Rethinking public transportation and logistics as collaborative scenarios

Gunter TEICHMANN
SALT Solutions AG
Charlottenstraße 34
01099 Dresden, Germany

and

Frank-Michael DITTES
Weinberghof 4
University of Applied Sciences Nordhausen
99734 Nordhausen, Germany

and

Uwe ARNOLD
AHP GmbH & Co. KG
Karl-Heinrich-Ulrichs-Straße 11
10787 Berlin, Germany

ABSTRACT

A collaborative approach to optimizing resource utilization of vehicles by the formation of dynamic networks in logistics and passenger transport has been developed. It maintains knowledge about free partial freight and free transport capacities as well as the transport possibilities of the participating companies. Privacy interests of different companies are taken into account by defining trust circles sharing among their members only specific kinds of information. The approach is implemented in a prototypic way as a cloud computing solution capable of optimization and cost simulations carried out on the basis of real data.

KEYWORDS: Collaborative Enterprise, Collaboration By Design, Cloud Computing, Optimization Algorithms, Logistics Networks, Public Transportation, Privacy

1. INTRODUCTION

For over two years, a research project on the dynamic, tailored design of on demand solutions for public transport in Germany runs together with Deutsche Bahn, leading universities, and several IT companies [1].

The aim of the research project is to develop a smartphone app for dynamic agenda planning and comfortable door to door navigation with public transportation. It takes advantage of modern cloud computing, with information from various sources efficiently processed and used for a flexible travel planning. This way the software can integrate all planning components and algorithms necessary for the creation of individual timetables. It includes locational data and other appointments or travel requests, as well as offers of third-parties or timetable deviations in real time.

The research project reflects demographic changes in rural areas. Bus services according to rigid timetables and routes will be replaced by on-call traffic that represents a real alternative to individual drives by car. As a software company with ~~a~~ focus on supply chain solutions, we asked ourselves the question, what does such an approach mean for the future of distribution logistics.
Passenger transport and freight logistics are, as well as other industries, at the beginning of a disruptive change. On the one hand, the classical systems have been pushed to their limits due to a variety of factors, on the other hand, digitization and information and communication technologies offer new opportunities. The key to successfully mastering the challenge lies in the implementation of collaborative scenarios in order to pool / share resources. Those scenarios are for instance: Collaborative rationalization of the use of existing capacities (assets, workforce, client- and partner-networks), support for finding appropriate network-partners for complex tasks such as e-commerce-fulfilment with significant contents of value-added services and service integration by means of a virtual collaboration platform.

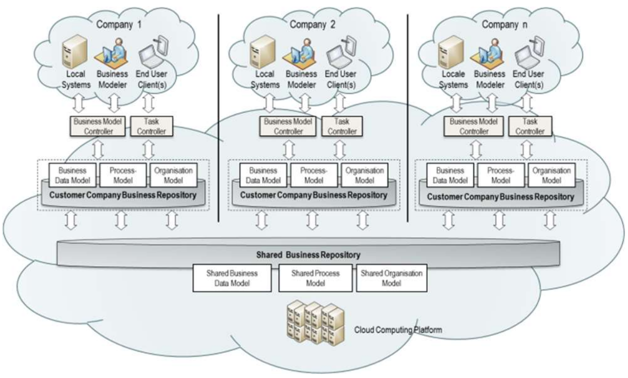

Figure 1: Virtual platform architecture for collaboration [2]

2. CLASSIFICATION FRAMEWORK

Freight exchanges, car-sharing centers and similar services are well established nowadays and provide better utilization of resources. At a closer look the currently available systems are limited to simple scenarios – typically on single trips and the basic task to ensure that a "logistic object" is to be transported in time to a specific location.

Trying to classify these basic logistic tasks in a larger context we choose a distinction in three viewing levels and three horizons according to the following definitions:

For the viewing levels:

Definition of **"Micro level"**: The smallest possible scale of a traffic resp. transport system, concerns specific individual entities (one passenger, one vehicle, one line). Entities of this level are used for building a daily agenda or a tour plan within a company or project.

Definition of **"Meso level"**: The level between macro- and micro-level, in which the actual services are planned, provided and billed. Entities of this level typically are companies or partnerships between companies.

Definition of **"Macro level"**: The highest level of consideration of traffic / transport systems that are available nationwide or throughout a whole continent. The participating entities of this level are regional and national officials working out guidelines for the design of systems, companies, corporate groups and associations or municipalities.

And for the horizons:

Definition of **"Operational horizon"**: The smallest meaningful time scale for planning, typically less than or equal to 1 day.

Definition of **"Tactical horizon"**: Temporally located between operational and strategic horizons of view, this horizon contains all processes needed to complement the operational and strategic planning. Typical processes located here are all processes for the preparation of emergency plans (strikes or natural disasters) and also planned seasonal fluctuations and the reaction to it.

Definition of **"Strategic horizon"**: The largest viewing horizon in time used for planning, always longer than 1 day, but typically longer than a quarter or a year. At this level, we find long-term planning and long-term contracts.

The following table shows the conceptual framework for the classification of planning and decision making processes:

	Operational horizon (≤ 1 day)	Tactical horizon (between operational and strategic)	Strategic horizon (1 quarter to >1 year)
Macro level			
Meso level			
Micro level			

Table 1: Classification framework

Essentially, the established scenarios are almost exclusively operational planning processes at the micro level, which are matched with the tactical planning on meso level – if matched at all.

3. SCENARIOS

The following everyday scenario is a classic challenge and standard task of the transport manager in transport logistics:

A freight forwarder who already has freight orders of different size, destinations and other specifications – however only partial loads which don't cover full transport vehicle capacities – is looking for complementary freight orders/reverse freight orders. He/she is looking for matching freight orders, haulers or other freight forwarders in a similar situation. The main goal of all involved parties is to minimize idle capacities and specific unit cost and to maximize transport efficiency and surplus per transport. From the point of view of infrastructure suppliers (e.g. state) the associated benefits consist in the minimization of the number of vehicles using the infrastructure (e.g. number of trucks per freeway segment and time) and in the maximization of the cargo throughput-capacity of the road/railway/air corridor-connection.

The same scenario from the shipper's point of view is the following:

An SME manufacturer (shipper) is looking for an attractive possibility to deliver his products to one of his clients. The freight size does not cover a full truck and reverse cargo is not available. So far, freight transport offers were either too expensive or too inflexible. The shipper is looking for an idle transport capacity more or less matching the required transport relation, time intervals and cargo specifications in a synergetic way. So far, the parties as described in the previous scenario may use one of the available and widely established online-freight exchanges. Transport freight matching support, however, is usually limited to road transport, and the search and matching instruments are predefined by the platform provider. Moreover, advertising of "idle" capacities usually takes place in a relatively large and anonymous community. From the user's point of view, the functions offered by the exchanges might not offer sufficient privacy protection, and might not be flexible enough in matching demand and supply.

The scenario described above needs to be upgraded, because the used transport network model is still too rigid: The transport route, the freight volume and the idle capacities of every single truck must be known in advance and need to be contractually fixed. Subsequent changes are not intended. If we extent the contemplation space to multimodal logistics, some additional challenges arise. Considering water transports may require rescheduling shipping because of low tide. If a planned port stop cannot be reached due to low tide, a modal change is necessary very quickly. It has to be decided which rail or road transport means can provide the missing capacity in time and budget. Or imagine a really serious event such as a shipwreck of a large container ship: all the goods in the containers are planned in supply chains, which could collapse if the goods are not delivered in time. To make logistic processes more resilient other aspects and coherences are to be taken into consideration.

There are some basic concepts that can be helpful in upgrading our scenario:

- Flexible network construction and reconfiguration
- A smart matching algorithm and cloud services

Flexible network construction and reconfiguration means:
State of the art logistics networks are classical joint cargo service systems. Goods are collected, pooled and then separated again along rigid routes. These systems require appropriate investment and operating costs.
The key for an economically profitable operation of these structures is utilization. The competition is done with partially cut-throat prices. With a dynamic approach logistics networks can be formed on demand and in real time to meet individual requirements which accesses available resources and utilizes them in an optimized way.

Smart matching cloud service means a service that knows the characteristics of all free partial freight and free transport capacities continually and sorts them by a matching algorithm according to the degree of similarity. Comparative criteria include volume, weight, cargo specifications and time windows. The matching algorithm sorts matching results by a sliding value from 0 (does not fit) to 1 (fits 100%).

A really smart cloud service which focuses on establishing cooperation for the reduction of part-load transport should not be reduced to the pure aspect of transport but needs to cover warehouse capacities and stock management as well. The warehouse aspect matters in transport contexts because trucks are rolling warehouses and ships are swimming warehouses. Such a smart service needs a data base backbone including the specification possibilities for offered and demanded idle capacities which are much more detailed and flexible than in the case of existing online freight exchanges as well as an API for actual idle capacities and capacity demands that are updated in real time or according to user defined intervals.

If we integrate multimodal logistics and warehouse aspects into the optimization requirements, we need to consider additional dependencies and constraints to construct a dynamic logistics network. In order to avoid a possible explosion of complexity, we try to keep it simple and ask ourselves the question, where the optimal network nodes (i. e. the transshipment points) have to be located. This question will be discussed as scenario number II in the next section.

4. OPTIMIZATION PROCEDURE

In order to work, the basic scenario described above requires the implementation of an algorithm which automatically decides whether the inclusion of an additional freight order into already existent (or planned) transportations is meaningful or not. Consider, e. g., the situation depicted in Figure2.

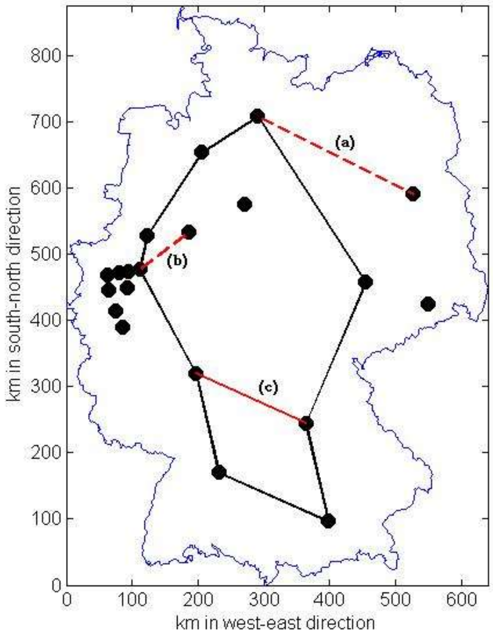

Figure 2: Original transport routes (black lines) and their modifications due to the inclusion of additional logistic orders

It shows the 20 largest cities in Germany. In black, two transport lines are indicated, connecting Hamburg in the North to Munich in the South. In red, additional freight orders are shown; two of these orders (a and b) require only a small modification of one of the original lines, so it could be favorable to modify the lines in order to pick up and deliver the additional orders. The final conclusion, whether this modification of transport line is preferable (compared to a separate transport) depends on the length of the detour and the costs per kilometers as well as on requirements in the time domain like time windows for the delivery and the urgency of the original transport. On the contrary, the additional freight order shown in the lower half of the picture (c) would suggest a separate transport, since the modification of any of the original transport lines would require a severe detour.
In practice, there are not only two transportation lines given at the beginning, and not only a single additional order to be taken into account. Finding the optimal solution is then a much more difficult task requiring methods of global optimization for spatial-temporal problems. We come back to this point after considering the second scenario.

Scenario number II: finding optimal locations for transshipment points (TSP) or haulers. This is a typical problem both at the strategic level and in the operational business. On the long time scale, a new TSP has to be planned so as to locate it as close as possible to the customers; on the operational level optimal solutions for emergency cases have to be found (say, a certain TSP cannot be reached or due to an accident the transport mode has to be changed). In both cases, one or more locations have to be determined so as to minimize the total logistic costs. Again, additional requirements like time windows could be present, which add additional complexity to the optimization problem.

The problem is simple as long as *one* location has to be found: Consider again the largest German cities and try to find the optimal location for a single hauler supplying these cities (see Figure3).

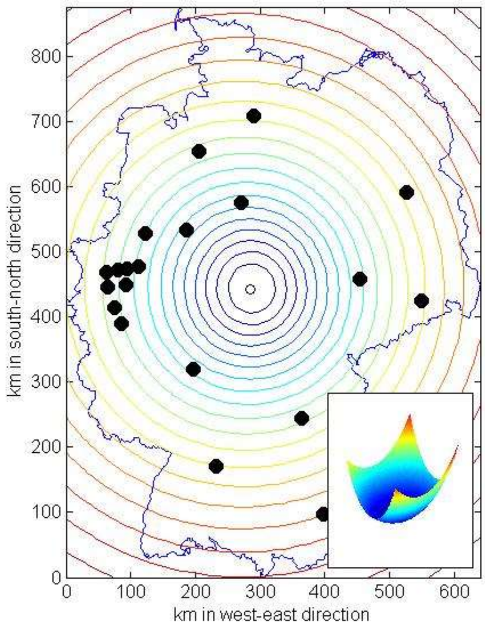

Figure 3: Optimal solution and cost landscape for the location of a single hauler or transshipment point

The picture shows this optimal location (small circle) together with the contour lines of the cost landscape; the insert represents this landscape as a surface in three dimensions. There is only *one* optimum and it can be found by usual methods of local optimization like steepest descent.

A much more complicated situation arises, when two (or more) locations have to be determined, see Figure 4 for an illustration. The cost landscape then usually has a complicated structure with many local minima. In order to find the best solution, a *global optimization* has to be performed.

Global optimization algorithms try to avoid the search being captured in a local minimum (where it would be brought by steepest descend). There are many concepts on the market which perform this job more or less satisfactory (depending on the complexity of the problem). Among them, there are the traditional methods of simulated annealing, assigning a “temperature” to the system [3], as well as genetic algorithms, performing the search for the optimum by a whole set of interacting searchers [4].

We made best experience with a heuristic method called “democratic optimization” [5]. It reduces the complexity of the original problem by temporarily excluding a certain amount of components of it (in the example described here: by reducing the number of cities to be served). This gives rise to a flattening of the cost landscape which, in turn, reduces the probability of being captured in a local minimum. By dynamically excluding different parts of the problem, the searching algorithm turns out to approach the global optimum very efficiently. In Figure 4 we see two pairs of local minima for the location of two haulers: one in southwest-northeast direction, the other one in northwest-southeast direction.

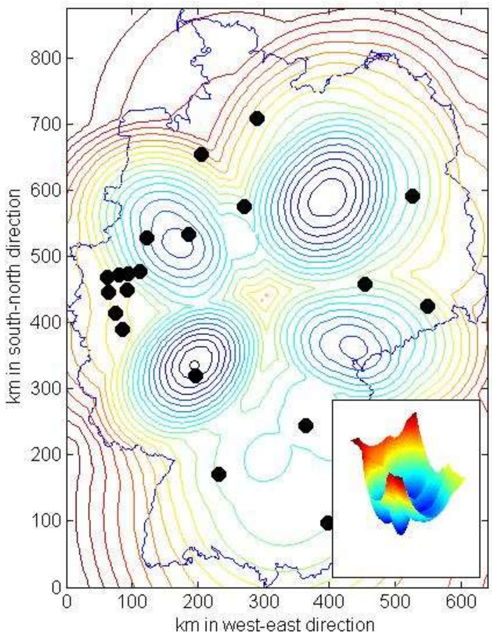

Figure 4: Optimal solution and cost landscape for the location of a pair of haulers or transshipment points

The first pair represents the *global* minimum, whereas the second one is slightly less optimal. Although we are always looking for the global optimum, finding other good solutions can be of interest, as well. They could become candidates for real locations, if other aspects of the problem are taken into account, e. g. infrastructural ones.

5. BRIDGING THE TRUST-GAP

Additional attention needs to be paid to privacy issues and privacy control over the business data used in finding optimal solutions. Appropriate tools for privacy protection in an environment of collaborative cloud services for distribution logistics are the development goal of a current R&D project “PREsTIGE” funded by the Federal Ministry of Education and Research of Germany (BMBF) [6].

The optimization algorithm described in section 4 requires data, especially operational transport capabilities and demands as well as sensitive and confidential business data such as cost calculations and staff utilization. In the context of the research project PREsTIGE we define several categories of data and 8 different “trust circles” (that means companies or persons in specific companies, that match specific criteria).

Categories of data to share:

1) Core Data
   a) General contact information of the company
   b) Contact information of special contact persons within the company
   c) Location-specific data (such as number of employees, services)
   d) Capacity data (to what extent services can be provided)
   e) Permits, permissions, certifications
   f) General staff data
   g) Sales data
2) Capabilities and products
   a) Logistic services
   b) Transport services
   c) Warehousing services
   d) Handling services
3) Operational business data
   a) Transport capacities
   b) Transport relations
   c) Warehouse capacities
   d) Staff utilization
   e) Tracking data
   f) Order data
4) Commercial business data
   a) Price calculations
   b) Cost calculations
   c) Income calculations
   d) Profit calculations

With whom to share ("trust circles")?

A) Management of the own company

B) Entrusteds of own company

C) All employees of the company

D) Business partners with special data protection agreement

E) Business partners in general (without special privacy policy)

F) Business partners in the industry network (well-known companies with common codex)

G) Potential business partners in the industry network (not well known, but with common codex)

H) Public/private individuals (anyone)

Based on this categorization, we asked representatives of 60 logistics companies whether and under what circumstances they would be willing to share data with others, differentiated by the individual trust circles. Table 2 shows the responses to the survey normalized to how many of 10 companies would share a specific category of data [7].

	A	B	C	D	E	F	G	H
1	10	9	6	4	4	4	6	2
1a	10	9	8	6	6	6	6	4
1b	10	9	8	6	5	5	5	4
1c	10	9	5	6	6	6	6	4
1d	10	9	6	6	5	5	4	1
1e	10	9	6	6	5	4	6	1
1f	10	8	3	0	0	1	1	0
1g	10	9	3	0	0	1	1	0
2	10	9	2	3	3	3	3	2
2a	10	9	8	6	6	6	5	3
2b	10	9	8	6	6	6	5	3
2c	10	9	8	6	6	6	5	3
2d	10	9	8	6	6	6	5	3
3	10	9	2	1	1	1	1	0
3a	10	9	4	4	4	3	3	0
3b	10	9	4	4	4	3	3	0
3c	10	9	4	3	3	2	3	0
3d	10	9	2	0	0	0	2	0
3e	10	9	4	2	2	1	2	0
3f	10	9	4	2	3	2	2	0
4	10	8	2	1	1	1	1	0
4a	10	8	4	3	3	2	2	0
4b	10	8	4	0	0	0	0	0
4c	10	8	3	0	0	0	0	0
4d	10	8	2	0	0	0	0	0

Table 2: What data to share within which trust circles

Based on these survey results we cannot assume that there will be a pool of commonly shared resource and demand information just through the provision of a platform. We need to add special control possibilities. Such control possibilities must allow the user to stay anonymous in the beginning and prevent that he is forced to reveal capacity coverage and price information to the public if he does not want to. Moreover, the user should be able to differentiate the data access rights according to user-defined groups which can be modified by the user at any time. Thus the user could allow data visibility and access temporarily to a subset of the registered system users.

Partial freight and free transport capacities are added to the matching/pooling process only if their access rights "fit" reciprocally. Pairing with incompatible reciprocal access rights can be used to indicate the restrictive effects of the privacy configuration to the dispatcher or his management and possibly initiate an adjustment of rights requirements. By this mechanism potential economic cooperation between logistics companies is positively motivated. With ongoing usage of the system the volume of idle capacity offers and demands will grow and thus the likelihood of matches will grow as well.

6. BUSINESS ASPECTS

Considering the location problem as illustrated in figure 4, another problem becomes clear. The cost landscape was calculated based on the distances assuming that the transport costs for a kilometer are always the same. In reality we would have to use here different calculations depending on which company carries the actual transport. If we have to decide between the two potential pairs of minima, the company-specific cost calculations can significantly influence the decision. However, it is just this information that is classified by all the companies as highly confidential.
Table 3 shows a typical cost calculation sheet depending on loading meters and distance.

		distance										
		100	200	300	400	500	600	700	800	900	1000	1100
loading meter	3	2,63	7,72	12,60	17,27	21,74	25,99	30,03	33,86	37,49	40,90	44,10
	4	3,35	9,86	16,09	22,06	27,76	33,19	38,35	43,25	47,87	52,23	56,32
	5	4,07	11,97	19,54	26,78	33,70	40,29	46,56	52,50	58,12	63,41	68,38
	6	4,78	14,05	22,93	31,44	39,56	47,30	54,65	61,63	68,22	74,43	80,26
	7	5,48	16,10	26,28	36,03	45,33	54,20	62,63	70,63	78,18	85,30	91,98
	8	6,16	18,12	29,58	40,55	51,03	61,01	70,50	79,50	88,00	96,01	103,53
	9	6,84	20,11	32,83	45,01	56,64	67,72	78,25	88,24	97,68	106,57	114,91
	10	7,51	22,07	36,04	49,40	62,16	74,32	85,89	96,85	107,21	116,97	126,13
	11	8,17	24,01	39,19	53,73	67,61	80,83	93,41	105,33	116,60	127,21	137,17
	12	8,81	25,91	42,30	57,99	72,97	87,24	100,82	113,68	125,84	137,30	148,05
	13	9,45	27,78	45,36	62,18	78,25	93,56	108,11	121,91	134,95	147,23	158,76
	14	10,08	29,63	48,37	66,31	83,44	99,77	115,29	130,00	143,91	157,01	169,30
	15	10,70	31,44	51,34	70,37	88,55	105,88	122,35	137,97	152,72	166,63	179,68
	16	11,30	33,23	54,25	74,37	93,58	111,89	129,30	145,80	161,40	176,09	189,88
	17	11,90	34,99	57,12	78,30	98,53	117,81	136,14	153,51	169,93	185,40	199,92
	18	12,49	36,71	59,94	82,17	103,40	123,63	142,86	161,09	178,32	194,56	209,79

Table 3: cost calculation template (tariff table)

So far, the best locations for the TSP within a dynamic logistics network were determined by using the shortest distances to be overcome as optimization criterion. The decision on who is actually running the optimized transports is not yet fallen. Based on the different (deposited per carrier) tariff tables the actual transport costs by the respective carriers can be calculated and used to choose the optimal carrier.

Similar to the mechanism for the non-matching data access rights we are able to indicate the restrictive effects of an uncompetitive cost calculation to the dispatcher or his management and possibly initiate an adjustment of his tariff table. This way we are able to handle different cost calculations in a way that nobody has to reveal confidential information.

7. SUMMARY AND OUTLOOK

The presented paper describes a collaborative approach to optimizing resource utilization of vehicles by the formation of dynamic networks in logistics and passenger transport. We have implemented this approach in a prototypic way as a cloud computing solution and are capable of optimization and cost simulations carried out on the basis of real data. To transfer the approach actually into practical application still remains to be done. To this end, an evaluation with selected companies from the logistics sector will be concluded at the end of the PREsTIGE project. In case of a positive assessment by the experts, the prototype is to be developed to market maturity.

8. REFERENCES

[1] Project website http://www.dynapsys.de/

[2] Teichmann G, Schwartz E, Dittes F-M: "Collaborative Engineering of Inter-Enterprise Business Processes", Journal of Systemics, Cybernetics and Informatics, special Edition “Collaborative Enterprises" (2011)

[3] Metropolis N, Rosenbluth A, Rosenbluth M, Teller A, Teller E: Journal of Chemical Physics 21 (1953) 1087–1092; Kirkpatrick S, Gelatt C D, Vecchi M P: Science 220 (1983) 671–680

[4] Schöneburg E, Heinzmann F, Feddersen S (1994) Genetische Algorithmen und Evolutionsstrategien. Addison-Wesley, Bonn

[5] Dittes F-M: Physical Review Letters 76 (1996) 4651–4655; Optimierung, Springer (2015), Berlin Heidelberg

[6] Project website http://prestige.wifa.uni-leipzig.de

[7] Arnold U: PREsTIGE – Result of the user survey (2015), internal project report, BMBF joint research project PREsTIGE, work package AHP GmbH & Co. KG