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Getting rid of fixed delivery areas: the implications of dynamic vehicle routing on a German parcel delivery company

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Abstract

The growing demand for parcel deliveries has demonstrated the limitations of traditional vehicle routing. Parcel delivery companies that rely on static approaches and fixed delivery areas face difficulties in meeting customer expectations. In addressing this problem, this applied research is the first to uncover the implications of dynamic vehicle routing systems for parcel delivery companies and to develop an action plan for the successful implementation of such systems. The case study-based findings demonstrate that improved economic performance comes with human, organizational and technological challenges. The central challenge for parcel delivery companies is to enhance the technology acceptance of their drivers. It is crucial to train them sufficiently, constantly communicate the system's value, identify lead users and implement new incentive programs. Nevertheless, this study also presents steps that can be taken to improve the technological and processual implementation of dynamic vehicle routing systems.

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Keywords: Vehicle routing problem, dynamic vehicle routing, parcel delivery company, software implementation, technology acceptance

1. Introduction

Parcel delivery companies are facing a growing demand for parcel volumes. This trend is due primarily to the fact that the worldwide e-commerce market is growing. In Germany, for example, the number of parcels shipped from business to consumer increased by 9.7 % in 2017 to more than 2 billion parcels (Esser and Kurte, 2018). Irrespective of the parcel volume, the number of appointments and the delivery standards are rising. With today's omnichannel retailing, a seamless customer experience includes reliable same-day and time-window delivery (Vallée et al., 2018).

Meeting the growing demand and retailers' expectations is challenging for parcel delivery companies since they have to contend with a lack of drivers, intensifying cost-pressures, and environmental regulations. In dealing with all

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these challenges, they focus on digitization with a view to significantly increasing efficiency and reducing staff levels. In this regard, the area of route planning demonstrates considerable potential. The limitations of traditional, static vehicle routing with fixed delivery areas become evident when it comes to dealing with a high number of appointments. Even though a number of pilot projects have been undertaken with regard to breaking up delivery areas and implementing dynamic vehicle routing enabled by fast computing technology providers, there has been relatively little applied research on this subject.

The purpose of this research is therefore to understand the implications of dynamic vehicle routing systems for parcel delivery companies and to develop a first-hand plan of action for successful implementation. More precisely, this research explores the following research questions:

(1) What are the implications of dynamic vehicle routing for parcel delivery companies?

(2) How are dynamic vehicle routing systems successfully implemented?

The remainder of this paper is structured as follows. The review of relevant vehicle routing literature in the next section is followed by Chapter 3, which demonstrates the unique routing characteristics for parcel delivery companies. The subsequent sections deal with the case study design and methodology, as well as the findings. Finally, the contributions of this study are discussed and summarized, including limitations and suggestions for future research.

2. Literature review

2.1. Methodology

A structured literature review was undertaken to identify papers relevant to this study. First, journal articles, research projects, and case studies published over the past ten years were studied in order to identify key concepts. Special attention was given to literature published and cited in established journals in the field of operations research and related sectors with a view to gaining meaningful insights. Second, keywords were derived from these concepts in order to structure the literature review. Table 1 presents the keywords and search strings applied in the literature review.

The Web of Science research platform was chosen to retrieve the literature for this research. It covers leading publishers such as Elsevier, Emerald, Springer, and Waley. Using the search terms *traveling salesman problem (TSP)*, *vehicle routing*, and *collaborative routing* in combination with different specifications such as *courier* or *dynamic* resulted in a high number of findings (see Table 1). The following selection criteria were added to increase the quality of the initial review: papers had to be published between 1954 and 2018 in peer-reviewed journals with full-text availability and had to be written in English (Newbert, 2007). The authors evaluated the titles and abstracts of the remaining articles to reduce the number to a relevant sample of 52. The process included forward and backward searches. Ultimately, 63 full texts were reviewed.

Table 1. Keywords applied in the literature review

Search term	In combination with
Travelling Salesman Problem	Multiple, solution methods, courier, parcel delivery
Vehicle Routing	Problem, optimization, solution methods, courier, parcel delivery, capacitated, dynamic, time windows, pick-up and delivery, algorithms, heuristics, metaheuristics,
Collaborative Routing	Route choice behavior, dynamic traffic

2.2. Fields of research covered by present literature

In general, there is extensive literature on the TSP as well as on the vehicle routing problem (VRP). The TSP was mentioned as early as 1954 in “Solution of a Large-Scale Traveling-Salesman Problem” by Dantzig et al. (1954). These authors describe the classic problem of a salesman beginning his tour from a specific point to various cities or clients with the objective of finding the shortest route ending up at the place of origin. Dantzig and Ramser (1959) subsequently introduced the term “vehicle routing problem” in the paper “The Truck Dispatching Problem”, which dealt with the case of trucks delivering gas from a central terminal to a high number of service stations. In contrast to the TSP, the objective is to detect the optimum routing for the whole fleet rather than for one salesman. Furthermore, the capacities of each truck are limited.

The VRP, in particular, gained the interest of the research community, and numerous subcategories were added to represent practical applications. Initially, the capacitated VRP was added, which combines the sequence problem with the given capacities of the used vehicles. Braekers et al. (2015) point out that to date this is the version that is dealt with most frequently in the literature and that has the most models, followed by that with restrictions due to time windows. Table 2 below includes these two subcategories as well as a number of other important VRP characteristics and details relating to the literature covering the topic.

Table 2. Extract from existing literature

Literature	Characteristics							
	Capacitated	With time windows	With pick-up and delivery	Dynamic	Multiple depot	Time-dependent	With backhaul	Driving and working hours
Anbuudayasankar et al. (2014)	X	X		X	X		X	
Berbeglia et al. (2010)			X					
Braekers et al. (2015)	X	X	X	X	X	X	X	
Bruck and Iori (2017)			X					
Cheng et al. (2017)				X				
Dantzig and Ramser (1959)	X							
Ehmke (2012)		X				X		
El-Sherbeny (2010)		X						
Fan (2011)			X					
Ferrucci (2013)	X	X	X	X	X	X	X	X
Florian et al. (2008)				X				
Gansterer and Hartl (2018)	X							
Gao et al. (2016)				X				
Goel and Gruhn (2006)				X				
Labadie et al. (2016)	X	X	X		X			

Larsen (2000)		X						
Meyer (2011)								X
Montemanni et al. (2003)				X				
Pillac et al. (2012)				X				
Rodriguez-Vasquez et al. (2017)	X							
Ulmer et al. (2017)	X	X		X				X
Wang and Kopfer (2015)			X					
Xu et al. (2018)				X				
Yang et al. (2017)		X						

In terms of a mathematical and solution-oriented view on the TSP and the VRP, both are known as combinatorial optimization problems (Labadie et al., 2016). These kinds of problems can be divided into the grouping (e.g., cutting and packing), allocation (e.g., linear allocation problem), selection (e.g., knapsack problem) and sequence problems (e.g., TSP, VRP). Many of these problems solved by combinatorial optimization are non-deterministic polynomial acceptable (NP-hard) problems. NP-hard problems have the disadvantage that they are not solvable by a known algorithm in a polynomial runtime (Anbuudayasankar et al., 2014). However, there are established solution methods, as set out in Table 3 below.

Table 3. Overview of solution methods

Category	Solution methods
Exact methods:	Branch and cut
	Branch and bound
	Lagrangian relaxation
	Dynamic programming
Heuristics:	
Constructive heuristics	Nearest-neighbor procedures
	Savings-algorithm
	Minimal spanning tree approach
	Insertion procedures
Local search improvement procedures	r-opt heuristics (e.g. 2-opt method)
Two-phase heuristics	Cluster-first, route-second
	Route-first, cluster-second
Metaheuristics:	Space-filling heuristics
	Simulated annealing
	Tabu search
	Greedy
	Genetic algorithm

	Memetic algorithm
	Ant colony algorithm
	Particle swarm optimization
	Neural networks
	Cross-entropy method
Simulation:	Monte Carlo simulation
	Discrete-event simulation
	Agent-based simulation
	Continuous simulation

The fact that the TSP and the VRP are NP-hard problems, already indicates that exact methods are not the solution methods of choice. According to Anbuudayasankar et al., 2014, the more places or clients added to the routing problem, the higher the number of possible solutions [(n-1)!]. Based on the exponential growth of the problem, the exact methods would not be able to find a solution, or the run-time would be too long. Heuristics constitute a more valuable alternative. These methods determine a result approximately and provide permissible solutions in an adequate time range. Nevertheless, they guarantee a high solution quality and are therefore favored for difficult routing problems (El-Sherbeny, 2010).

To achieve rapid results, which are more likely to be optimal, starting procedures such as the savings algorithm are combined with optimization procedures such as the r-opt method. In this case, the initial route is improved by improvement methods for solving combinatorial optimization problems. Just like classical heuristics, these methods do not guarantee an optimal outcome. However, they are more flexible than classical heuristics and additionally offer a higher solution quality and lower run-times (El-Sherbeny, 2010; Labadie et al., 2016). The greedy algorithm, for example, is often applied for the knapsack problem, whereas the genetic and ant colony algorithms are frequently used for solving the TSP and the VRP. In recent years, hybrid methods have increasingly been chosen in which exact methods are united with heuristic methods (Anbuudayasankar et al. 2014).

Although the TSP, and particularly the VRP, have already been thoroughly studied, there is considerable potential in investigating the various subcategories. There is a lack of appropriate literature particularly on complex models such as the dynamic VRP. Moreover, a large number of solution methods are available with variations in terms of their solution quality and run-time. There is also a lack of knowledge in this field regarding specific characteristics. Equally important, however, is the fact that such knowledge is seldom applied in practice, with the result that parcel delivery companies, for example, often demonstrate inefficiencies in route planning and optimization.

3. The vehicle routing problem in parcel delivery companies

3.1. Characteristics of the VRP in parcel delivery companies

Parcel delivery is an exceptional case of application in the field of vehicle routing. Various specifications are combined, with the result that the model includes an optimization problem of high complexity. The complexity is based primarily on the following characteristics: vehicle capacities regarding volume and weight, time windows, pick-up and delivery, real-time requests, stochastic demand, working hours of the driver, stochastic travel time, heterogeneous fleets, and single or multiple depots. Table 4 below provides an explanation for each of the parcel delivery-specific characteristics that can be regarded as restrictions or drivers of uncertainty (Ulmer, 2017).

All these specific characteristics influence the modeling of the VRP. Irrespective of whether the objective is to minimize the travel time, the distances or the number of deployed vehicles, the modeling and the method of solving of the problem differ from the classical VRP. Parcel delivery companies need to select an adequate solution method that fits their operations in order to achieve the dynamism demanded in their sector.

Table 4. Characteristics of the VRP applied in parcel delivery companies

Characteristics	Explanation
Capacitated	The vehicles have restricted capacities regarding volume and weight
With time windows	Certain time windows must be respected especially in the city center where only short time ranges for the delivery are permitted
Pick-up and delivery	Delivery and pick-up can be jointly covered in one tour or dealt with separately
Dynamic	Routing can be affected by changing information or demand, including real-time requests
Heterogeneous fleet	The fleet can be made up of different types of vehicles varying in their capacities and motorization
Stochastic demand	Non-predictable demand defines the parcel volume anew every day, including seasonality
Working hours	The parcel delivery company should ensure adherence to the legal restrictions relating to working hours
Stochastic travel time	The travel time can differ depending on the current traffic situation
Single or multiple depots	Differentiation between optimization of the routing beginning from a single depot or taking multiple depots into account

3.2. From a static to a dynamic approach

Confronted with the discrepancy between theoretical solution methods and real-world applications, parcel delivery companies and their subcontractors are making use of static approaches. At present, the majority of parcel delivery companies are partitioning their delivery area into geographical clusters (e.g., by zip codes or block groups). Consequently, every driver delivers parcels in the same distinct cluster every day. Since the parcel volume is stochastic and only known a few hours before distribution, the actual demand for delivery is not considered in the planning. Therefore, the dynamic demand is addressed by a static solution. This leads to an unbalanced parcel volume between the clusters, with the result that drivers are unable to distribute the entire number of packages within the intended number of working hours.

Furthermore, partitioning leads to suboptimal results within VRP for three reasons. First, discrete clusters cannot be covered ideally, as the boundaries between them are artificial. Second, vehicles travel through adjacent regions without delivering any parcels. Third, vehicles need to return to previously visited locations to keep appointments within a given time window.

Two major levers can create improved results and change a static process into a dynamic solution. On the one hand, it is possible to break up the geographical clustering. Instead of defining static delivery areas, the implementation of so-called spaghetti-routes promises significant savings. Spaghetti-routes allow the vehicles to deliver parcels in every area they drive through. Parcel delivery companies can start with their distribution straight away and do not have to drive into their allocated cluster before commencing work. Considering time dimensions, this kind of method is particularly suitable for tours with a high number of appointments.

On the other hand, real-time solutions for route planning and navigation help to optimize deliveries. All substantial information can be taken into account so that the route continuously gets overworked. Companies specializing in fast computing offer route optimization programs with algorithms that generate results within seconds. Thanks to efficient technologies, dynamic solutions are now adaptable and affordable. The possible savings and implications are explained in detail in the following case study.

4. Case study design and methodology

4.1. Methodology

To explore the implications of dynamic vehicle routing on parcel delivery providers, an exploratory single-case design was chosen. Case studies enable the researcher to develop an in-depth analysis of a process (Eisenhardt, 1989) and generate concrete and practical knowledge (Flyvbjerg, 2006). The study at hand focuses on one deep case study with a single case, because it was, at the time of the study, a unique case (Yin, 2009). The investigated company was the first company to do away with its traditional delivery areas and implement dynamic vehicle routing, and thus the only company where significant issues of relevance could be identified. The company provided an ideal research setting to explore the phenomenon under investigation, as it provided the researcher with data and access to people at all organizational levels.

4.2. Case setting

The unit of analysis in this study is a German parcel delivery company. It functions as a domestic subcontractor for one of the leading German parcel delivery companies (contractor). With more than 80 vehicles, it covers both urban and rural areas.

The contractor's supply chain – including the different runs of parcel delivery companies – is illustrated in Figure 1 below. Pre-carriage starts with the collection of customers' parcels at different collecting points, such as small shops, gas stations or supermarkets. This process can be integrated into daily tours. Sorting takes place at Hub 1 before the designated parcels are transported in main-carriage to regional hubs close to their final destination (Hub II). Ultimately, the local distribution takes place (on-carriage).

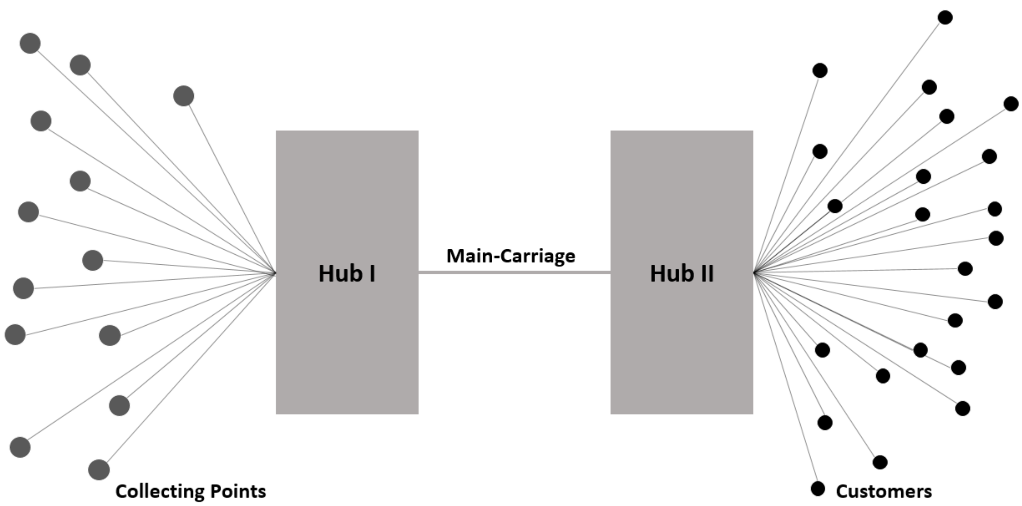

Figure 1. Supply chain of the contractor

The subcontractor analyzed in this study is responsible for Hub II and the local distribution. The process chain can be described as follows:

- Step 1: Receipt of the parcels: Every morning before 7:30 am one or more of the contractor's trucks deliver full roll containers to the depot of the subcontractor. Warehouse staff manually unload the truck.

- Step 2: Commissioning: Each parcel comes with a label that states the delivery area (tour) of the parcel. Each delivery area has an assigned storage location. Warehouse staff manually distribute packages to the assigned storage area.
- Step 3: Loading: The driver assigned to a particular delivery area manually collects his parcels, scans them and loads them into his van.
- Step 4: Delivery: The driver travels to his delivery area to distribute the parcels to the receiver. Based on the scanned parcels, a routing system calculates the ideal route for the driver. However, the driver is not forced to follow the system.

The process chain of the subcontractor is based on fixed delivery areas. Irrespective of the dynamic demand (number of parcels), the solution is static. The subcontractor's delivery area is partitioned into 80 subareas (geographical clusters). Every day, 80 vehicles leave the depot to meet the demand of their area. The static solution leads to an uneven distribution per area and driver and, more importantly, to extreme peaks in workload. As a result of today's burgeoning e-commerce, such peaks can result in twelve-hour tours, with more than 150 parcels. In addition, as explained in Chapter 3, from a vehicle routing perspective, fixed areas lead to certain regions not being ideally covered, vehicles driving through adjacent areas without delivering parcels, and high operational costs for appointments.

To give an indication of the potential of dynamic vehicle routing, the technology provider calculated the tours with its vehicle routing problem-solver. The input data included addresses and names of recipients, as well as the given time constraints for pick-up and delivery of 44 adjacent tours (delivery areas) in total. Moreover, assumptions concerning the service time estimations per checkpoint, depot hours, capacity limitations, and preparation and working hours of the drivers were taken into account for optimization. Finally, the calculation was compared with the actual delivery (or pick-up) time stamp. In order to ensure reliability, data from two different days were used to validate the results. Figure 2 below illustrates how the new routes differed from the optimized ones.

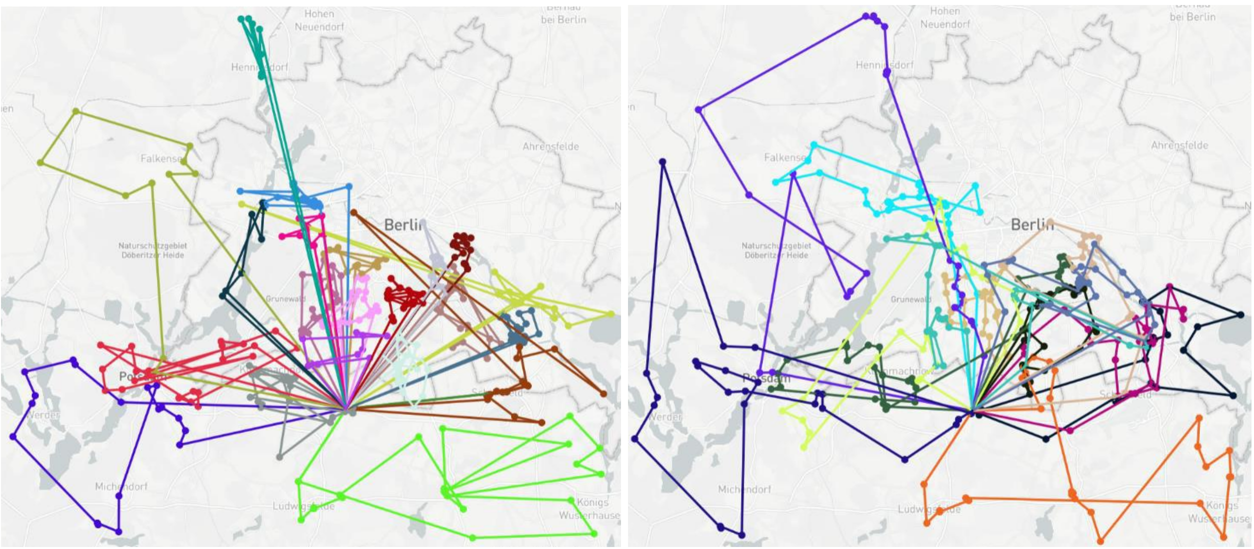

Figure 2. Comparison of static (left) versus dynamic routing (right)

The optimization led to distance savings of 16% and time savings of 48% (complying with legal restrictions relating to working hours). The massive time-saving potential results in an increase in fleet efficiency. Twenty-nine trips are sufficient to match the demand, saving 15 vans in total (35%). An extrapolation of these distance and time savings to 250 operating days per year, with a simplified cost model – including trucking costs (€0,36/km) and personnel costs (€8,84/h) – reveals that up to €450,000 per year can be saved. Table 5 provides an overview of the savings.

Table 5. Savings of dynamic vehicle routing by parameter

Optimization parameters	Fixed delivery areas	Dynamic vehicle routing	Savings in %	Annual savings	Annual savings
Distance	4,191 km	3,507 km	16 %	171,000 km	€61,560
Working Time	373 hours	195 hours	48 %	44,500 hours	€393,380
Vehicle Count	44 vans	29 vans	34 %		

Over and above the financial benefits, the dynamic optimization also impacts the customer experience. The original data reveal that from 12 pm a growing number of time windows for appointments cannot be met using the static planning approach. Figure 3 illustrates the difference in appointment reliability for both the original (green dots) and the simulated data for the dynamic solution (brown dots). The x-axis indicates the time the parcel was delivered and the y-axis by how many minutes the time window was missed.

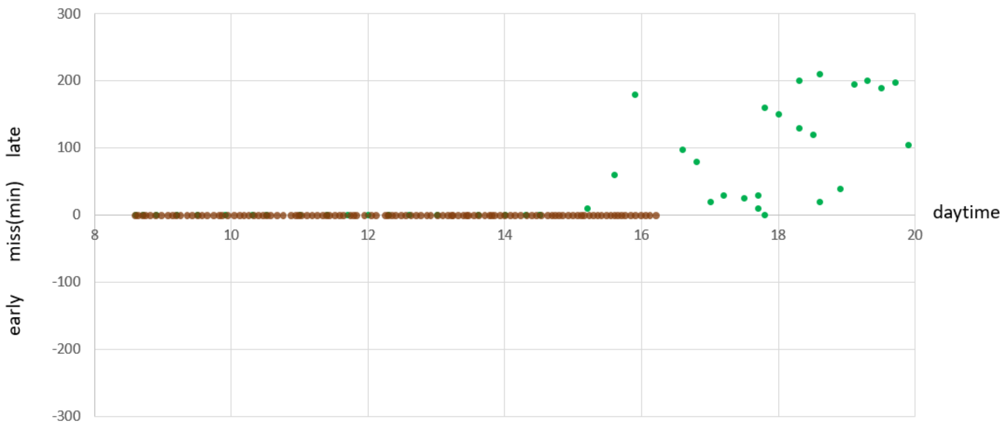

Figure 3. Appointment reliability of static versus dynamic routing

4.3. Data collection and analysis

The entities of interest for the data collection were drivers, warehouse workers, and informants from different organizational levels. The technology provider's project team was also included. Open-ended interviews were conducted with four drivers, one warehouse worker, one warehouse manager, one forwarding agent, the managing director and the project lead of the technology provider. However, a different approach was chosen for two of the drivers. They were observed by means of the complete observer technique (Gill and Johnson, 2002). In terms of this ethnographic technique, one researcher joined one driver for one day, including the commissioning, loading and delivery stages. The purpose was not revealed to the driver. It should be noted that a logistics manager in charge selected the drivers, resulting in a selection bias. However, this was due primarily to the fact that the observation was limited to German-speaking drivers. However, based on discussions with other drivers in the warehouse, they did not differ significantly from those who were observed.

After the data collection, the authors analyzed interview transcripts and notes from the ethnographic research in accordance with the three simultaneous activities of qualitative data analysis advocated by Miles et al. (2014): data condensation, data display, and drawing and verifying conclusions. Open coding was used to analyze the empirical material, as it enabled the research team to remain unbiased towards any kind of associations or connections (Charmaz, 2014). By talking to members of different organizational levels, different perspectives of the phenomenon were taken into consideration. This triangulation of sources produced coherent conclusions (Miles et al., 2014). One expert from the technology provider was chosen as a peer debriefer to discuss the findings and add validity to the process (Creswell, 2014).

5. Case study findings

5.1. Human

A critical finding of this research is that the implications of dynamic vehicle routing on parcel delivery companies can be structured in three different categories (each representing different themes). In accordance with Yusof et al. (2008), the analysis and interpretation in this paper is structured into human, organizational and technological factors. Hence, it is useful to take these three factors into account when trying to understand why it is challenging to implement dynamic vehicle routing systems in traditional parcel delivery companies.

Finding suitable drivers is a key challenge for parcel delivery companies. Even though the required qualification is relatively low, the job is physically demanding and stressful. Due to the growing parcel demand, the working hours tend to increase day by day. Many drivers stop working after the training period, which results in a high turnover rate The implementation of dynamic vehicle routing systems has a significant impact on the drivers' working conditions; however, as with every change process, it also presents certain challenges.

One core idea of dynamic vehicle routing is that it breaks up traditional delivery areas to apportion the parcels in such a way that each driver ends up with the same workload – i.e. a tour of approximately eight hours, or at least within legal limits. Discussions with the informants revealed a general feeling that there was a need to balance the workload of all drivers. One informant admitted that delivery areas had not been modified, even though demand had increased significantly in recent years. However, even though the implementation was regarded as a blessing by the majority of the drivers, there were certain drivers who saw a downside to the situation; especially the more experienced drivers who were rewarded with the more comfortable delivery areas in the past. For example, one driver explained:

> *"I've been driving in my area for many years now. I know every street, every house and many of the customers. I know all the details – like where to put the parcel when they are not at home. I need five to six hours for 120 parcels. I am done faster than others, because I am so experienced. I don't even need a routing system."*

This is consistent with the experience of the project manager of the technology provider. It is always a challenge to convince the experienced drivers to trust in new technologies. Some experienced drivers are convinced that they know better than the system and choose to take another route or deliver parcels in a different order. Moreover, they want to take their own decisions and are not keen to be supervised by their back office. However, the researchers found out that it is crucial to win experienced lead users early on in the project to promote dynamic routing systems internally. In addition, based on vehicle monitoring, the management should think about new incentive systems. Fuel consumption, accident rate or parcels without damage could be new parameters for assessment.

For new couriers, however, a dynamic routing system is of significant advantage. The system helps them with their daily routine. They do not need to navigate on their own in areas they do not know. One young driver admitted that he was trained for three days without the system, managing 30 to 40 parcels a day. From day four onwards, he used the dynamic routing system. *"I managed more than 120 parcels on my fourth day in an unfamiliar urban area. The training process was very smooth and easy; the learning curve was amazing."*

Irrespective of the experience, all drivers recognize a significant advantage with regard to appointments. It is challenging to meet appointments; especially those in the afternoon. The comment was made that they sometimes have to drive "back" for 30 minutes to deliver a parcel in a particular time window. Alternatively – and even worse – wait for one or two hours after the end of their tour because there is one final appointment in the evening. According to the forwarding agent, it is crucial to communicate the benefits of the new system frequently, with a view to increasing its level of acceptance among drivers.

5.2. Organization

As a result of intensifying cost-pressure, parcel delivery companies increasingly focus on optimizing processes, and staffing levels are being reduced to a minimum. Dynamic vehicle routing enables these companies to increase the efficiency of their processes. However, the informants discussed a number of changes in the process management required for the implementation of the new system. All the steps described in Chapter 4.2. require changes.

When parcels arrive, and warehouse workers unload the truck, one more process step needs to be implemented: a labeling process. The contractor delivers parcels labeled with the old delivery areas. Therefore, each parcel needs to be scanned and equipped with a label indicating its tour instead of its delivery area. The technology provider provides the subcontractor with a scan-and-labeling device that is *"very easy to use"*. Once the parcels are labeled with the tour information, the commissioning process can start. Each tour has an assigned storage location. The warehouse manager stated that every tour number is assigned to the same storage location every day to facilitate the commissioning process. The drivers assigned to one tour collect their parcels, scan them, and load their vans. They start their tour following the routing system, and they are forced to follow the system so that they remain on the ideal route.

One issue that was frequently brought up during discussions with drivers and the management team on the delivery process was that of local distribution. One driver admitted:

> *"When we deliver parcels in unfamiliar areas, we don't know where to park best, we don't know the details about the houses, we don't know where to leave the parcels, we don't know whom to trust. When we lack this information, we need more time per checkpoint."*

According to the managing director, the only way to overcome this challenge is to provide the driver with the required information at each checkpoint. The drivers can already interact with the routing system and add information to each checkpoint. The next time a driver delivers a parcel to the same receiver, the routing system displays the relevant information. The project manager admitted that this was regarded as proprietary information and not shared with other clients. The technology provider was well aware of this problem. In the future they plan to furnish the drivers with parking instructions.

Another theme explored in the interviews was that of workforce planning. With fixed delivery areas it is straightforward to plan the number of drivers required per day, i.e. one driver per delivery area. However, this changes with dynamic vehicle routing, as the number of vehicles required for the distribution varies throughout the week (e.g., more parcels at the end of the week) and over periods such as Christmas. As the tours cannot be calculated before the last truck leaves the contractor's logistics hub, the subcontractor receives the calculated tours only a few hours before the drivers start working. This requires the subcontractor to have drivers on call to react to peaks. Despite the improved flexibility, the implementation of dynamic vehicle routing reduces the demand for new drivers. During the interviews, it was constantly highlighted that it is challenging to find suitable drivers. Moreover, the managing director expected the high turnover rate to decrease, as the new system increased drivers' level of satisfaction.

Finally, the forwarding agent felt that it was easier to communicate and – more importantly – to meet the time windows promised to the customer. For example, as a parcel delivery company, they offer same-day pick-up and delivery in their delivery area. When a customer requested same-day service, the forwarding agent needed to work out how best to achieve this. Consequently, the request was allocated to a driver that was close to the pick-up location. Today, the system can determine the optimal driver and tour within seconds, and the appointment can be met. The agent commented that *"The punctuality of our appointments is a major driver of customer satisfaction."*

5.3. Technology

Due to the complexity of dynamic vehicle routing for parcel delivery companies, it requires fast computing technology to provide pseudo-real-time solutions for the VRP problem. The technology provider provides the subcontractor with a completely separate inter-cloud subsystem. Consequently, data access, authentication and authorization issues, and outage management are separated from other clients. Furthermore, data privacy is ensured. The subcontractor can manage its cloud using a simple programmable interface. The system is realized as a software as a service (SaaS) solution with an application programming interface (API) and middleware toolchain. E-mail, file transfer protocol (FTP), hypertext transfer protocol (HTTP), WebSocket, and other technology can be easily connected and transformed. To facilitate integration into existing solutions, it is also possible to exchange individual components such as map processing or geocoding. According to the informants, the most crucial characteristic for successful implementation of the system is SaaS, because it does not require them to change the current system or purchase servers to enhance existing processing power.

In the case under examination, a full tour optimization for the depot can be realized within a few minutes. This is crucial, as the optimization is run at a very late stage during the process chain. Once the contractor transmits the data relating to the upcoming parcels, the forwarding agent adds other pending orders to it and copies the data into the system. The system searches for an optimal tour assignment. The loading and driving sequence is downloaded to routing devices in real time. When new orders arrive, the optimization can be triggered again. However, once a new order is added to the system, the loading and driving sequence can change. The forwarding agent mentioned that this means that the loading sequence is obsolete in some cases, leading to extended search times.

The main challenge to novel technology adoption was felt to be driver acceptance and hence user acceptance. The project manager commented that the system implementation depended primarily on people:

> *"It is extremely difficult to convince the drivers that the calculated way is the optimal one. They are permanently changing their tours, which leads to large deviations. For example, on bigger streets, we route them in a way that they cover one side of the street first, and the other side on their way back. They don't see that the crossing takes time and is dangerous."*

Intensive training of the drivers can help to demonstrate the benefits of the system and explain the causes of misunderstanding.

In general, it is suggested that dynamic vehicle routing initially be piloted in a few delivery areas. It is useful to start with a small group of open-minded workers, particularly with regard to the changes required in the depot. The pilot project helps to identify technological and processual teething problems and measure the savings. The acquired knowledge facilitates a full roll-out. In addition, warehouse workers and drivers can share positive experiences from the pilot project with their colleagues.

6. Conclusion

6.1. Discussion and managerial implications

This research was undertaken to understand the implications of dynamic vehicle routing systems on parcel delivery companies and to offer practitioner guidance for successful implementation. In managerial terms, the contribution of this paper is threefold. First, it highlights the economic and social benefits of dynamic vehicle routing and specifically of breaking up fixed delivery areas. Second, it identifies three critical types of effects when implementing dynamic vehicle routing systems, namely human, organizational, and technological implications. Third, the paper provides a first-hand plan of action for successful implementation of dynamic vehicle routing systems.

The economic benefits of dynamic vehicle routing are tremendous. In the case at hand, the company was able to save 16% in terms of distance and 48% in working time, leading to a reduction of 34% in the number of vans required. Taking the growing demand for parcel delivery into account, the implementation of a dynamic solution is inevitable. However, the implementation of the system is challenging and has a number of different implications.

The first set of implications relate to the extent to which the employees of parcel delivery companies are affected by dynamic vehicle routing. In general, the new system is a blessing for the majority of the drivers, as it ensures that their workload is within legal limits and it assists them in their daily routine. However, drivers need to give up their familiar delivery areas and explore new territory. Furthermore, they are not always willing to trust in technology and to be monitored. This is in line with the argument put forward by Davis (1989) that the perceived usefulness and ease of use influence the user acceptance of computer systems. The findings of this paper suggest that it is crucial for the parcel delivery company and its technology provider to identify lead users among the experienced drivers, provide drivers with sufficient training, consistently communicate the system's value to the drivers, and implement new incentive programs.

With regard to organizational implications, tremendous changes in the process chain are required for implementation. For example, a new labeling process needs to be implemented. As a result, a dedicated process manager should join the project team early on in the project. In terms of efficiency, the drivers need more time per checkpoint when they drive through unknown areas. The management team therefore needs to encourage the drivers to incorporate information on local distribution into the system so that other drivers can access it during their tour. Workforce planning is another organizational challenge, as it is no longer static. Human resource management needs to cope with dynamic workforce planning, including buffering capacity and having drivers on call to react to peaks.

With regard to technological implications, the integration of a SaaS system is feasible, even for smaller firms. One challenge the researchers observed was the time of optimization. When the forwarding agent optimizes the tours more than once, this changes the tour and leads to different loading and driving sequences. When the process has already started, this causes problems for the drivers. The researchers recommend building on the experience of the technology provider and testing it during the pilot project. Every firm should pilot the dynamic vehicle routing approach in certain delivery areas to avoid teething problems during the roll-out. Finally, in relation to human implications, technology adoption is a vital driver of a successful implementation. When the users (drivers) do not accept the technology, the implementation fails, which is why technology providers focus specifically on the training of drivers. Table 6 demonstrates the proposed plan of action.

Table 6. Plan of action regarding identified implications

Implications	Plan of action
Human:	
Drivers prefer to stay in their delivery area	Constantly communicate the benefits of the system
Drivers refuse to use new technologies	Train drivers sufficiently and find lead users among experienced drivers
Drivers do not want to be observed	Implement new incentive programs
Organizational:	
Changes in the process chain	Dedicated process manager in the team
Efficiency in local distribution	Add information to the system
Workforce planning	Dynamic workforce planning including buffering capacity
Technology:	
Technology acceptance	Train employees
Teething problems	Pilot with a few delivery areas and a small group of employees
Point of optimization	Request assistance of technology provider

6.2. Limitations and further avenues of research

This paper has certain limitations with regard to research design. However, these limitations also point to several important directions for future research. First, the research involved a single case study, conducted within a specific industry and setting. Logically, a single case study cannot cover all themes that are related to the implementation of dynamic vehicle routing systems. Other parcel delivery companies are different in nature. For example, they may not be bound to a larger parcel delivery company; they may be equipped with fully automated storage technology; they may use different vehicles and be in possession of keys to enter buildings etc. Therefore, with a view to a generalization of results, additional cases should be studied in the future (Yin, 2009; Creswell, 2014). Moreover, the implementation of dynamic vehicle routing in other industries, such as waste management or street cleaning, could be interesting topics for future research.

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