantitative results of developing and simulating a new approach. In a theoretical potential analysis with a data set of more than 1.8 millions of shipments of an online based freight market and a corresponding depot network, a quantitative evidence of the effectiveness of the developed and modeled traffic procedures could be provided for the first time. For this moment, the framework conditions were set very simple. Finally, an economical potential analysis, as part of the presentation, revealed a cost advantage of 5%, compared to the classic production form. Therefore, all respective cost and performance factors of different production processes were elaborated and taken into account as well as the expenditure (transport distance) through dynamical routing. This paper will give an introduction into the new approach.

1 Introduction

The production process in full truck load transport is characterized today by a significant lack of productivity. The main reason for this situation is the so called “artisanal” kind of production, characterized by an inevitable driver-vehicle bond (often including trailer), and therefore a tight coupling between working time of the driver (limited by law) and the deployment time of the vehicle. The processing of a transport order is accompanied from the beginning to the end of the contract by the same driver who performs the transport with "his/her truck”. The value added share of the truck (production performance) is – also due to statutory driving and rest periods, and the applicable law on working hours for the driver – lower than 30% [2]. To design road transport more efficiently, the operating times of the vehicles must be extended. No practical imple-mentation of concepts exists in the FTL-Market, while LTL transport networks and industrialized general cargo production successfully exist since many decades. A significant increase in productivity of the truck can be achieved by the use of a driver-vehicle decoupling by sequential multiple occupation with the aim to increase the operating time of the truck regardless of the individual drivers work time. The intended driver change in turn can only take place in in a purposeful way if realized always at the same place (home depot) and it has to

be separated from the actual destination of the transport order. These multi-shift operations have to be implemented according to a new, not previously practiced implementation process. Therefore, the biggest challenge will be to make the overall network robust against fluctuations in volume and temporary individual traffic imbalances. For that reason, a novel system for dynamic routing of the line haul steering settlements and nodes will be developed as a function of the total amounts in the network. The network operation (line hauls) will be the basis for the initial expansion of the network design with the inclusion of alternative transport modes. This leads to a new networking and dynamics of transport processes.

This paper is organized as follows. In Section 2 the conception of the FTL-Network compared to LTL-Networks is shown. Following chapter 3 explains benefits and advantages of the new organization. In the last section, a conclusion and an outlook to further research steps is given.

2 Concept of FTL cargo network

The significant increase of productivity of resources in the national freight transport will be made possible by the following processes [Apfelstädt 2017]:

- Splitting the single-term transport chain in (pre-), main- and post run
- Establishing a network of depots (or regional hubs) with area responsible carriers (thus fixed radius of each vehicle)
- Developing a mathematical model which allows the simulation of this approach to the design, control and assist the network
- Implementation of the respective main runs through an innovative system for dynamic routing of the line steering settlements and nodes in a net-work of fixed shuttle services between the respective depots

The basic idea of the dynamic pairing of FTL cargo main runs between depots, which can be handled by depot shuttle traffic, is a dissolution of the previously fixed transport paths, shown in figure 1.

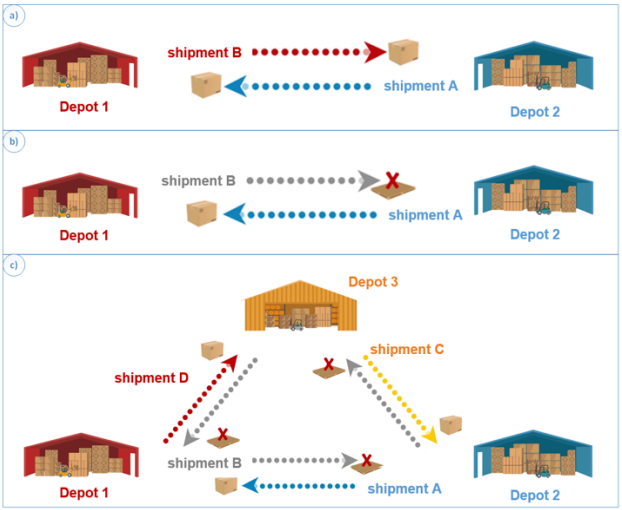

Figure 1. Compensation of unpaired transmission streams by dynamic linkage.

In the initial scenario (a), the shipments A and B can be processed by encounter traffic or shuttle services between the depot (1) and depot (2). Both shipments have to be sent to the respective output depot of the other shipment. If one of the two shipment is not available (scenario (b), shipment B is not available), the available shipment A cannot be processed in preferred way because there would be an empty run from depot 1 to depot 2. With help of dynamic routing, further depots now must be investigated by the matching algorithm. In scenario (c), there is no shipment B which runs in pairs to shipment A, but a shipment C could be identified with the help of a further depot (3), which should be processed from depot (3) to depot (2). Finally, a shipment (D) for depot (3) is also available at depot (1). Thus, by dynamically adapted routing every shipment in the shown figure can be processed by shuttle service between the depots – without any empty run. Furthermore, the mathematical modeling and development of the conceptually described matching variants is not part of this paper. For the first investigations into the efficacy of the various approaches, the results of cooperative work by the author with other authors from the Department of Mathematics are used (see for example [3], [4]).

3 Potential analysis

The potential analysis is based on a data set provided by the electronic marketplace "TimoCom". TimoCom Soft- und Hardware GmbH from Erkrath is one of the European market leaders in field of electronic marketplaces for the transport industry. Transport orders which cannot be processed by self-service of a carrier (that means by own resources) are given to the portal. All other registered freight carriers will be offered these orders to find suitable shipments for their own free

resources. A total of 1.8 million shipment data from this application are available for potential analysis from 68 evaluation days. In order to be able to evaluate data in regard to their potentials to be processed by encounter traffic or shuttle services, a network configuration is needed. Using the postcode areas of Germany provides a solid basis in the first step. To simplify individual area definitions, a few very narrow areas and areas that enclose each other are summarized. So, 86 areas of operation are available for an initial analysis, with 100% areal coverage of Germany. Figure 2 (page 3) is showing all areas and depot locations.

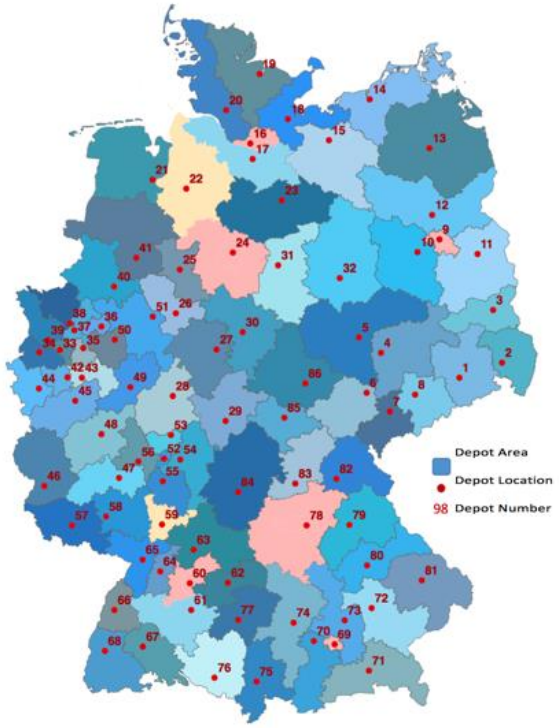

Figure 2. Network configuration

A first, quantitative comparison is showing a low number of matchings which can be identified by "direct pairing" of shipments between the outgoing and the in-coming depots like it's shown by scenario (a) in figure 1, while the maximum permitted distance of outgoing and incoming depot is 500 km.

So without any tool of dynamic paring only 203.760 FTL cargo shipments could be paired ("parallel") and processed by encounter traffic between to depots. By implementing the new approach of the innovative system for dynamic routing into the mathematical model, the total number of matchings could be increased significantly. That means, by using a matching algorithm, following the ideas shown in fig. 1 (scenario c), 444.168 shipment could be paired within the network and can be produced by shuttle services between depot with a maximum distance of 250 km. The total share of networkable shipment increases finally from 11% up to 25%! For more detailed results of this investigation see [1].

The cost indicators available for both production processes are used for a monetary evaluation of the individual shipment data. Based on the daily rates and kilometer rates [5], the transport production is calculated in both methods by using the following key figures (Table 1.)

Table 1. Cost and performance indicators

Index		Name	Direkt-production	Network-production	Unit
c_f	=	fixed costs	**320,81**	**532,04**	€/d
c_v	=	variable costs	**0,652**	**0,63**	€/km
v	=	Ø speed	**65**	**68**	km/h
t_A	=	working time / period	**9,6**	**19,2**	h/d
t_B	=	loading time	**1**	**1**	h
t_E	=	unloading time	**1**	**1**	h
t_D	=	time at depot	**0**	**0,25**	h
t_W	=	time for exchanging trailers	**0**	**0,35**	h
d_T	=	transport distance	x	x	km
d_L	=	distance empty run	**d_T*0,104****	**30**	km
d_U	=	distance detour	**0**	**40***	km

notional indicator for the theoretical model notional
*** (BGL 2014)*

Based on available cost and performance indicators, the equation to be used can be determined as follows:

$$C(d) = (d_T + d_L + d_U) * c_v + \left(\frac{\frac{d_T + d_L + d_U}{v} + t_B + t_E + 2t_D + t_W}{t_A} \right) * c_f$$

For a complete evaluation of transport costs of all shipments, produced in direct traffic, the following equation is determined as a function of transport distance:

$$C_{Dir}(d) = 1{,}104 d_T * 0{,}652 + \left(\frac{\frac{1{,}104 d_T}{65} + 2}{9{,}6} \right) * 320{,}81$$

The evaluation of transport costs of all shipments, produced by the new network approach is to be solved by following equation:

$$C_{Netz}(d) = (d_T + 30 + 40) * 0{,}63 + \left(\frac{\frac{d_T + 30 + 40}{68} + 2{,}85}{19{,}2} \right) * 532{,}04$$

Using the matching algorithm and routing methods of [4], an increase of 31.2 kilometers of total transport distance per shipment was shown in the network scenario. Despite this, a descend of production costs of nearly 3.1 Mio € resulted. A reduction of the anticipated distance of empty runs in the network, to 15 km/per shipment (not 30), will rise the cost advantage up to a final 10 Mio. €. The cost of transport production decreased by nearly 5% in total, using the network process, which allows a significant increase in productivity of the truck, that can be achieved using a driver-vehicle decoupling by sequential multiple occupation with the aim to in-

crease the operating time of the truck regardless of the individual drivers work time.

4 Conclusions and future work

In contrast to previous approaches, the proposed new model of transport organisation is not aim of optimize vehicle disposition and tours, but to ensure a redesigned, systematic dealing with traffic. That means, all vehicles move in a restrictive radius of action and take over the pro rata processing in the transport chain taking place in this field. The drivers' return to the (home-) depot at the end of his working shift will be realized for the first time in this transport segment, regardless of the actual shipment distance. A further improvement of the matching algorithms and routing methods should increase the number of shipment which can be produced within the FTL cargo network concept.

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