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Special Issue:
Production Networks Sustainability

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CIRP Journal of Manufacturing Science and Technology

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Concept of transport-oriented scheduling for reduction of inbound logistics traffic in the automotive industries

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ABSTRACT

Nowadays ecological issues are of high public priority. Within industries namely the automotive sector, often new machines, facilities or technological innovations are the key to ecological improvements. Although it is seen less prominent, logistics play an important role in optimizing the ecological system. Due to the high amount of transport traffic in inbound logistics, small changes lead to substantial savings in CO_2 emissions. Through transport-oriented scheduling this potential savings can be realized. By means of smoothing and bundling demands in scheduling, transport planning can be optimized resulting in increased utilization, avoided transports and reduced CO2 emissions. The developed concept was evaluated by means of a simulation model using real scheduling data.

1. Introduction

Over the last two decades, ecological thinking has been increasingly growing in importance in the public eye. The reasons therefore are often high operating costs [1]. To reduce these costs companies are searching for new technologies and concepts to reduce them. Some solutions can be seen in the design and technologies of buildings (e.g. low-energy housing) or products (e.g. hybrid technology) [2,3]. These concepts focus on new approaches to reduce the need for energy. Another way to reduce operating costs is in raising the efficiency of using common technologies. In logistics both cases can be applied. On one hand new technologies like "green" transports can be used, and on the on the other the amount of transports can be reduced. This paper focuses on the second approach.

Industries with a high degree of customer oriented products often face unsteady demands. This effect is based on a multitude of different configuration possibilities of the products [4,5]. The outcome of customer oriented goods is fluctuations in demand. Especially parts, which are not build in every product. In the automotive industry these parts are called "low-runner-parts". Because of unstable demands, low-runner-parts cause several inefficiencies in logistics, i.e. unsteady traffic volumes at good receipt or low utilization, which raise the overall CO_2 emission in the system [6–8]. Based on the fact that cars have many different parts, the automotive industry can be a beneficiary of this concept.

Upon closer inspection the automotive industry achieves the material supply with two different supply concepts. Full-truck-load transports (FTLs) and less-truck-load transports (LTLs) are also common supply concepts for other industries like the paper industry. The differences between these concepts can be found in flexibility and costs. *Full-truck-load transports* can be used when demand is constant and high over a certain time-period. The outcome is high utilization. These transports often deliver high-runner parts. The supply times are specifically as signed by transport planning. On the other hand, *less-truck-load transports* are very flexible and deliver mostly low-runner parts [9,10]. Because of the high flexibility of LTL transports the transportation costs are higher than the costs of a FTL. An application analysis of these supply concepts shows that a good deal of incoming trucks per day is using the supply concept LTL. In comparison with FTL the chargeable weight is very low (Fig. 1).

Transports with LTL concept represent the ideal area to reduce logistics costs and CO_2 emissions by reducing the amount of necessary LTL transports. The approach, which will be described in this paper, is to smooth and bundle demand of low-runner-parts to increase utilizations of transports and reduce transport costs through avoidance of transports. The starting point for the development of a transport-oriented scheduling approach is the analysis of the planning processes employed by the automotive industry. Other industries with products which have to be scheduled are operating in similar ways.

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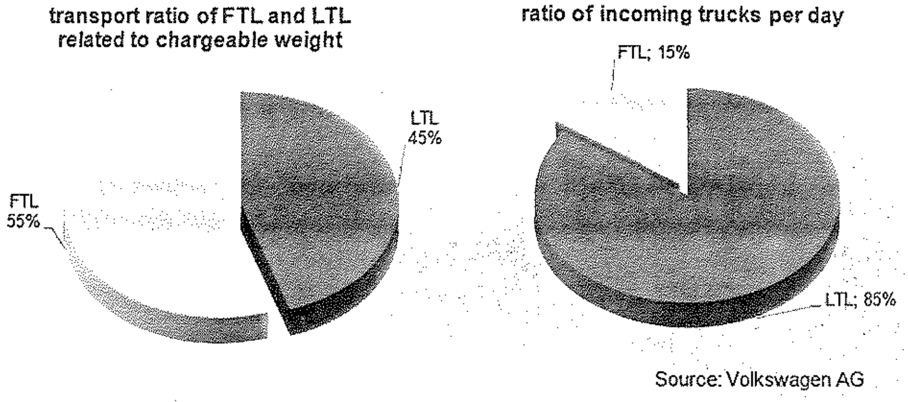

Fig. 1. Ratio of full-truck-loads (FTL) and less-truck-load (LTL).

2. Actual planning processes in automotive industry

One important objective in the automotive industry is to assure the building of cars with low lead and supply times, low stock and high flexibility [11]. Regarding inbound logistics, the primary objectives are to guarantee low supply times or low waiting times in the dispatch area, in order to minimize costs. Due to these circumstances and other requirements, processes in the automotive industry are very complex. The sources for all processes are the customer orders. These orders are attributed to weeks in which diverse factors are considered. Factors for example can be restrictions from sales or productions plants. After smoothing customer orders over the weeks, the scheduling times all orders on the basis of planning restrictions into a defined tact. To avoid overload in the assembly stations the production restrictions have to be considered [12]. Here on the disposition dissolve the customer orders into demands for the inbound logistics. With this and other logistical information disposition determines time and amount of demand for materials from the suppliers [11] (Fig. 2).

2.1. Processes of scheduling

The task of the scheduling process is to schedule the customer orders into the right time slots. To reduce the complexity for this process all orders are constantly scattered over a volume of a week. On one hand therefore delivery times of the cars, on the other the ability to build all orders in a week has to be considered by restrictions which are based on production restrictions. In a second step, the orders of a whole week are scheduled into the right sequence [13].

Planning restrictions define rules for the sequencing to avoid overloads in the assembly stations. Therefore OEMs use different algorithms to sequence the orders. Beside mixed-model sequencing, car sequencing or level scheduling is forms of applying orders to a tact. These models assure a consideration of different lead times of orders as a result of different variants [12]. Car sequencing, for example, is overload oriented. It does not or will not work with detailed car configuration information, but ban overloads of partial sequences with so-called Ho:No rules. After the appliance of the algorithm on the entirety of the orders, from No sequenced variants the maximum amount of Ho options can be included to assure no overloads. One example for a rule of 1:3 for the option sunroof says that from three sequenced orders only one order can contain a sunroof. Most of the Western European OEMs use the car sequencing algorithm [14].

After the planning process the sequenced orders are transferred to disposition to initiate the supply of demands.

2.2. Processes of disposition

Processes of the disposition are based on the sequenced orders of the scheduling process and on the actual transport network. The task for the disposition is to assign the demand of the production to the available transport capacities, which were planned in the transport planning process. By defining the supplied demands, the disposition has to consider on one hand safety stocks, stocks in the warehouse and other stocks and on the other the worth of goods and the fluctuation of demands. Because of stocks the disposition has to appoint the right time and amount of demand to get it delivered in time.

To determine the right time of material delivery, the disposition has to run a backwards scheduling where the transportation times are considered (Fig. 3). Therefore an ideal dimensioned supply batch for a part is essential which has been calculated by the disposition. Initial point of the backward scheduling is the first need of a part out of this batch. This guarantees that all parts are supplied when the demand is needed in the production. Besides transport duration, the disposition has to consider the safety stock

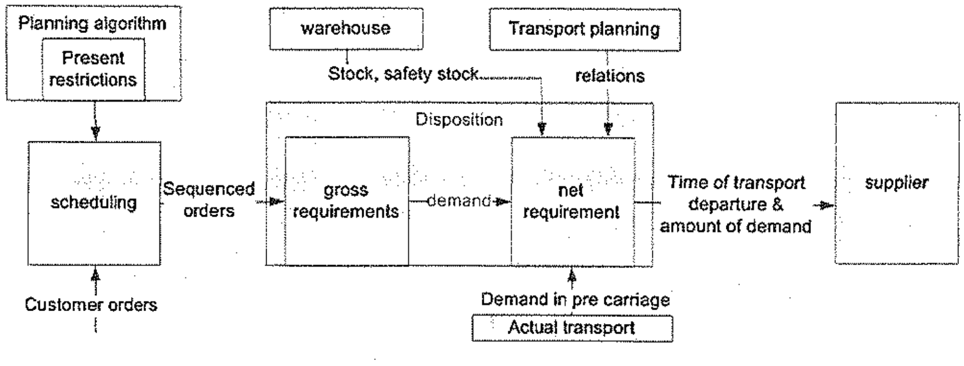

Fig. 2. Linkage between scheduling and disposition.

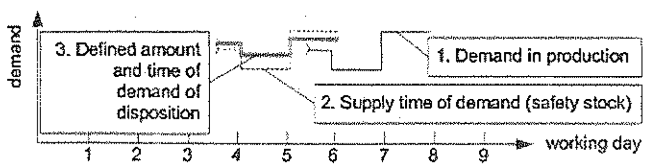

Fig. 3. Determination of amount and time of demand.

or "safety days". When the safety stock is high it is possible to adjust the planned supply time. This configuration element is also important to define the right transport concept. While using FTL or milk-run, a certain planned day has to be kept because these concepts are bases of stability. LTLs are more flexible and therefore supply days can be adjusted every time. This implies that high stocks could enhance the use of FTLs or milk-runs. By an economical view this approach is not sustainable.

To determine the right amount, disposition aligns the gross demanded requirements of a viewed period of sequence planning with the actual stock in warehouse and demand in pre carriage. The gross requirements are derived from manufacturing resources planning (MRP), where orders have been broken down according to the part list. They describe the total demand of these considered orders [11]. The net requirements describe the demand which is needed to guarantee no production stop in the factory. To raise the utilization of the bins the net requirements are rounded up to the capacity of the transport equipment. In case of an FTL or a milk-run, the demand is rounded up a second time to achieve high utilizations of the transports. If an LTL is used the demand will not be rounded up a second time.

2.3. *Inefficiencies in actual planning processes*

Because of the reactive character of disposition, the inbound logistics is operating on an inefficient level. Low utilizations or unbalanced part arrivals can be identified (Fig. 4). Besides higher logistics costs this also causes unnecessary CO_2 emissions. Especially OEMs, which often are located in urban areas and therefore have limited space for production, have to plan the arrivals of supplier transports very accurately.

To smooth the incoming traffic volume or bundle demands, the part requirements have to be shifted in the scheduling. The starting point for an optimization is to link the scheduling with disposition to become additional sequencing information within the logistics. Hence, a new concept has to be developed, where sequence planning is expanded by logistical parameters.

3. Concept of transport-oriented scheduling for reduction of inbound logistic traffic in the automotive industries

To optimize the transport logistics in an efficient way it is important to understand the behavior of the system. The system changes the behavior when the orientation changes. Fig. 5 shows an overview of dependencies of system orientations. System orientations in the second quadrant are called active components, since they have a strong impact on the system and are weakly influenced by the system. These objectives have the highest positive leverage effect on the others [15].

When exploring stock movements it shows a direct link to the transport logistics and the production. Transports bring the parts into stocks where the production requests defined parts which are timely appointed by the scheduling. Based on a constant stock movement the scheduling has to smooth the demand over a certain time period. Fast stock movements require a bundling of demand in the scheduling.

Because of this characteristic, constant stock movements (smoothing) and fast stock movements (bundling) constitute the fundament of the transport-oriented scheduling:

- Smoothing of demand

  Smoothing means realizing a steady demand of parts. The resulting constant stock movement and flow of parts provide a basis for a steady transport schedule [16].

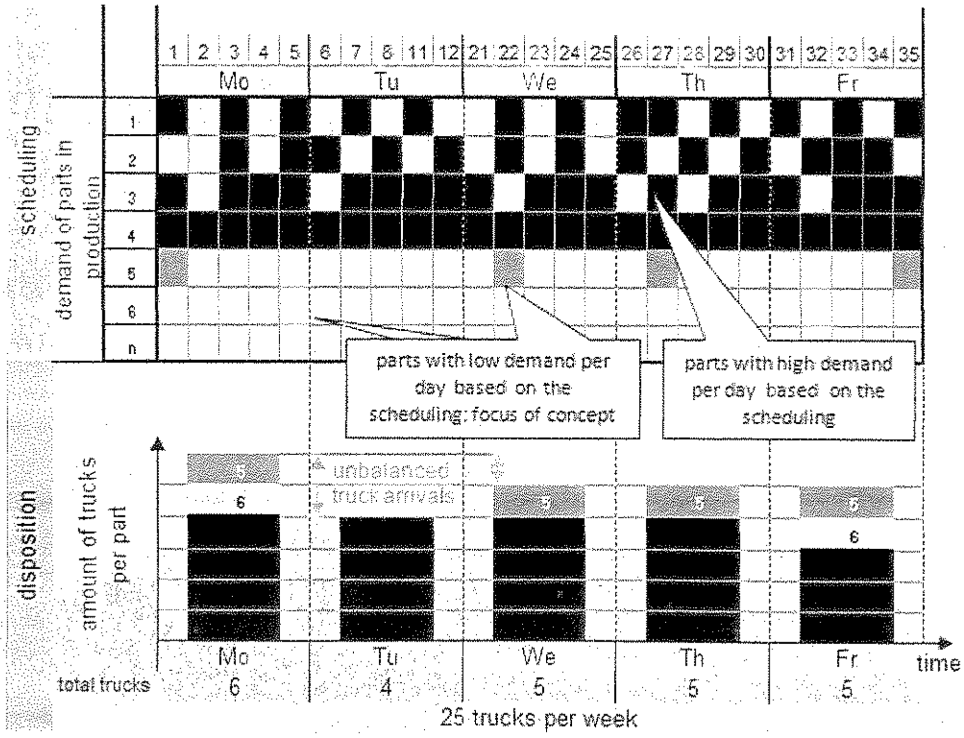

Fig. 4. Sequence related demand of parts and transportation capacities.

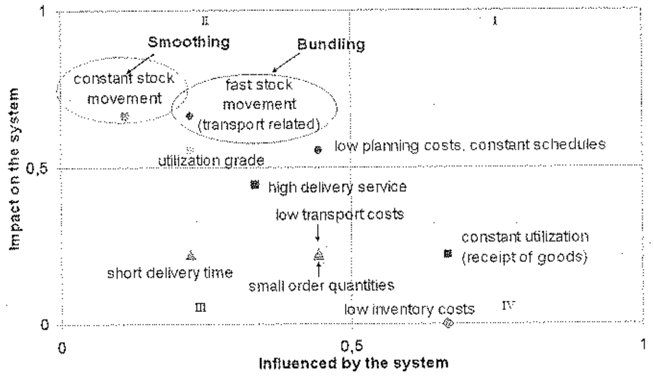

Fig. 5. Work dependencies of system orientations.

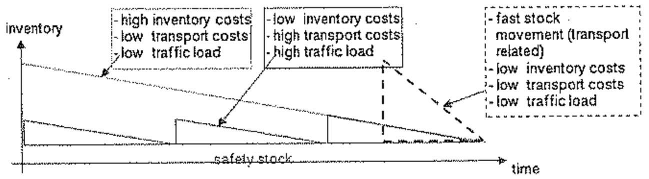

Fig. 6. Low inventory, transport costs and traffic load through bundling.

In consideration of mass customization, a constant demand exists only for parts with a high installation rate as mentioned in Fig. 4 (parts 1–4). Typically these parts are frequently sourced from supplier parks or with lean JIT transports that are within close proximity [17]. For those parts FTL transports or milk-runs are mostly applied.

- Bundling of demand

Bundling means; concentrating the demand of certain parts into a shorter time span. By bundling parts, which are supplied over the same transport relation, high transport utilization and low inventory costs can be achieved.

Parts with a low installation rate (parts 5 and 6 in Fig. 4) are characterized by sporadic demand. The demand of these parts is based on the highly individual configuration packages of a car. Fig. 6 shows how low runner parts can be supplied to the factory. Low-loaded FTLs (red line) generate high inventory costs but guarantee low transport costs and traffic loads. Using LTLs (blue line) low inventory costs but high transport costs and high traffic loads are produced [18]. To realize low inventory and transport costs as well as low traffic loads, the demand of low runner parts has to be concentrated in the scheduling (black line).

Economical bundling effects cannot be realized by all low runner parts. Reflecting the system orientations of inbound logistic, only the most relevant parts and transport relations should be considered. Relevant factors are:

- Long distances between source and sink. The longer the distance the higher is the saving potential of transport costs and pollutant emissions.
- The amount of different types of parts. The smaller the amount of different types of parts, the smaller the amount of transport-/part related restrictions
- High inventory costs. The higher the inventory costs, the higher the present transport frequency and therefore the saving potential of transport costs and emissions.

Smoothing and bundling of demand constitutes the fundament of the developing concept. Smoothing of demand is a general focus of scheduling. This has to be applied on parts with high installation rates. Bundling of demand focuses on parts with low installation rates. In this respect, a smoothing of low runner parts should also be considered over a long term horizon. For the concept of transport-oriented scheduling, smoothing describes the basic orientation. The big effect of reducing transport traffic can be achieved by bundling of low runner parts. This will be the focus of this concept.

To consider additional information in the planning processes, a link between disposition and scheduling has to be provided (Fig. 7). Therefore transport restrictions have to be defined which include information about the bundling-relevant parts. These relevant parts have to be found by an analysis based on the factors which are mentioned in Section 2:

- Considering relations with low supply volumes (FTL).
- Considering relations with high frequented supplies.
- Considering supplier relations with less combination of properties. A property in the automotive industry defines a car-configuration element which can be chosen by the customer (e.g. engine, sport packet, and rims). Because of the impact of combinations on the components (e.g. different types of water tanks concerning the type of engine) this consideration is very important for the concept.
- Considering expansive parts.

After finding these part restriction bases on the car sequencing algorithm (Ho:No) have to be defined.

After defining all relevant restrictions the scheduling algorithm has to smooth and bundle the demands. Considering transport restrictions at the scheduling, the amount of trucks over a defined time period are smoothed and reduced by bundled demands (Fig. 8).

As a consequence of the accelerated stock movement and high order quantities, the amount of truck deliveries for parts 5 and 6 decreases from 6 to 2 deliveries per week. Gaining these

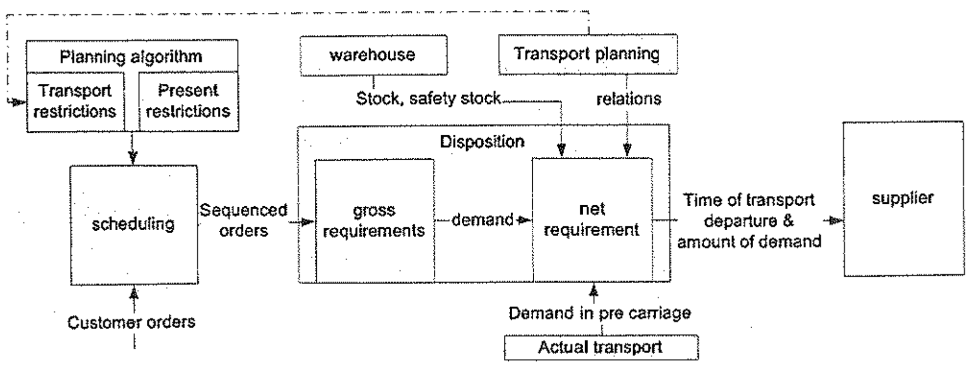

Fig. 7. Integrated process of transport and scheduling.

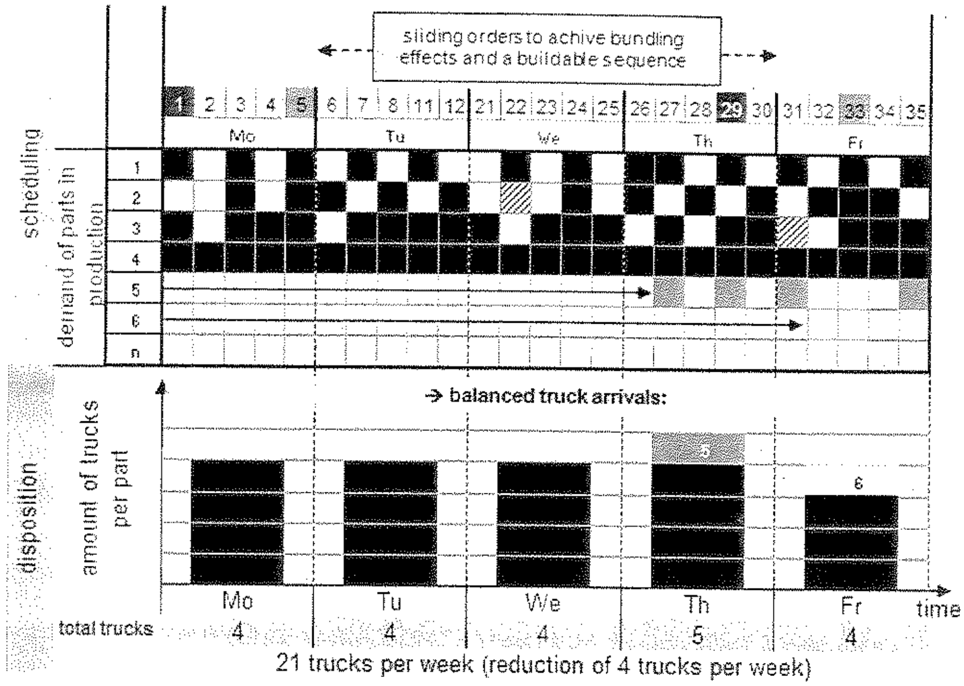

Fig. 8. Bundled sequence concerning to parts 5 and 6.

advantages means accepting a changed demand of other parts like 2 and 3. Change of orders is accepted as long as the present restrictions allow it.

An evaluation of the feasibility considering transport-related restrictions was made. The results, based on authentic data and a car-sequencing algorithm of a German car manufacturer, are introduced in the following section.

4. Evaluation of transport-oriented scheduling

A production plant which produces two different models on two separate lines was chosen for the evaluation. The production volume of model A amounts to 3000 and model B to 1300 cars per week. The considered time horizon amounts 5 weeks.

First of all, relevant parts and suppliers have to be identified. Therefore all suppliers were scanned by the distance to the production plant, the amount of different parts, the average chargeable weight and the delivery frequency. A rating of these factors generated a rank which shows the relevance of the supplier by the concept. The case study showed that only 7 suppliers fit in the requirements of the bundling concept which were mentioned in Section 3. Considering the high numbers of OEM suppliers the concept targets only on a limit amount (Table 1).

After identifying the relevant suppliers transport restrictions were defined. The definition of transport restrictions was based on Ho:No rules. The initial situation for the case study was a scheduling without transport restrictions. According to the rank of the suppliers, the transport restrictions were considered sequentially in the scheduling. The amount of transport restrictions was gradually increased, until they came into conflict with one of the present restrictions. The consequences of the implementation are presented in Table 1.

As can be seen, noticeable reductions of the transport frequency could be achieved for the selected suppliers. The total sum of transport-deliveries, pictured in Fig. 9, could be reduced by 2.5–3.0%, depending on the amount and priority of the present restrictions. This small reduction is based on the high rate of truck deliveries per day and the high amount of suppliers. The identified suppliers constitute only some percent of all suppliers.

The reduction of the delivery frequencies causes a decrease in the pollutant emissions. The mentioned effects basically depend on the transport utilization of the pre and main carriage.

On closer inspection of the computing runtime there was no rise identifiable. This results because of a definition of a minimum of additional Ho:No rules for this concept.

Table 1
Selected suppliers and consequences of transport-oriented scheduling.

Supplier	Rank	Distance (miles)	Amount of different parts per supplier	Average chargeable weight (m^3/week)	Average delivery per week (present restrictions)	Change through concept	
						Average delivery per week (present + transport restrictions)	Change (%)
Supplier 1	1	320	2	36.35	3.80	1.80	−52.63
Supplier 2	2	300	2	23.45	2.60	1.60	−38.46
Supplier 3	3	350	3	13.67	3.20	2.20	−31.25
Supplier 4	4	270	2	18.89	1.80	0.80	−55.56
Supplier 5	5	370	2	24.53	4.60	3.60	−21.74
Supplier 6	6	200	3	30.16	3.60	2.60	−27.78
Supplier 7	7	330	2	32.34	2.80	1.80	−35.71

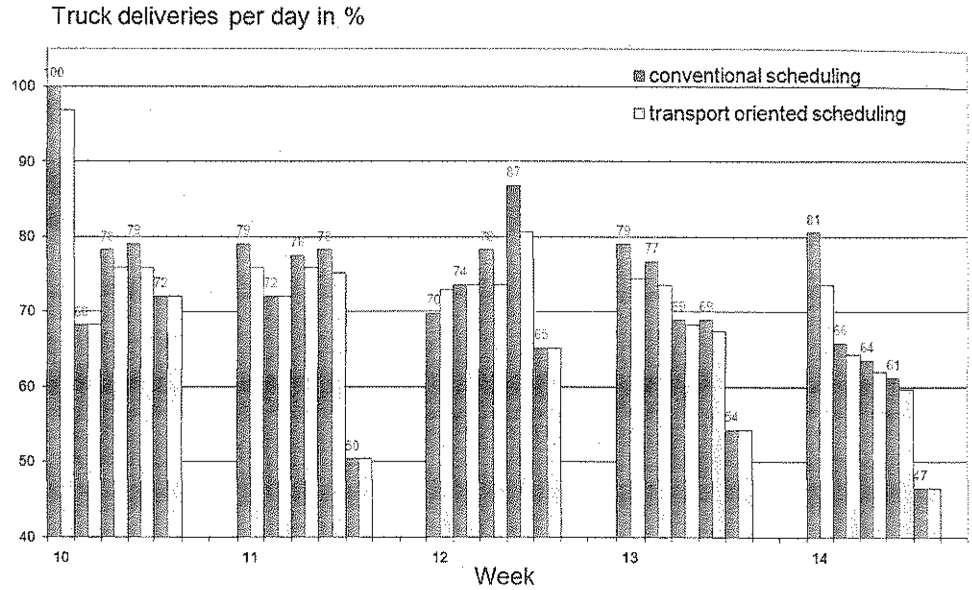

Fig. 9. Linkage between scheduling and disposition.

5. Summary

Considering that transport-related restrictions like bundling at the schedule-planning are possible due to the amount and priority of the present restrictions, the possibilities to expand the transport restrictions are limited. The evaluation with a time horizon of 5 weeks shows that the reduction of the total sum of transport is limited to 3.0% maximum. This deals with the limited number of suppliers which can be considered by the concept. Nevertheless the transport oriented scheduling allows the reduction of traffic and emissions for a limited selection of the most polluting and expensive relations and parts.

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