USING MILK RUN TO DEAL WITH UNCERTAINTY IN DEMAND IN A CAR ASSEMBLER

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Abstract
This work presents a collaboration process between university and a company to solve a specific problem using geographic information systems and logistics modelling process applied to transportation. Car assembler companies in the periphery of Europe have an additional challenge when building their attractiveness in the scope of the economic groups they belong to as longer distances to receive their supplies involve additional costs. Adding to this challenge, the economic crisis brought a new scenario of uncertainty in demand, which is translated into additional inventory costs. In order to deal with these additional costs as well as to reduce transportation costs, the purpose of this research was to develop a logistics model, based on custom made software that allows generating transportation runs that was able to reduce inventory and transportation costs without sacrificing service quality for the analysed car assembler company.

INTRODUCTION
Milk run logistics relates to a route in which products are moved from a point of origin to multiple points of destination or from several points of origin to multiple destinations (Chopra and Meindl, 2007). It is specially fitted to situations with points of origin close to each other (Arvidsson, 2013). This routing strategy leads to reduction in transportation costs and improves vehicle space utilization (Chopra and Meindl, 2007). The gain in this concept is to increase supply frequency without increasing freight costs and decreasing the inventory costs in material and containers as well as warehouse space. This is achieved with the following strategy: The goods are not supplied from each supplier to the customer on radiating individual tours but each truck coming from suppliers who are involved in Milk Run collects part of the materials in a closed "traffic circle".
The benefits resulting from Milk Run are: 1) Same freight costs despite increased delivery frequency and smaller partial deliveries; 2) Better visibility of inventory; 3) Improved supplier communication; 4) Reduced stock in warehouse and thus reduced handling expenses; and 5) Increased inventory turnover for full and empty packages (Piontek, 2009).
Volkswagen Autoeuropa (AE), a car assembler plant located in Portugal, wants to implement this concept to achieve savings but due to its dynamic production demand it is a risk to use this concept. To overcome this problem, this paper aims at analysing inbound logistics flows and identifying solutions for possible suppliers to join a new milk run delivery system using geographic developed software. This software is based on demand and tries to fit milk run routes based on production data and pre-defined criterion from AE.
The most important operational decision related to transportation in the supply chain is a dynamic orders environment, where pre-defined transportation plans could be changed. Typical objectives when routing and scheduling vehicles are a combination of minimizing cost by decreasing the number of vehicles needed, the total distance travelled by vehicles, as well as eliminating service failures such as a delay in shipments. Also a daily deliveries is an important goal to achieve. The proposed model structure takes into account:

- Vehicle Routing Problem (By Vogel's Approximation Method) and Traveling Salesman Problem (Lahyani et al., 2015);
- Capacitated Transhipment Problem (Ozdemir et al., 2013);
- Main variables; 1) Ct = Cost per trip; 2) L = Distance covered by a vehicle for a milk run; 3) K1 = Minimum fixed transportation cost for a vehicle; 4) K2 = Transportation cost per kilometre; 4) K3 = Loading cost at each vendor; 5) N = Number of suppliers in a milk run; 6) Only one type of truck (limited by 24T or around $100m^3$) is considered as mode of transport; and 7) Loading and unloading time and cost is assumed to be constant for all cases.

CASE STUDY DESCRIPTION

This section is based on information provided by the logistics department of AE where the systematization process was performed. All the suppliers of the components of AE receive the respective orders of parts by EDI (Electronic Data Interchange), as illustrated on Figure 1. The electronic exchange of data between suppliers and AE is made in real time and two types of messages are made available from the internal proprietary system from Volkswagen: FAB - weekly requests with forecast of 6 months and LAB - daily requests with maximum horizon of 10 days. The EDI systems, besides reducing the cycle of request/supply, allow decreasing costs and operational mistakes, fundamental optimizations in a Just in Time organization. The expected results are low inventories, situation in which AE is Best-in-class in the Volkswagen group. AE applies the simple principle of replacing stock with information. The supply chain department parameterizes in the VW system, the defined transit time for each supplier. Depending on the country of origin it can vary from 1 to 12 days. The frequency to collect reused packing's (Inverse Logistics: once a month, weekly, daily) is also agreed.

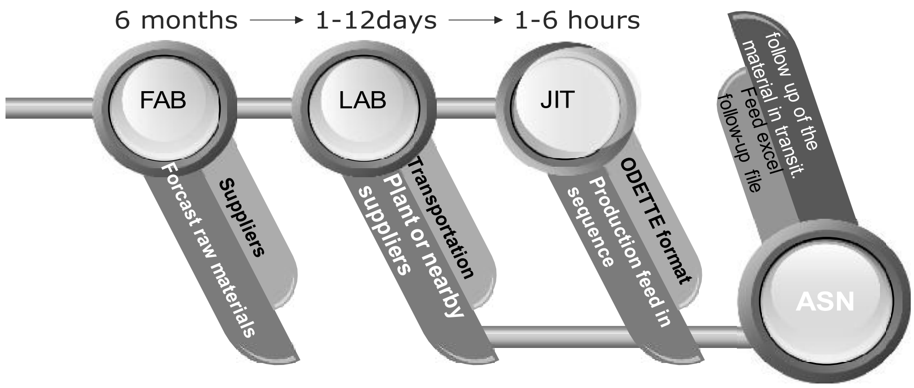


Figure 1 – High level vision of Electronic Data Interchanged implemented at Volkswagen.

Transportation Characterization

In order to characterize transportation the following information was required: price of the parts, volume, weight, daily volume and readiness of containers. The analysis of this data allowed configuring the optimized number of weekly deliveries. It will serve as the basis to the weekly requests to the suppliers. When receiving the requests, each supplier has the responsibility of requesting, until the 12h day prior to delivery, to the pre-defined transport company that collects in its region, the needed space to transport its volume, making information available about the number of unit loads, weight and volumes. Two types of collects are possible:

- The chosen transportation collects and direct sending to AE.
- Use of Cross-Docking (consolidation) centres from where, on a daily basis, direct trucks exclusively dedicated to this operation leave to AE.

After the transporter collects the volume, the supplier should issue an ASN (Advance Shipping Notice) by EDI, which is integrated in the AE supply chain systems. This allows the Supply Chain analyst to follow up of the material in transit. When a truck arrives at AE it goes to the main gate to proceed to the verification and registration.

It is important to mention that transport at AE is received from 1) two Cross-Docking centres in Germany. These are experienced in consolidating collected materials from the suppliers in the whole Central Europe; 2) two Cross-Docking centres located in Barcelona and Madrid; and 3) several 'direct relationships' of suppliers whose volume justify the option of direct trucks. Each transporter should access an online informatics application until 24h before the arrival time of AE in Palmela: it selects and books a discharge window. Having migrated about 2 years ago from an exclusively road transportation concept to a concept of multi-providers of transport services, AE increased complexity in the management of its loads, movements and materials discharges. This transition led to significant savings in the transportation costs, around 10%. The supply chain started to integrate agents who currently work closer and share information with AE. Up to this moment that information was considered confidential. AE started to take advantages from synergies in a mix solution of collaboration and competition.
Important synergies, mainly at the collect level, were perceived not only from the sharing of transportation with other factories in that step of the supply flow, but also at the level of the Cross-Docking centres. Contracts of direct trucks, negotiated inside of the global volume of Volkswagen, also allowed reducing the transports costs considerably. This new reality resulted in two main types of problems which are identified in Figure 2 (rounded box). The rack inventory doubled in a year with this new reality. One solution pointed to solve this situation is the introduction of milk runs.

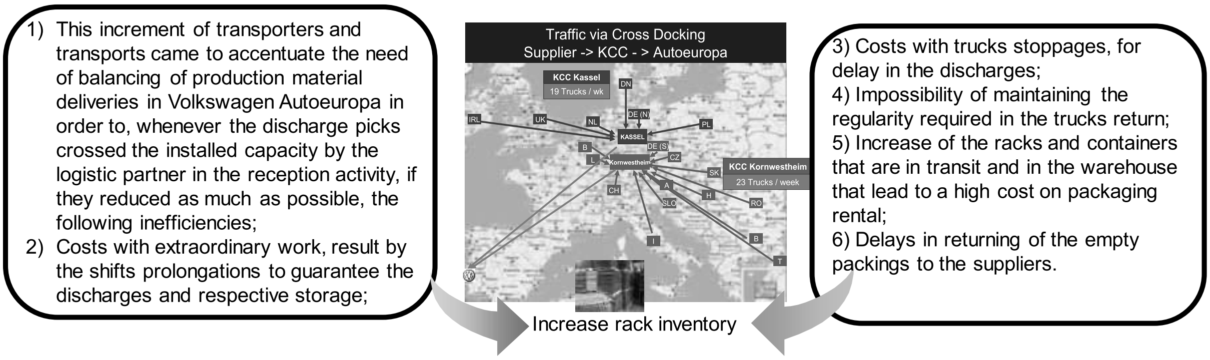


Figure 2 - Map of suppliers' flows in Central Europe using consolidator centre and associated problems.

THE PROBLEM

The price in containers stock doubled (from 80K€ to 180K€ in one year) in one year period following the volume increase. Taking into account logistics best practices AE logistics wanted to implement the milk run concept to save on transportation costs, decrease the containers stock and also the level of inventory. The change to this new concept is a risky situation without a proper tool to support the concept because demand is dynamic.

MILK RUN SOFTWARE

Based on available transportation data, a complex excel downloaded from the transportation mainframe system in Germany, this project aimed at creating a prototype software that could handle the problem of identifying milk runs in a dynamic orders environment. Along with AE logistics this project proposes the development of a process and a logistic software tool to take care of a proper milk run implementation. The main process is based on geo-referencing available in Google Maps to identify nearby suppliers. Based on the supplier address, a geocode process is performed from zip codes and street address to find geographic coordinates. Based on this, a geo-reference process is executed through Google Maps API. Taking into account a pre-defined distance (user configured parameter) a list of nearby suppliers is identified using once more the Google Maps API. This can be executed in two ways: (1) real distance, taking into account the existing roads; and (2) a circular distance based on a pre-defined radius (example of Figure 3). Implementation procedures were based on:

1. Fixation of weight and volume of suppliers in a particular region. In the AE case data was extracted from an excel file with orders' data;
2. Selection of potential Milk Run Suppliers route and delivery frequency fulfilling maximum volume availability and weight legal limits;
3. Selection of Milk Run Suppliers based on the Milk Run potential savings;
4. Definition of Milk Run Parameters: limit of weight and volume, time windows, delivery frequency and maximum number of Milk Run Suppliers;
5. Development and evaluation of Milk Run Alternatives;
6. Specification of the Milk Runs with respect to the fourth point under these parameters, plus the necessary contingency plans;
7. Implementation of the Milk Runs: definition of a Milk Run Schedule, conduct supplier workshops, testing and Milk Run Controlling.

The main problems identified were:

1. Excel data extraction is complex;
2. Diversity of rules and restrictions to implement.

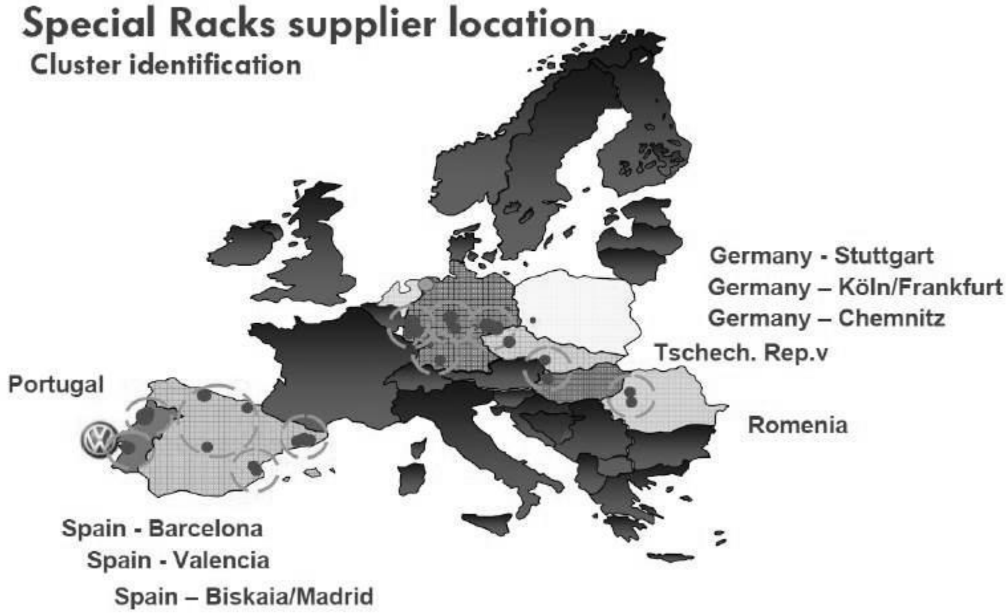


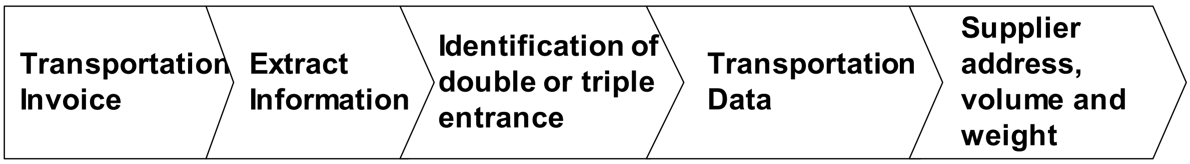
Figure 3 - Output of a geo-reference process of AE suppliers based on Google Maps API.

An informatics tool was developed to support AE based on the requisites defined above to define the milk runs. Milk runs are preferable on a daily basis (save storage space, transportation and racks) than the route optimization or even the reduction of the number of truck runs (AE works in JIT and this is a requisite from logistics department). The most important data is the precision schedules to work in a low stock basis. For this problem we looked first into suppliers' daily volumes to identify the most important ones (largest volume). Suppliers with a daily volume above 10Ton or 40m^3 were identified; nearby suppliers (distance under 150Km -configurable parameter) were associated to this anchor supplier.

If the number of nearby suppliers was bigger than 5, different runs were attempted. The number 5 is a request by AE because it limits the transit time costs and creates uncertainty. If the number of supplier stops increase, the probability of losing the pre-defined slot for loading at the supplier also increases. This could cause serious delays in a transportation operation in which time is the most important asset.

In the created process the weight and volume of each part is an important parameter and we find that most of times the correspondent VW information system does not have the information, because Germany Engineer does not fill this field. To solve this problem we extract this missing information from transportation invoices using the process identified in Table 1. The transportation data extraction is complex due the fact several transportation companies can be involved in the same transportation process, at different stages and each of them creates an invoice. For example, the same material can have up to three registers (see Table 1) on that database, which would formally correspond to three different transportations in the supply flow, e.g. 1) from the supplier to a consolidator centre; 2) from consolidator centre A to consolidator B; 3) from the consolidation centre to AE (see example on Table 1). In the added squares on duplicated data correspond to different trucks used at different stages in the transportation process. From the transportation database, part numbers weight and volume with associated supplier were identified and this was introduced in a database.

Table 1 – Process of extraction parts weight and volume from transportation invoices.



Zip Code	City	Weight	Volume	Volume with Rack	Arrive Date
42553	velbert	0,31	191	191	22-01-2011 16:16
42553	velbert	0,31	191	191	22-01-2011 16:16
42551	Velbert	0,421	78	105,25	22-01-2011 16:16
42551	Velbert	0,335	55	83,75	22-01-2011 16:16
42551	Velbert	0,421	69	105,25	22-01-2011 16:16
42551	Velbert	0,426	109	109	22-01-2011 16:16
42551	Velbert	0,426	109	109	22-01-2011 16:16
42551	Velbert	0,426	109	109	22-01-2011 16:16
42551	Velbert	0,426	109	109	22-01-2011 16:16
42553	Velbert	1,707	417	426,75	22-01-2011 16:16
		3,62	919	1021	

Double Entrance two transportation used

Triple Entrance three transportation used

APPLIED METHODOLOGY AND MAIN RESULTS

In this section, the main results using 5-week data are presented. First, the main suppliers are identified on a volume basis (more than 10 Tons in a week). Nearby suppliers will be clustered and from this process the possible runs are identified. We show 3 cases were performed and only one is shown in this paper. Additionally, this type of proposal should be complemented by a decision support system that can react to changes (flexibility) on pre-defined actions. Maximum truckload will be limited to 90% for security reasons (last minute situations may occur).

For Milk Run Proposal 1, see Figure 4 (A) – Johann Borgers/ISE. The first milk run analysed has 2 suppliers (7 part numbers) – Johann Borgers and ISE. The current situation consists of collecting 6 types of raw materials (6 part numbers) twice a week at Johann Borgers (inbound transportation) and empty containers were sent back once a week (outbound transportation). The inbound transportation from ISE to AE occurs four times a week and the outbound is three times a week (from AE to ISE); a single part number (raw-material) is collected. Average monthly weight is 79 and 49 Tons, respectively. Data analyses of 6 months shows: 1) Johann Borgers week average of 18 Tons; 2) ISE week average of 11 Tons. The restriction to this circuit is the volume as shown by the total values to the suppliers per month: 807 m^3 and 109 m^3. Data analyses of 6 months shows: 1) Johann Borgers weekly average of 183,41 m^3; 2) ISE weekly average of 24,77 m^3. Considering the purpose of this project and data available 3 different milk runs were considered. As a consequence: 1) Collect the information about current transportation (total/week); 2) Based on standard trucks dimensions define the number of required trucks per week. Table 2 shows the added weight and dimensions to the milk run. Afterwards, based on standard dimension/weight to 2 types of trucks (blue table) we define the number of trucks required to satisfy the transportation. The restriction in this case is the volume (m^3). The chosen solution uses TIR truck type because it is less expensive than the Mega ones. The truckload

of this milk run is only 77%, on average, so it might be possible to add more suppliers (low frequency suppliers) to optimize transportation.
It should be noted that calculations should be done considering 90% of truckload due to need of flexibility to accommodate dynamic schedules. When running our geo-reference approach in a radius of 150km we have identified further suppliers (due to confidentiality reasons their names are not identified, only the city name) with lower cadence. Milk Run 1 (see Figure 4 (B)) starts at 6 a.m. at Supplier A (loading time is 30 minutes) and driving time to supplier B is 2 hours. At 9 a.m. the truck is ready to collect at other suppliers. These suppliers require around 69 m^3 and 9.7 Ton per run (on average). In this region we can put together the following suppliers (Figure 4-left): (C) 42551 Velbert; (D) 42287 Wuppertal; (E) 42899 Remscheid; (F) 40724 Hilden; (G) 41324 Mettmann; (H) 40699 Erkrath; and (I) 41468 Neuss. Since AE wants a run for 3 or 4 days per week our proposal is to create 3 different milk runs, always with these 2 main supplier added with more 1 to 3 suppliers in the same run (restriction of max 5 supplier per milk run).
The second milk run analysed has 2 suppliers (5 part numbers) – Bosh and Meritor, see Figure 5. The current situation consists in collecting raw material from each supplier independently. Once a week collect at Arvin Meritor and one transport per week of empty containers (outbound) from AE back to the supplier. There are 3 inbound runs with Bosh. The problem associated with this situation is the volume of raw-material and empty containers in stock that occupies too much space. The improvement procedure used the same steps as in Milk Run Proposal 1 (see Figure 5). The restriction is again the volume. In this situation 4 TIR or 3 MEGA trucks are needed. The decision will be based on truckload. This situation is different from the first one and there is no nearby supplier with lower frequency.

Table 2: Transportation Volume and Dimension for the identified cluster 1

		Total/month			Total/week			Total	
Milk Run	Supplier	n/Parts	Volume	Weight	n/Parts	Volume	Weight	Dimension	Weight
1	Johann Borgers	6	807	79	6	183,41	17,95	208,18	29,09
1	ISE	1	109	49	1	24,77	11,14		

	Truck Traits	
	TIR	Mega
Dimension	90	103,53
Weight	24	24

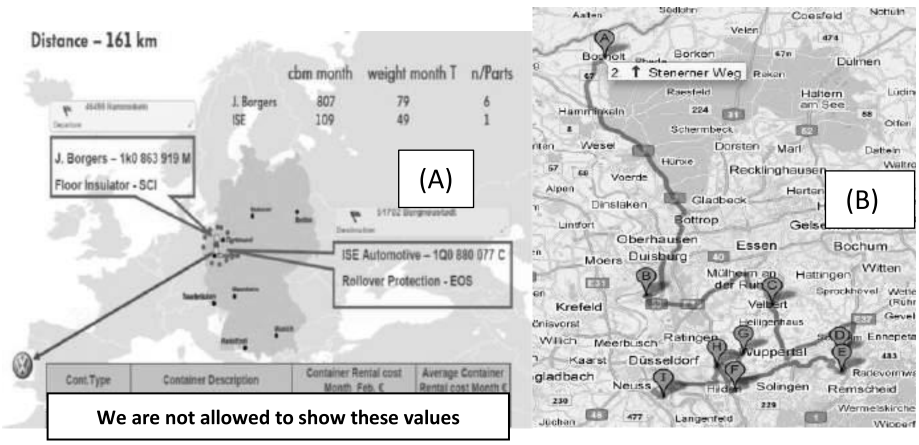
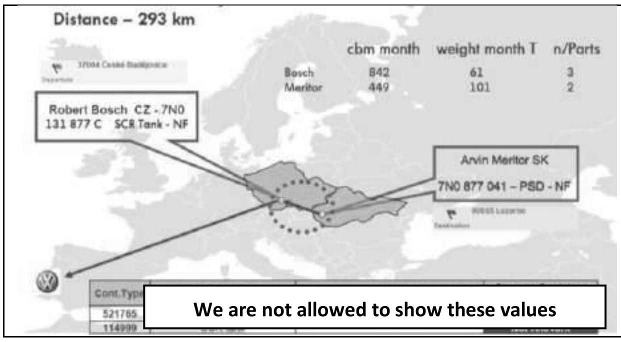


Figure 4 – Cluster 1 supplier main data, case (A) with two main suppliers, ISE and J.Brogers and case (B) smaller volume and more suppliers in the milk run

MEGA trucks could be a problem because truckload averages 94%. Therefore, following the definitions of AE, the recommendation is 4 TIR per week with 82% of truck load. Consequently, in this case there are four inbound runs a week (Monday, Tuesday, Wednesday and Friday) and one outbound per week.
Milk Run Proposal III – Takata/Oris/ETM, see Figure 6. This proposal involves 3 main suppliers in Germany. Weekly values for these suppliers are: 1) Takata: weight is 16 Tons with a variance of 6 Tons. Volume is around 81 m^3 with a variance of 20 m^3; 2) Oris: weight is 20 Tons with a variance of 5 Tons. Volume is around 67 m3 with a variance of 13 m^3; 3) ETM: weight of 8 Tons with a variance of 3 Tons. Total volume is around 77 m^3 with a variance of 15 m^3. The first proposal is for 3 trucks per week (Monday, Tuesday and

Thursday) from these 3 suppliers. As the restriction is again volume, the required volume is for 3 TIR or 2 MEGA per week, see Table 3. Based on truckload and on the restriction of 90% of truckload, this milk run should work 3 times per week using TIR truck type and achieving 75% of truckload. Now it is needed to analyse the nearby suppliers with lower frequency. The proposed solution to collect from these 12 suppliers involves one more truck than initially planned. It does not exceed 5 suppliers per milk run and not the 90% of truck load required by AE. This way milk run should work 4 days per week: 1) Run 1 (Monday) additional stops at Roedental and Salach, additional 9,1 m^3 available. Milk run is about 5 hours with 2 hours for loading; 2) Run 2 (Tuesday) no loading at ETM (only supplies 3 times per week). And it also collects at 3 small suppliers, Koenigsberg, Suhl and Bohmenkiruch, achieving a total of 69% of truck load; 3) Run 3 (Wednesday) the 3 initial suppliers should be collected from and also 2 additional ones, Mellrichstadt and Erlenbach. Using a TIR truck the truckload will be 77%; 4) Run 4 (Friday) is equal to Run 3 but the 2 additional suppliers are Schweinfurt and Ditzingen, achieving 87% of truckload.



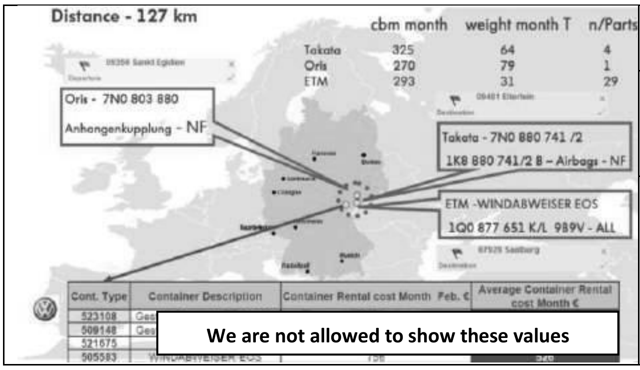
Week values: Dimension 293,41 m^3 and weight 36,82 Ton

Milk Run	Supplier	Total/month n/Parts	Total/month Volume	Total/month Weight	Total/week n/Parts	Total/week Volume	Total/week Weight
2	Bosh	3	842	61	6	191,36	13,86
2	Meritor	2	449	101	1	102,05	22,95

#Truck/week		
TIR	Mega	TruckLoad
4	3	94%

#Truck/week		
TIR	Mega	TruckLoad
4	3	82%

Figure 5: Milk Run proposal 2 - Transportation Volume and Number of Trucks required



Week values: Dimension 201,82 m^3 and weight 39,55 Ton

Milk Run	Supplier	Total/month n/Parts	Total/month Volume	Total/month Weight	Total/week n/Parts	Total/week Volume	Total/week Weight
3	Takata	4	325	64	4	73,86	14,55
	Oris	1	270	79	1	61,36	17,95
	ETM	29	293	31	29	66,59	7,05

#Truck/week		
TIR	Mega	TruckLoad
3	2	97%

#Truck/week		
TIR	Mega	TruckLoad
3	2	75%

Figure 6: Milk Run proposal 3 - Transportation Volume and Number of Trucks required

Table 3: Milk Run proposal 3, with additional suppliers in 4 runs per week.

Milk Run	Supplier	Total/week n/Parts	Total/week Volume	Total/week Weight
3	Takata	4	73,86	14,55
	Oris	1	61,36	17,95
	ETM	29	66,59	7,05
Suppliers	Roedental	-	4,6	1,165
	Salach	-	4,5	1,148
	Koenigsberg	-	6,8	1,693
	Suhl	-	1,2	0,308
	Bohmenkirch	-	20,3	5,067
	Mellrichstadt	-	3,4	0,856
	Schweinfurt	-	0,8	0,195
	Erlenbach	-	9,66	2,512
	Ditzingen	-	21,747	4,793

	Run 1	Run 2	Run 3	Run 4
Takata	18,5	18,5	18,5	18,5
Oris	15,34	15,34	15,34	15,34
ETM	22,2		22,2	22,2
Roedental	4,6			
Salach	4,5			
Koenigsberg		6,8		
Suhl		1,2		
Böhmenkirch		20,3		
Mellrichstadt			3,4	
erlenbach			9,66	
Schweinfurt				0,8
Ditzingen				21,747
Total (Ton)	65,14	62,14	69,1	78,587
#Suppliers	5	5	5	5
Type of Truck	TIR			
Truck Load	72%	69%	77%	87%

CONCLUSIONS

This paper introduces a milk run approach in a dynamic order environment and demonstrates its viability under these conditions, maintaining service levels while reducing transportation and inventory costs. Data from a car assembler in Portugal was used and the full information of transportation and production demand activity was considered. A software tool was developed to implement a dynamic milk run in a real scenario with support of geographic information manipulation of information with uncertainty. The developed model was able to reduce the weekly number of trips by 5 to 9% (see Table 4 with results for this case: three round trips per week, about 150 round trips per year, as well as the average distance coved per week). By reducing transit time and allowing a more often placement of orders, inventory rotation increased and inventory holding costs are lower. Due to the level of uncertainty in demand, the model also impacted positively in terms of flexibility in production scheduling. While developing the logistics software that underlays this model, nearby suppliers were clustered and a maximum load factor of 90% was considered. Two transhipment platforms were located in Germany (already existed, no cost associated). Three different milk run scenarios were developed and compared. Table 4 shows the main results with the introduction of three milk runs that are adjusted based on production demanded. This implementation allows savings on: 1) container rental; 2) transportation, 3) warehouse space and 4) inventory value. This gives an saving of 200K€/year that gives more less 1,5€/car.

Table 4 – Results of current milk run study proposal implemented in 2012

1. Milk Run Proposal – Johan Borgers/ISE

Previous Situation of both suppliers: 6 truck inbound and 4 outbound

	Inbound week	Outbound week
Johann Borgers	2 x	1 x
ISE	4 x	3 x

New - 4 X Week Round trip

2. Milk Run Proposal – Arvin Meritor SK/Robert Bosch CZ

Previous Situation of both suppliers: 4 truck inbound and 1 outbound

	Inbound week	Outbound week
Arvin Meritor	1 x	1 x
Bosch	3 x	-

New - 3 X Week inbound (Outbound Meritor 1 x week)

3. Milk Run Proposal – Takata/Oris/ETM

Previous Situation of both suppliers: 11 truck inbound and 7 outbound

	Inbound week	Outbound week
Takata	3 x	2 x
ETM	3 x	2 x
Oris	5 x	3 x

New - 4 X Week Round trip

It was not possible to access information concerning information about windows time to load. Therefore some overlapping conflicting time windows may occur at some suppliers when AE tries to implement this new configuration of collect. Another possible problem is related with returnable packaging between customer and suppliers (empty containers in outbound). In terms of the value added by this project, milk runs are often used in stable environments. The results of this research lead the company to adopt milk run in their transportation options. By experiencing considerable savings the company reinforced its competitive position inside the economic group it belongs to and strengthened its economic viability. The results presented in section 4, presents a solution for a specific production environment, others can be easily adapted and created based on the current solution.

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