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COMBINED CALL-OFF AND TRANSPORT CONTROL FOR MILK RUNS BASED ON ORDER PEARL CHAINS IN THE VEHICLE SECTOR

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ABSTRACT: Milk runs and pick-up-tours controlled by OEMs are transportation modes which have strongly been discussed in the vehicle sector for many years now. At the same time, they have not been broadly applied yet. The following paper differentiates these concepts from the consolidated freight and the direct transportation mode. After this, the paper focuses on the special concept of order pearl chain controlled milk runs. It is shown which organizational, process and control attributes are crucial to a successful implementation in practice. The paper closes with a case study on the monetary potential of milk runs.
KEYWORDS: milk run, pick-up-tour, pearl chain, transportation mode, control

COMMON TRANSPORTATION MODES IN THE VEHICLE SECTOR

Within the terminology of inbound logistics one is often encountered with transportation mode and supply concept. Both terms are related to the physical process from suppliers to their customers. But while supply concepts are coined by the way material is buffered inside and outside the customer's production site, transportation modes can be distinguished by the number of hubs and the way material is consolidated. In the vehicle sector, supply concepts can be split up into concepts with or without warehousing [1]. Warehouse-less concepts are commonly known as just-in-time (JIT)- or just-in-sequence (JIS)-concepts. Wide spread transportation modes encountered in the vehicle sector are direct transportation and consolidated freight (cf. figure 1).

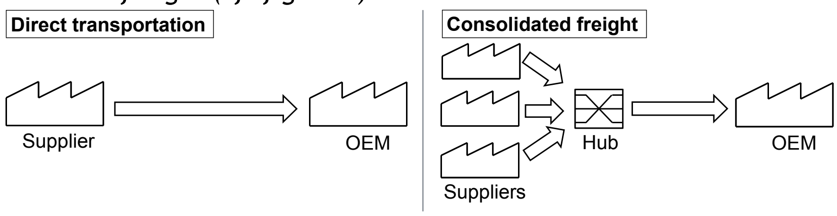

Figure 1 - Main transportation modes in the vehicle industry

Direct transports are mainly run for the bigger suppliers that supply enough to fill up a whole trailer at the customer's required frequency. Usually, OEMs (Original Equipment Manufacturers) call off material; suppliers advise the carriers for shipment, who plan and carry out the transports. The advantages of this concept are reduced freight cost and effort at the receipt of goods owing to a high degree of capacity utilization, a simple transport control and no handling effort in hubs [2]. On the other hand, it can lead to high stocks and inventory ranges if transport frequencies are low. Therefore, for smaller suppliers the consolidated freight transportation mode is used. The transport chain is divided up into at least two parts: the pre-run of part loads to a hub close to the suppliers, the main-run and, where appropriate, the post-run [3]. Vehicle producers select and charge different carriers with consolidating material in fixed areas. Generally, these carriers already dispose of their own hub-and-spoke-networks. Areas can be postal code regions, federal districts or countries, for instance. This type of organizing the transport is also called area freight forwarding concept. Normally, the carriers do not only get transport orders from one OEM's production site, but also from other production sites of the same OEM or other OEMs. Thus, synergies can be raised. For example, the material can be picked up at suppliers for several customers at the same time. In hubs nearby, the goods can be bundled to common transports according to their destinations. This way a high degree of capacity utilization can be reached without reducing the transport frequency. In return, costs for operating the hubs and planning the transports arise. This concept is only used for supply concepts with warehousing, while the direct transportation mode is applied for supply chains both with and without warehousing.

Alternatively, material can be gathered and forwarded in so-called milk runs or pick-up-tours (cf. figure 2).

In contrast to the other transportation modes, milk runs and pick-up-tours are planned by the OEM itself. One after another part loads are collected from the suppliers. Usually the order and the time tables of the tours are fixed [4]. In the case of milk runs, empties are included in the transport. The transportation process starts at the OEM with empties. At every stop, empties are exchanged with full containers until the trailer reaches the OEM with full containers only. Compared to other transportation modes, the concept of milk run is based on an increased communication effort to ensure a trouble-free supply process for the OEM. To set up such a system with the required level of reliability, high demands are made to the transportation infrastructure and communication network.

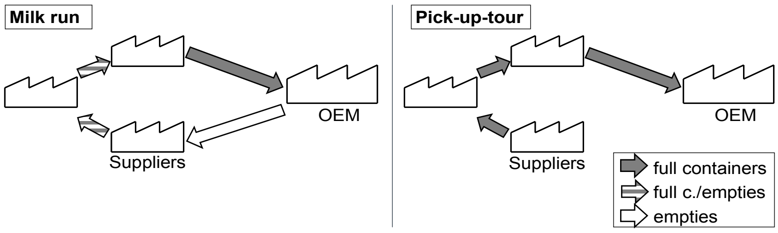

Figure 2 - Milk run and pick-up-tour

If suppliers of former direct transports can be combined to milk runs, frequencies can be raised; stocks and tied capital can be reduced. However, additional stop-overs and a further journey increase the transport costs. In comparison to the consolidated freight concept, the handling in hubs can be avoided, while synergies with other production sites and/or OEMs do not apply any more. In the following, milk run will be used as a generic term for all types of milk runs and pick-up-tours.

MORPHOLOGY OF MILK RUNS

Besides the integration of empties, there are several other attributes which characterize milk runs. Table 1 shows the different attributes and their corresponding options in a morphological box.

Table 1 - Morphology of milk runs

	Attribute	Option		
1	Supply concept	With warehousing		Without warehousing
2	Place of use	Pre-run		Main-run
3	Distance to recipient	Close to recipient		Far from recipient
4	Number of recipients and places of unloading	1 recipient 1 place of unloading	1 recipient >1 places of unloading	>1 recipients >1 places of unloading
5	Type of loading	Side loading		Rear loading
6	Return of empties	1:1	Unpaired	Separate
7	Transport cycle	Static	Dynamic (cycle time)	Dynamic (suppliers)

Analogues to the direct transportation mode, milk runs can also be applied for supply concepts with or without warehousing. They can be used in pre-runs as well as main-runs. Pre-run milk runs can be integrated into the area freight forwarding concept with the same advantages and disadvantages. This paper only focuses on main-run milk runs that are operated by OEMs. Baudin [5] distinguishes between local and local-far milk runs. The main difference is that local milk runs can be driven within a day, while local-far ones take more time respecting legal rules for driving time and rest periods. Moreover, the more distant the suppliers are, the higher the transport risk is. For possible hesitations at stops and traffic jams, the risk also rises with the number of participants in a milk run. This also includes the number of recipients. Theoretically, they can vary from one to a few. However, this only makes sense if the OEM operates production sites that are close to each other. The number of places of unloading depends on the shipped goods. Another distinctive feature of milk runs is given by the trailers that are used. Some allow for side loading, others rear loading only. It is recommended to employ trailers with side loading because it eases the handling owing to a better access to all the units.

As described above, milk runs may include empties. If so, a 1:1- as well as an unpaired exchange of empties with full containers is possible. Unpaired exchanges arise if empties can be collapsed. Lastly, it can be distinguished between static and dynamic milk runs. Static milk runs correspond to fix routes and transport schedules. Dynamic milk runs can relate to varying time-lags between transports or the number and names of the suppliers that are integrated in a milk run. Varying time-lags arise if the capacity of trailers is taken into account by the control. Usually, OEMs dispose of more accurate information on future demands than carriers. Therefore, with a capacity-related control a reduction of transport costs is expected.

PEARL CHAIN CONTROLLED MILK RUNS

One of the main aims of transportation logistics optimization is the reduction of transportation costs. The concept of milk run contributes to this objective by trying to use the trailers for the transportation of goods to full capacity. To realize the efficient use of shipping space on trailers, a change in philosophy has to take place when it comes to the planning of transports. In contradiction to other established concepts of transportation planning, the principle of strict transport schedules has *to be abandoned. With regard to transportation costs, the most efficient way to use milk run in the vehicle production industry is to consolidate goods until a trailer is fully loaded and then launch the concrete milk run tour. As a consequence the pick-up times at the supplier's factory site now become dynamic and will change from one planned milk run tour to the other. The main reason is the varying consumption rate of different prefabricated parts from the same supplier in case of multi-variant products of the vehicle production industry.*

In contrast to planning concepts based on fixed pick-up times and varying trailer capacity utilization, milk run requires the consideration of a trailer's capacity already at the OEM's material planning. In the vehicle production it is common practice that suppliers are responsible for the planning of transports to the OEM's factory site. The OEM only provides them the information on when the purchased goods have to arrive. For the planning and control of milk runs, the OEM now also provides information about dynamic pick-up times for trailers to the supplier and the carrier. In this context, the timestamp to schedule a trailer arises out of the most urgent needed part of all prefabricated parts that are planned to be loaded on the trailer.

In the trailer planning process, the decision if a single part should be loaded on the current or the following trailer has to be made very often. To ensure a safe coverage with the needed parts from the supplier at the OEM's production site, the appropriate basis for this decision is the time of demand. For example, a trailer is partially filled with needed parts for one day. The time to arrive at the OEM's factory site is already determined by the most urgent part planed for the trailer. According to an efficient use of trailer capacity, the free space on the trailer now has to be filled with parts that can be picked up on the milk run route. In order to decide which prospectively needed parts should be additionally loaded on the trailer, the exact time of demand has to be considered. But the knowledge just about the day of demand would be too improper in this case. A reliable milk run planning method needs more detailed information about the time of demand, if for example needed parts for one production day have to be split up into several trailers. Now the question is where the information about the time of demand on the required detail level should come from.

In the vehicle production industry, the pearl chain concept is commonly used and understood as the principle to strictly follow the planned and fixed sequence of orders throughout the complete production and even the planning cycle [6]. Based on this fixed sequence of orders, a reliable short-term forecast about future demands is possible. As the pearl chain itself is determined by the cycle of the production line, it is possible to predict the need of parts at the level of single minutes. This informational background allows deciding on a part's time priority compared to others.

Currently, the pearl chain information is used for JIS or JIT direct supply, only. However, it can also be applied to milk runs. A pearl chain control requires a strict abidance of the pearl chain throughout the production. The results of a so-called order pearl chain controlled milk run are shown in figure 3. In the example, three different suppliers are combined to a milk run. The prefabricated parts of every supplier are assigned to a certain line station. Such a supplier specific part cluster can consist of different parts that are built-in at the same point in the production line. The built-in rate for all part clusters in the shown example is smaller than 100%. This means not every vehicle in the pearl chain needs one of these parts. In consequence of a varying built-in rate throughout the pearl chain, the composition of a trailer differs from its predecessors and successors. Another assumption for this example is that each trailer covers approximately the same period of time at different points in the production line with its parts loaded. This can be the case if different JIS or JIT part clusters and suppliers are combined to a milk run and a strict warehouse on wheels concept is carried out at the OEM's factory site. As a consequence of only one single unloading place for a direct shipping of loaded parts to the different line stations, all part clusters on the trailer have to be dissipated at the same time. This is essential in this case to ensure a safe coverage with parts for every line station. As the future needed parts are stored on the next trailer, it can only be unloaded if the former trailer is empty and has left the only defined unloading place for this milk run.

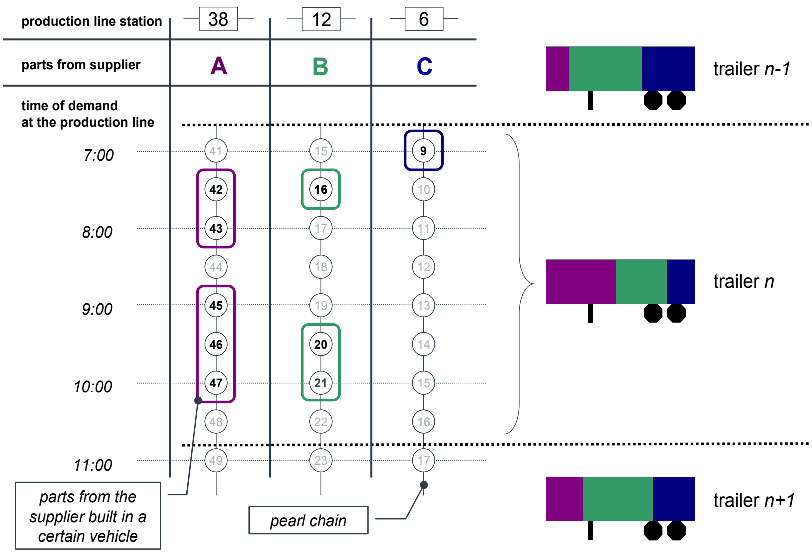

Figure 3 - Order pearl chain loaded trailers

CRITERIA FOR A SUCCESSFUL IMPLEMENTATION IN PRACTICE

With regard to a successful implementation of the milk run concept, several points concerning organizational attributes, processes and control have to be considered.

From an organizational point of view, three general spheres of activity shown in figure 4 can be identified with regard to identification an implementation of milk run. When it comes to the identification of milk run routes with a cost saving potential, a reliable data base is very important. At first, a system of freight rates especially designed for milk run is necessary. This must be given by the carriers to be able to calculate a cost saving potential that can be realized without further negotiations. Furthermore all necessary internal data has to be provided. This concerns basic logistic data such as weight, volume, future demands, and geographic data. It is also important to have an overview about actual transportation costs and an evaluation of which suppliers can actually be integrated in a milk run route.

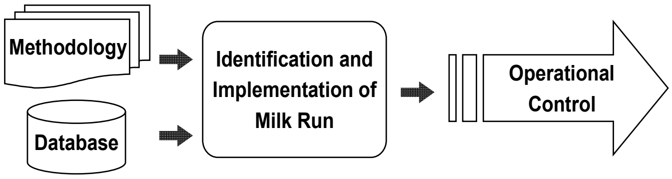

Figure 4 - Spheres of activity for implementing milk runs

A standardized methodology for the identification of an implementation is a basic precondition to realize cost saving potentials in the case of milk run. To avoid steps of manual planning and iteration, a powerful software tool is needed to consider and analyze all the necessary data and suggest possible milk run routes as a result. Furthermore the responsibilities within an OEM's organisation have to be cleared, as milk runs usually involve many divisions of a company.

For a contemporary implementation of a concrete milk run candidate, it is essential to have a predefined and established operational control. Just changing a standardized control's parameters to set up a milk run will help to reduce a milk run's go live period to a minimum.

When it comes to the physical process, the integration of empties is an important point to consider. In sophisticated theory milk run concatenates the transportation of incoming goods and empties in the concept of an integrated milk run solution. In consequence, transportation costs are reduced to a minimum, as the trailer is always filled to full capacity with empties, full containers, or a mixture of both. In order to avoid rising stocks of empties at the supplier's or the OEM's factory site, it is necessary to return the empties to the supplier as close as possible to the time they were delivered to the OEM. To reach this aim, two basic approaches are imaginable, both are visualized in figure 5.

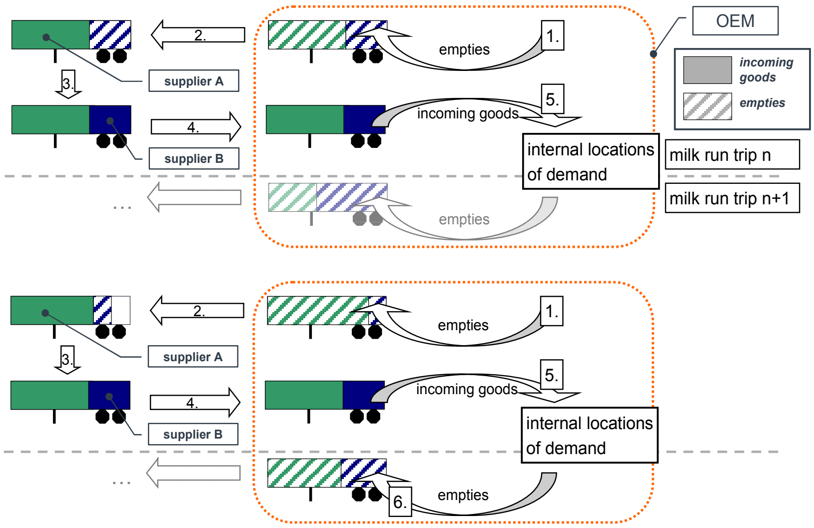

Figure 5 - Alternative redelivery processes of empties

The first concept presupposes to start at the OEM with a trailer of empties, whose composition is exactly equivalent to the incoming goods that are planned to be loaded on this trailer throughout this milk run trip. As the ratio between the container types may vary from trip to trip, a stock of empties at the OEM's factory site is necessary to counterbalance these fluctuations.

The second solution is to send back a trailer of empties with a composition corresponding to the amount of containers that were loaded on the last trailer which arrived. Because of regulations concerning the order that goods can be loaded on a trailer and the limited space claimed by the empties, a switchover of the supplier sequence in the milk run can be necessary from trip to trip.

All in all, the integrated redistribution of empty containers makes high requirements on the discipline and the operative processes. If a decision on an integration of empties shall be made, the first alternative is preferred. The second one with its dynamic routes may lead to disadvantageous detours. Moreover, time delays may arise due to incompatible suppliers' pick up time windows. The only exception concerns a built-in rate of 100% for all parts transported on the trailer. In this case, every trailer has the same composition with regard to boxes, whether they are full or empty on their way back to the suppliers.

Another point affecting the physical processes in case of milk run is the trailer handling at the OEM's factory site. What was once transported on separate trailers is now concentrated on one single

trailer. As a consequence, this single trailer now possibly has to be unloaded on several locations within a factory site. In general, 3 major categories of trailer unloading can be quoted:
- *direct unloading to the warehouse,*
- *unloading to a footprint close to the place of demand,*
- *using the trailer as a warehouse on wheels, unload goods piece by piece according to the demand.*

What has to be especially considered is the sequenced unloading of a trailer. It is not always possible to move a partly unloaded trailer to another unloading place. The major aspect in this case is the lashing service of the remaining containers on the trailer. This circumstance has already to be considered on the general design of a milk run. To allow several unloading locations despite this fact, the sequence of suppliers in the milk run has to be arranged the way a partly unloading process at the OEM can be realized. Another solution to avoid this planning problem is to define a central goods entrance, from where all good are distributed to their different places of demand.

When it comes to the operational control of milk run, a major question is who is to do the time planning of milk run trailers. On the one hand, the OEM itself could do this planning and provide the information to the carrier. On the other hand, the carrier is predestined for this job, as the daily planning oft transports is his major business. From a customer's view, and to focus only on what helps to optimize his products and production, the only thing that matters is the precise arrival of the trailers. So it would just be consequent to deliver the concrete time planning of the trailers to the carrier.

Furthermore, the loading of the trailer is an important point to consider when planning a milk run, as the efficient use of trailer capacity is a major precondition to realize cost saving potential. From a general view, there are two options. The first solution is to provide the suppliers with the information about the goods that should be loaded on the trailer. Eventually some general rules are provided by the OEM, what can be stacked for example. How the suppliers finally load goods on the trailer is their decision. Another solution is to give an exact packing scheme that is generated for every milk run trip. By doing this, the OEM can ensure an effective use of the trailer's capacity, corresponding to the packing algorithm used for planning. On the other side, this solution demands much more effort and discipline from all participants in the milk run.

CASE STUDY: PARAMETER ANALYSIS ON THE MONETARY POTENTIAL OF MILK RUNS

Using the example of a German commercial vehicle producer, the monetary potential of milk runs in comparison to the area freight forwarding concept and the direct transportation mode is examined. The current tariff structure of the latter transportation modes is qualitatively shown in figure 6. The empties process is not considered.

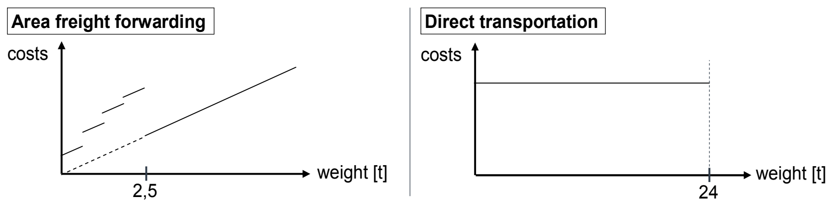

Figure 6 - Given tariff structure

In the area freight forwarding concept, the regarded OEM has to pay the total costs of C_A, which includes the main-run costs C_M, if the load weighs less that 2.5 tons, additionally the pre-run costs C_P. C_P is given in a transport cost matrix depending on intervals of the transported weight m and the distance $d_{S,Hub}$ between suppliers and the consolidating hub. The main-run costs C_M are linear with cost rate C_M only depending on m with maximum load m_{max} = 24t. The costs of direct transportation C_D are constant for a given distance $d_{S,OEM}$ between the supplier and the OEM. Since a milk run tariff does not exist yet, it has to be derived from the direct transport tariff. Assuming the direct transport costs are composed of twice stop costs C_S for loading and unloading as well as driving costs, an average cost rate per kilometer $\bar{c}_{km}$ can be calculated as

$$\bar{c}_{km} = \frac{\sum_{j=1}^{n_D} \frac{C_{D,j} - 2C_S}{d_{S,OEM_j}}}{n_D} \qquad (1)$$

with n_D = number of suppliers in the direct transportation mode within the considered area. With n_{MR} = number of suppliers in a certain milk run and d_{MR} = milk run distance, the milk run costs C_{MR} can be estimated as:

$$C_{MR}(d_{MR}, n_{MR}) = \bar{c}_{km} - d_{MR} + (n_{MR} + 1) \quad C_S \qquad (2)$$

Assuming an average milk run capacity rate c of 85%, the average load transported equals $a = c \bullet m_{max}$. If the stop costs of unloading and the driving costs are divided between the involved suppliers, the milk run costs per supplier are:

$$C_{MR,S}(m, d_{MR}) = C_S + (\bar{c}_{km} \bullet d_{MR} + C_S) \bullet \frac{m}{a} \qquad (3)$$

The milk run potential related to a supplier is the minimum delta between the supplier's milk run costs and the area freight forwarding costs ($\Delta C_{MR,A_S}$), rather the direct transport costs ($\Delta C_{MR,D_S}$). In our model, we assume the same kilometer cost rate for milk runs and direct transports as well as identical costs per stop. Thus, the supplier's milk run potential ΔC_{MR_S} calculates as:

$$\Delta C_{MR_S} = min(\Delta C_{MR,A_S} ; \Delta C_{MR,D_S}) = f(m, d_{MR}, d_{S,Hub}, d_{S,OEM}) \quad (4)$$

Other calculations have shown that the influence of $d_{S,Hub}$ on the transport costs is marginal. Moreover, with a given load m to be transported and $d_{MR} = d_{S,OEM} + const$, the milk run potential steadily drops with decreasing $d_{S,OEM}$. For a conservative potential estimation we therefore fix the minimum milk run distance $d_{MR_{min}}$ as the minimum possible supplier's distance $d_{S,OEM_{min}}$ to the OEM. In addition, because of the marginal cost influence we fix $d_{S,Hub}$ as the average distance $\bar{d}_{S,Hub}$ of all suppliers to the hub inside the considered freight forwarding area. Thus, the milk run potential ΔC_{MR_S} can be depicted as a function of load m and the milk run distance $d_{MR} \geq d_{S,OEM_{min}}$.

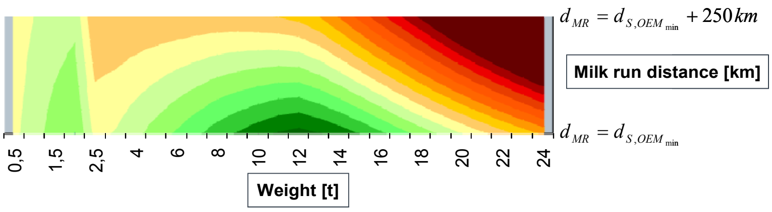

Figure 7 - Average absolute milk run potential in Germany

The results of the absolute milk run potential of all the freight forwarding areas in Germany are quite similar. Figure 7 shows the average German absolute potential depending on m and d_{MR} displayed in color shades from dark green (highest value) to dark red (lowest value). The green shades represent positive potential and the yellow and red shades negative potential. The highest potential can be raised at 12 tons and shortest possible milk run distance. While the absolute potentials slightly differ between the areas, the relative potential intervals vary from [-246%; +60%] in far areas to [-80%; +40%] in close areas to the production site. Therefore, the risk of high losses due to low capacity rates increases significantly, the closer the area.

If the conditions of relatively short milk run tours and suppliers with loads from 4 to maximum 19 tons are not given, milk runs cannot help to cut transportation costs. Calculations at the OEM result that around 10% of the total inbound transportation costs can be addressed to lower transportation costs by 13% assuming capacity rates of 80%. With a pearl chain control another 7% can be saved.

CONCLUSIONS

In the vehicle sector, the milk run transportation mode has to compete with the area freight forwarding concept and the direct transportation mode. Compared to the other modes, milk runs require much more planning and co-ordination in the forefront. However, the case study shows that under the right conditions potentials can be raised. For the German freight forwarding areas, up to 60% of the transport costs can be saved. The order pearl chain control helps to increase the trailer capacity and thus leverages the potential. It has to be taken into account, though, that an integration of empties in the process turns out to be quite complex in practice, unless the built-in rates of the considered material equal 100%.

The order pearl chain control is already in use for JIT and JIS transports. With the presented modifications it can now be applied to milk runs as an additional alternative for transporting goods. However, one has to keep in mind that only a dynamic planning process and assignment of transportation modes to suppliers can provide a sustainable efficient transportation system. Developing smart planning algorithms and guidelines may be subject to further research. Moreover, the transfer of pearl-chain-based control logics to different industrial branches than the vehicle sector has to be examined.

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