Can Routing Systems Surpass the Routing Knowledge of an Experienced Driver in Urban Deliveries?

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CAN ROUTING SYSTEMS SURPASS THE ROUTING KNOWLEDGE OF AN EXPERIENCED DRIVER IN URBAN DELIVERIES?

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ABSTRACT

Tests were conducted to determine solutions to future efficiency improvements in routing software, when used in the context of multi-carrier urban deliveries rounds with clean vehicles. The findings tend to show that current problems are hindering IT systems to produce optimised routes that would be better than an experienced driver in terms of distance, time and costs. However, in some cases, improvement potential was detected and manual effort added to optimised routing were leading to substantial savings. Far from ideal, current systems require substantial change to surpass the practical experience of urban delivery drivers in applying to frequent delivery within city centres.

INTRODUCTION AND ISSUES, HYPOTHESES, OBJECTIVES AND KEY RESEARCH QUESTIONS

Starting with the ground-breaking works of Taniguchi, Thompson, Yamada (Taniguchi & Heijden, 2010; Yamada et al, 2001, Taniguchi et al. 2003) and other pioneer researchers in the 90s, an increasing number of researchers from different science fields (transportation, economics, operational research) was developing several urban logistics solutions in the past 30 years, to improve the logistics efficiency, and reduce externalities, notably with new information systems for routing and scheduling. These systems are calculating the shortest path, and the sequence according to time and addresses, considering traffic and other factors.

Researchers developed models of vehicle routing problems (VRP) or vehicle routing problems with time windows (VRPTW) as fundamental method for understanding how to solve different problems such as operational costs, congestion and other difficulties around traffic related problems. Operations researchers and practitioners published several papers on VRP and VRPTW (e.g., Eksioglu et al., 2009). Many VRP solutions are available, at least in theory, but their deployment in the business world is slow, so the underlying practical problems persist. To find the shortest route to deliver goods does not seem like a difficult exercise when dealing with 10 deliveries per day in the same area; but the most productive current parcels delivery drivers are capable of effectively delivering more than 200 deliveries, in some cases up to 450 parcels a day as yearly average performance. Drivers' capabilities to generate the shortest possible route and journey time are limited, and it is crucial to investigate if the use of even more advanced VRP supporting IT technologies could further improve the performance.

In parallel to this, a full range of transport problems occurring in cities were tackled by increasingly ambitious urban logistics policies and management approaches (Taniguchi et al. 2000), also called urban logistics solutions or good practices. The research in this field is often performed with applied methods such as trials and experimental tests, with surveys, data collection and case studies, with impact assessments, and with the involvement of experts, practitioners, policy makers and scientists from a growing number of disciplines.

In this context, a trial is defined as a method to determine whether a solution is feasible, which are its strengths and weaknesses, what are the consequences of its application in the fields of business from the point of view of the organisation using it, and for its customers, what are the public-sector benefits of such a solution, what are its success factors and barriers, and what would be the best supportive action for a wider scale deployment (BESTFACT 2015).

The impacts are often defined with the help of measured or calculated quantitative indicators and parameters. With information on impacts, decision makers receive robust evidence on the consequences of their actions and plans (Thompson & Hassall, 2006).

Leading researchers and practitioners in urban logistics use a wide range of approaches in their studies, going from very basic and fundamental to very practical and applied. The most fundamental studies are presenting clear overviews based on theoretical modelling and operational research (Crainic et al., 2009), literature review (Taniguchi et al. 2016, Anand et al., 2012), or providing general educational guidance (Crainic, 2008). Some studies focus on guidelines for practitioners (Dablanc, 2010). The most applied studies are empirical surveys, with the recent synthesis of Russo and Comi (2016), technology development and evaluation (Smirlis et al., 2010), or evaluation of practices. Patier & Browne (2010) suggested a generic, more homogenous approach to evaluation of practices, but there is currently a heterogeneous, and perhaps confusingly wide range of tests and practices evaluated in different ways. Many hundred urban logistics evaluations and tests were taking place recently in the European projects BESTUFS (2008), SUGAR (2011), CIVITAS-Mimosa (Ribeiro et al 2013), LaMilo (2014), BESTFACT (2015), SMARTFUSION (2015), STRAIGHSOL (2015) and CITYLAB (2017). However very few of these tests were about IT and routing in urban freight, and using a consistent evaluation approach.

There is a risk of confusion through too much diversity and complexity, exacerbated through the need to include the perspectives of multiple actors in urban logistics practices and in collaborative research projects (Stathopoulos et al, 2012, Macharis et al. 2009). To tackle this risk, the solution envisaged here is to focus on common objectives, and to simplify the tasks to create joint understanding for logistics business leaders, IT software providers, public authorities and experts. Different stakeholder approaches used in local urban logistics policies were described and reviewed by Lindholm (2013). Other stakeholder oriented approaches are the agent-based modelling in economic studies (Stathopoulos et al, 2012). The central ambition of many studies, partly or fully centred around VRP and routing systems in urban logistics is similar: Objectives of these are to increase the routing efficiency, reducing congestion, time and CO_2 (Figliozzi, 2011) and improve the business models (Macario et al, 2008) with strategies such as reducing operative costs, total time or total distance driven. Early models of city logistics with or without mentioning routing systems, had the objective to generate an optimal solution by minimizing total transportation costs (Gattuso & Pellicanõ, 2014). These objectives are all integrated to the wider objectives of this study.

Another set of key objectives is greening businesses. Palson & Johansson (2016) reported in a recent Swedish survey that one of the first strategy of logistics businesses in reducing emissions is transport planning. Wang et al. (2015) showed in a UK retail freight survey that further CO_2 reduction can be achieved through diverse IT solutions. Rizet et al. (2012) found that the urban part of global supply chains is one where the most carbon emission occurs. For 30 years, the studies of McKinnon influenced and benefited research, technologies and policies on greening of logistics businesses and freight transport (McKinnon et al, 2015).

Figure 1 presents the system of observations of this study. It is centred around the main business actor, the transport operator delivering the parcels in cities, which is mostly a 3PL or carrier's carrier, responding to the demand of their customers with a viable urban logistics business model.

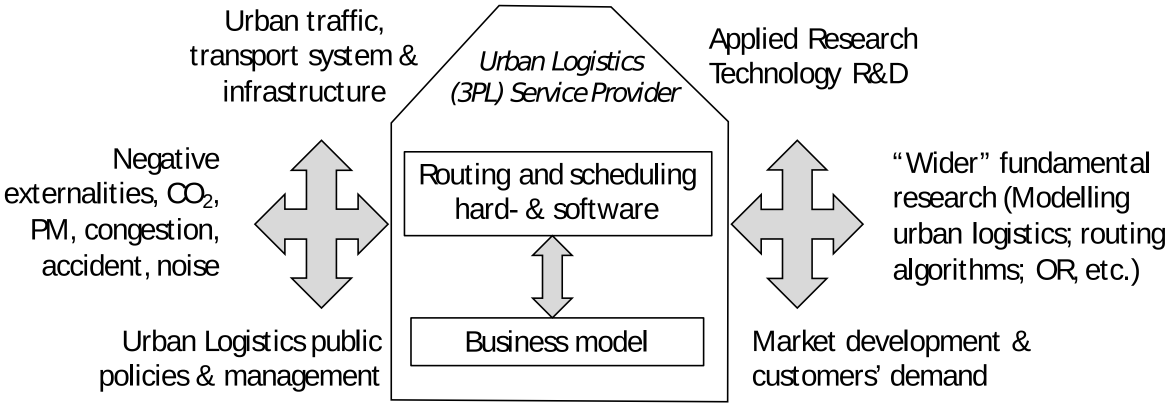


Figure 1: Routing and scheduling systems, business models in urban logistics, and the surrounding system of observations

The software and hardware systems implemented are influencing positively the business case, but also expected to mitigate the negative externalities. In such an urban logistics study, the focus needs to be broader than business model and software design alone, because of several surrounding influence factors. The biggest influence on business decisions of an Urban Logistics Service Provider is the need of his client and the underlying market development.

If research and development (R&D) on technology and wider fundamental research would want to develop routing and scheduling solutions that have a real chance of being widely applied in the business world, then it must integrate the needs of customers, and the needs of a profitable business model (Figure 1).

Urban traffic and transport system can be positively impacting the business model, for example when the information on parking is available. Or it can be negative, if the congestion is unpredictable and the risks of coming late, and the substantial penalties associated with late deliveries, are solely to the responsibility of the operator.

Public policies of local authorities are rarely including logistics. In London, there is an active freight management team, and this team is considering technology such as big data or logistics routing as potential solutions for multiple problems in urban transport.

Few logistics studies were surveying real businesses and collecting performance data with and without routing systems, analysing the benefits for the users and presenting paths for future R&D solutions. Baumgartner & Leonardi (2008) presented such a survey for Germany, but none of the business users were urban freight operators. Golob & Regan (2003) presented a pioneering survey of routing software used by trucking firms to avoid congestion in California, and mentioned that businesses performing deliveries in Los Angeles Area are likely customers of such IT applications. Also, very few studies were linking theoretical scenario and modelling approach of routing with experimental live business trials and case studies in urban logistics. One notable exception to the widespread separation of models and experiments is the work of Figliozzi (2011), linking local traffic data, routing system development and business trial, to the benefit of reducing congestion and CO_2 emissions in the region of Portland, USA.

Here we propose to link the modelling approach of technology assessment, presented for example in Taniguchi & Shimamoto (2004), with an empirical trial impact assessment using the before-after approach, presented e.g. by Leonardi et al. (2012). Details on test design and impact evaluation framework are presented below.

In UK, the use of routing systems and scheduling plan is limited in urban logistics businesses, because most companies consider the knowledge of their drivers as fully sufficient to practice the most effective routing. At the same time, the market for routing and scheduling software is changing. Recent developments have shown that it might be possible to improve the overall efficiency of urban deliveries by reducing the total distance driven and the average time spent per parcel for a given business day.

To sum up, following hypothesis and questions build the starting point of this study:

(1) Urban delivery businesses rarely use IT support for routing
(2) Some of the current systems might perform better than an experienced driver
(3) Theoretical solutions and algorithms with nearly optimal solutions produce even more efficient optimisations than the best current IT system on the market
(4) As a side-effect, a higher routing efficiency would impact positively on other direct and indirect external negative consequences such as congestion, accidents, noise, emissions of greenhouse gases and air pollutants.

So, the next hypothesis and lead research question for this study is:

(5) It is possible to link the business model in urban logistics operations, the current practice on driver routing, the IT routing solutions on the market and the state of the art in theoretical routing optimisation modelling, to obtain a better route than a driver.

Objective of this study is to verify these hypotheses and answer the question: what could be the future development of routing software applications, considering an overall improvement in traffic conditions and freight efficiency in urban area?

MEASURES, APPROACHES AND DESIGN OF THE STUDY AND THE TRIALS

The urban logistics business where the trials took place is Gnewt Cargo Ltd (= the operator). This growing business is a parcels distribution service provider, based in London, UK, performing operations mainly for e-commerce and large parcels carriers, and next day deliveries. It has the particularity of running a fleet of about 60-100 vans, all 100% battery electric powered, and with 100% regenerative electricity supply. The only remaining emissions of such vehicle use are particulates from tyre abrasion and road dust.

In past research, the authors performed series of studies where replicable scientific procedures were developed, integrating multiple design suggestions of the literature mentioned above. Key methods and approaches were presented in previous articles and reports (Baumgartner & Leonardi 2008, Browne et al. 2011, Balm et al 2012, Leonardi et al 2012, BESTFACT 2015, SMARTFUSION 2015).

This study was constructed with different building blocks, summarised in Figure 2. This architecture of research approaches was developed by Lam & van de Voorde (2010) in a maritime research context. Here, it was adapted for IT trials and specific subtasks.

The basic block is the *theoretical framework*, within which the whole question to be answered had to be placed. Route optimisation and efficiency increase while minimising transportation costs are the aim of the type of tests envisaged. How to achieve this optimisation has already been tested in multiple projects. The context and key literature is presented above.

This trial went beyond the current state of knowledge by capturing data on optimisation when one business starts to use a new software. With this framework, a clean business, run without any routing software was selected, addressing the urban logistics policies of making transport more sustainable and contributing to a better air quality, while at the same time potentially increasing the internal business optimisation. The main challenges tackled are climate change reduction and internalisation of external costs of transport such as congestion, accidents and health impacts of noise and air pollutant emissions. The maximisation of profit is also a big challenge in the profession, because margins are traditionally very low, thus leaving limited opportunities for innovations, and giving almost no room for testing of new business concepts. The minimisation of risks is often first when it comes to hierarchy of strategies and tactics in place, since no business can take the risk of failure or bankruptcy. This risk is very relevant, as one major parcel carrier active in London was going bankrupt end of 2014, generating turmoil on the market before trials started.

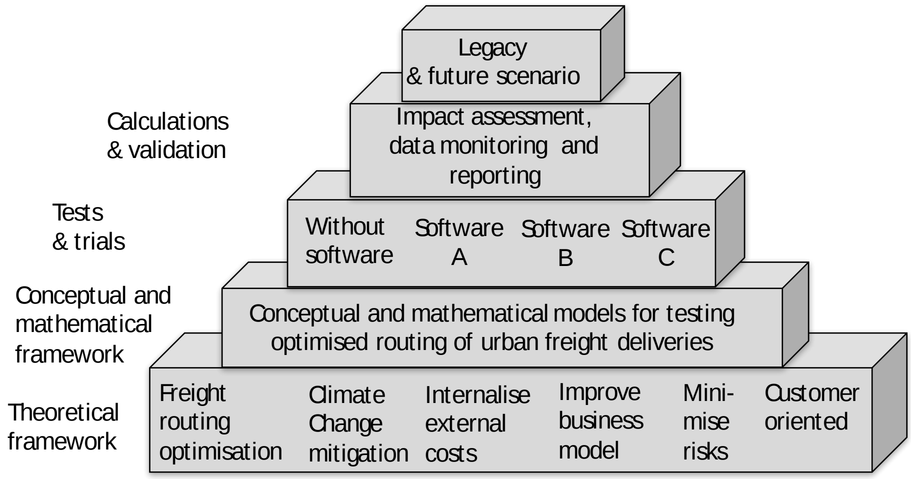


Figure 2: Building blocks of different approaches used in the trials
Source: Adapted from Lam & van de Voorde 2010

To deal with this framework, a second block, the *data and numerical models for testing optimised routing of urban freight deliveries*, had to be developed. The conceptual and mathematical model for sustainable urban freight deliveries was developed in previous studies, not only at the University of Westminster. It is simple enough to be handled in the frame of a business trial investigation, and complete enough to cover the relevant dimensions mentioned above in the theoretical framework (e.g. clarity for all stakeholders). The basis of the mathematical model used here is the linking of performance metrics, such as number of parcels delivered, number of trips, and distance driven on urban roads, with impacts metrics such as CO_2 per parcel, air pollutants or costs per parcel. Another basic element of this calculation model is the before-after (or with/without) comparison, a method of measurements prior and after any changes, which provided robust evidence on the reductions achieved. Due to the black box nature of the proprietary software, it was not possible to test the underlying routing algorithms. The results of these hidden runs of numerical routing models, however, were tested in form of optimised routes in real life business.

The next building block is the practical step of implementation of *tests and trials*. Reference data ('before') was collected first, and the data during the trial was collected later, 'after' all practical procedures have been successfully put in place, and the freight transport operations have started to change. But, this implementation cannot be successful if the data collection effort has not started much earlier. So, the trial has effectively begun before the effective transport process had started to change, and the first parcel has been delivered with the new IT support model. The operator was testing optimised operations in life business conditions with real clients after a preparation period that is integral part of the test. Tasks in this block are the testing of different software solutions.

The next block is the *calculation and validation of the test results*. The key tasks consisted of grouping all raw data collected and monitored during the trial, such as vehicles, fuel use, number of parcels, distance, etc. and to calculate the secondary impact indicators such as distance per parcel, CO_2 per parcel, etc. Here, the different elements of the numerical model are readily available and applied.

The final building block is the *legacy and scenario analysis*, in which the lessons learnt from the trial and the strategies and tactics for future developments are presented.

Design of the tests: To test the hypothesis (5), in London, the trial was set-up to test the current IT solutions in a real business environment, and to develop missing features, so that the day-to-day deliveries would be performed with less distance and less time. Already at the starting stage it became obvious that none of the current systems available on the market would perform in an effective way when purchased and used as such. Each system had first to adapt to the business situation, to the local street network, to the lack of GPS data in Central London, etc. After a more on less important development effort, each system was tested in a real business environment, for real deliveries to real clients, in a classical milk-round type trip, where a 2.4t van departs from an urban depot in the morning, performs 40 to 200 deliveries during the day, and come back empty in the evening, sometimes after a reload and 2nd or 3rd run.

The business is a parcel service provider, carrying goods for different large companies in a dedicated area in London. The field work consisted in collecting data relevant for answering the question: Can routing systems be better than an experienced driver in urban deliveries?

The field observations started for 3 different IT solutions, selected among a pool of 12 possible Software solutions initially reviewed in a market research exercise. Trials were conducted from 1 July 2014 to 30 June 2016 in Central London. The preparation and software development phase took place in 2014 and 2015. Progressively, each solution was implemented in 2015 and 2016, and compared to a situation without routing optimisation. Each software was adapted, installed and tested successively on similar routes in residential, commercial and office building areas of Central London. The results below present the specific design, problems and solutions of each Software. Data collection took place for 3 clients and 3 IT systems. The datasets were comprising data on parcels, distance, time, and stop locations. The field observation data in the 'before' situation is the reference case without software or optimisation. Data 'after' are on optimised routes.

Problems to be solved: Several software problems occurred, such as inaccurate Central London address map, loading bays and parking areas, compatibilities with software of clients, formats of the lists, scan of drivers, etc.

Solutions to the problems consisted in preparation of the software systems and adaptation to the needs of the operator and the needs of the trials (details below).

Data collection: All address lists and optimised routes were stored in data servers and folders dedicated to the trials, collecting evidence for evaluation. Current management systems of the operator were used to build the reference case without optimisation, enabling to compare trial data with the reference.

Samples problems: All tests were performed on standard routes with the main client. In parallel to the software trial, data was collected on 13,360 freight deliveries via electric vans, covering 148,500 miles, delivering about 2 million parcels during this 12-month project, between 1st July 2015 and 30 June 2016. It is assumed that all routes tested are corresponding to a typical urban delivery business, like most other routes driven by this business, and like other urban freight businesses that are occurring a thousand times every day in cities. The sample size was limited to few hundred routes and one operating company, however. The similarities in the results obtained with and without optimisation tends to give the impression that the sample selected was representative, and that other tests would have continue to produce similar results. Therefore, after a test period of two to six months for each software, the tests were discontinued.

RESULTS

IT supported tour planning in urban area aims to find the ideal sequence of customer sites to be served by each vehicle. The operator is making a limited use of route planning software, as driver knowledge is considered unbeatable. In Central London, the number of different addresses is around 300,000, the density of customers is very high, and the challenge for route planning is high.

Currently only depot management and driver knowledge are used by the company to pursue these targets. Every morning, the list of items arrives together with the parcels to be distributed, and there is no time for the drivers to undertake any software run or route calculations. Usually it takes at least 30 minutes to 1 hour to order the parcels for the day and to load the parcels into the vans in the right order.

The operator uses business data to plan the delivery rounds. In the daily business, rounds are planned manually, and the deliveries are not ordered according to the software data transmitted from the clients, but the ordering of parcels is done through a mix of client's listings suggestions and driver knowledge. The paperwork is listing the items in a certain order, given by the clients' internal management software packages, and these lists do not include a route optimisation.

While most large logistics companies have the resource to develop internal tour planning software as an in-house solution, small and medium-size businesses cannot afford the costs of such a system. The market for available software products was therefore analysed in 2015, and a shortlist of few potential tour planning applications was generated. The shortlist comprised Software A, B, and C, all capable of planning a tour and optimising multiple drivers' rounds and area served.

IT support, to be effective, would need to improve considerably, because all commercial systems are designed to streamline long distance logistics. All these capabilities can be considered invalid for short distance trips in urban area from the driver point of view. Testing initially led to tour suggestions with much longer trip distances than would be needed. It was immediately clear for the software partners and for the operator that the challenges are high. Adaptations to current system design were performed during the lifetime of the project.

In the first half year of the project, in 2015, the Tour Planning software testing was prepared. The time October to December 2015 could not be used for real trial, as the strain for drivers was high. The trials started in early 2016 with the phases of implementation and data processing. A dedicated computer was purchased, and software was installed.

Software A and B support teams trained the operator staff responsible for scheduling and IT. The training took place over 3 days for the Software A and one day for the Software B. The software C was tested without specific training. Data were collected more extensively for the Software A and B tests.

What is the tour data when it arrives at the operator? Early morning, parcels arrive from the depots of the clients. Simultaneously, the data with the address lists arrives. However, because of the multiple clients, the data arrives in multiple formats.

For example, the operator uses the IT system provided by one large client, which has as main component the products of the software company D. This software D is used for the orders list, parcel scan with hand held device, proof of delivery and driver communication. It is not possible for the operator to use software D for routing optimisation. However, the lists of client's delivery addresses can be exported in Excel format, and then used for the routing optimisation.

For some parcel business clients, the data arrives at the operator via the internet in standard csv format, which is usable in standard office spreadsheets.

Due to the complications with the heterogeneous data format of the different clients of the operator, it was not possible to generate, as originally intended, cross-carrier optimisations. The routing and tour planning trials were therefore rather less complex, and performed using the routes of one main client. All data were normalised, using the streamlined data and management information system, which was designed during the project.

Software A trial

Software A is a dedicated route, tour planning and scheduling solution aiming at reducing the overall distance and time of deliveries. This system was developed in Germany for long distance transport and is now in use in 60 countries.

The solution works as such: the order list of the client is uploaded into the system via an online web access of Software A provider. The run of an optimisation function allows producing a new ordered list, with an optimal route for each driver. A combination of routes is also possible. A first analysis was performed on the routes of the main client, then several tests continued. For the software A tests, the objective is to analyse the difference between normal day-to-day tours with manual planning and the software optimisation. The first results were available early for 5 rounds (Figure 3).

This result shows a typical problem of inaccuracy with the data obtained via the current information system. The routes in the left image were not driven exactly how they are shown on the map (Figure 3). In this map, each dot corresponds to the location where the operator's driver scans the parcel barcode information. Sometimes the scan occurs exactly at the place of delivery, but sometimes the driver is in a rush and scans the barcodes of multiple parcels a few minutes later at another place. Thus, the original client's data on the parcel scans are potentially not in the right sequence of delivery, not at the right place, and not at the right time. Therefore, there is a big difference of 51% distance reduction after optimisation in Figure 3 runs.

The reconfiguration of the delivery area (Figure 4) results from another type of optimisation run, including the functionality of merging the different routes of the initial delivery area, respecting the constraints of an 8-hour total duration of a delivery day. It shows that out of 5 rounds, only 3 would be needed for the same area.

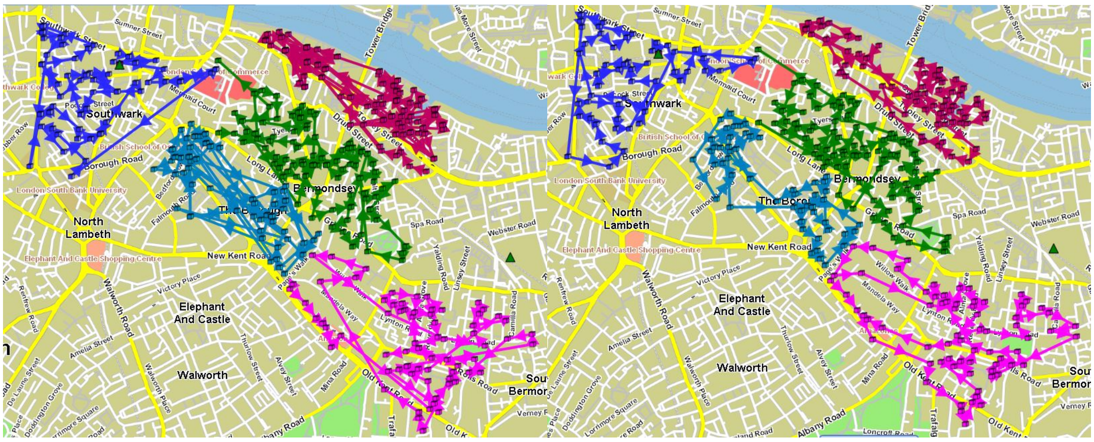


Figure 3: 5 rounds in Southwark, before (left) and after (right) optimisation
Source: Software A and Operator data

The run shown in Figure 6 indicates a potential reduction of 56% in the number of trips and number of vehicles on the road. But this important effect might also be strongly overstated, due to a distortion with the round data on the situation 'before', obtained with the current logging system.

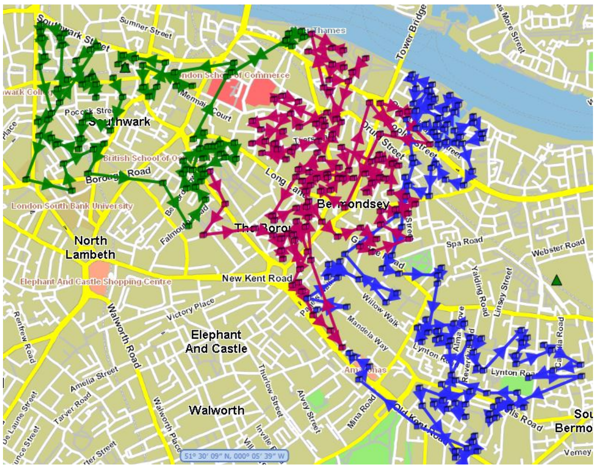


Figure 4: Optimisation with area reconfiguration: change from 5 to 3 routes

For almost all trips, the real data shows a shorter distance than the data obtained after running the optimisation software. In one case during the second week of April 2016, and after many months of improvement in the software application and usability, it was possible to run an optimisation that was shorter than the trip that would have taken place without optimisation. This one time beneficial result would need confirmation before an improvement could be claimed with certainty.

Combination of pedestrian and street routing optimisation

A further set of verification steps was conducted, with real test drives. The objective was to confirm with real drives if the optimised routes would be shorter than a driver would have done without optimisation. An innovation was developed here: combining pedestrian and street routing optimisation. The provider of Software A and the operator worked together to reduce the number of stops by allocating addresses to stopping areas in Central London.

In one example, the number of stops was reduced to 5 for 57 parcels delivered on 14 April 2016 (Figure 5 a). This solution was tested with real drives, after manual optimisation.

The manual work consisted of looking at the different delivery addresses and grouping them around central loading bays or stopping points that would be less than 100 metres or less than 50 metres away from the entrance doors. Manually, the tour-planning manager assigned each entry in the list of orders to a central stopping point (Figure 5b).

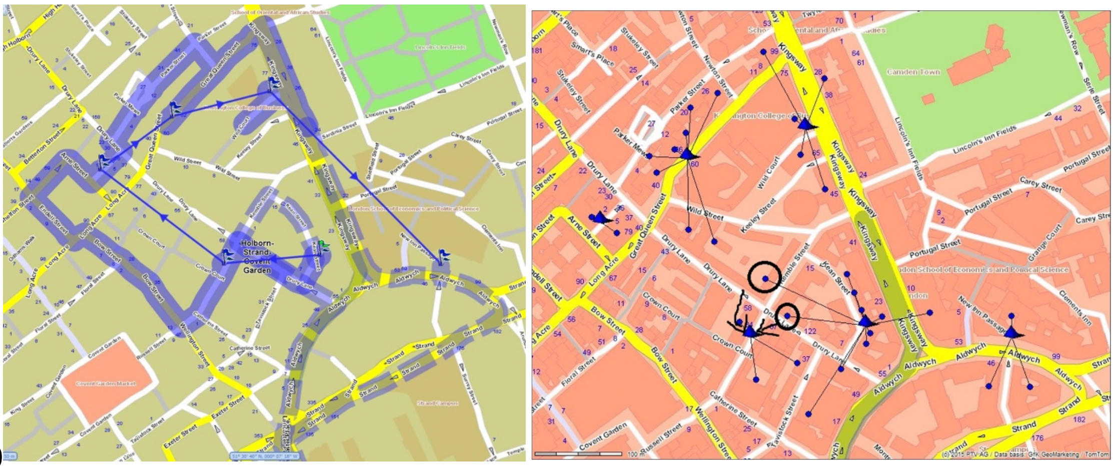
(a)  (b)

Figure 5: Tour planned and delivered, combining pedestrian and road distance to reduce total number of stops, Software A (a) Manual work linking delivery addresses with central stopping points to reduce total distance and number of stops (b)

Groupage of orders

Figure 6 presents one of the trial results obtained by including a wider area in a ‘grouping’ optimisation. Initially, the list included 480 stops for the main client deliveries (a). Grouping of orders within a radius of 100 metres was done with the help of excellent geodata and an external groupage function in Software A partner (b). As a result, the number of stops was cut down to 218, a reduction of more than 50% (c). This finding was positive and lead to effective test-drives on multiple days.

On these trips with fewer stopping points, the average distance of 11 miles per day was reduced by about half, down to 5.5 miles per day, of which 1 mile was the one-way distance to the area. So, the traffic in the target area was reduced by more than 50%.

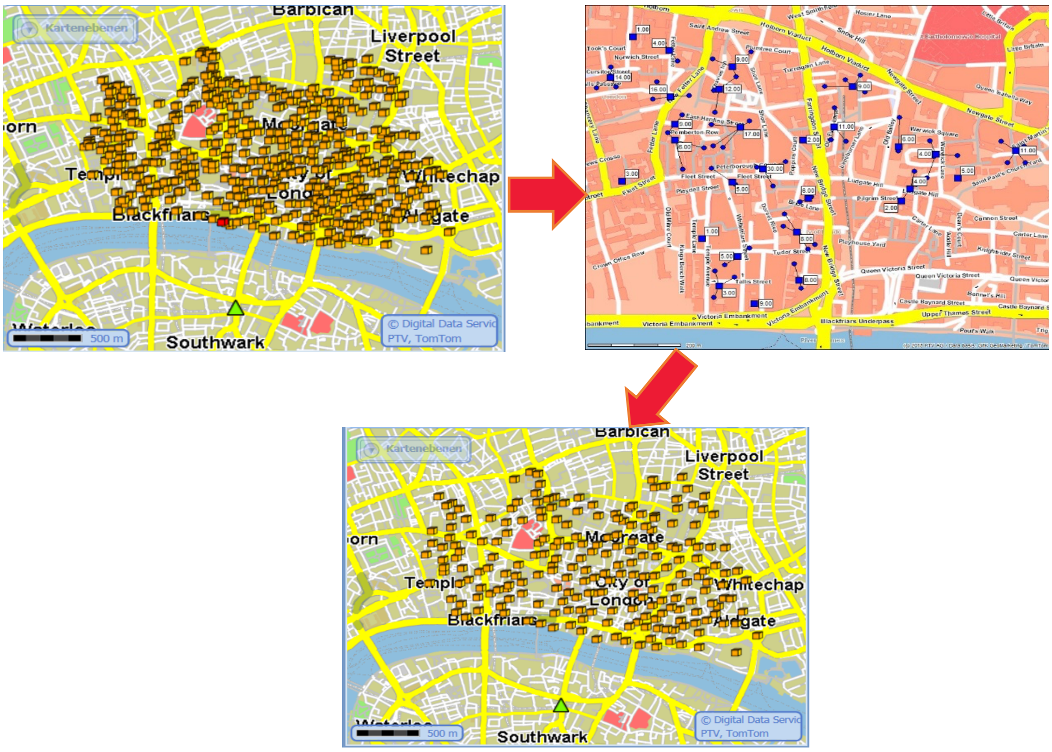


Figure 6: Initial delivery points (a), groupings (b), stopping points reduced by 50% (c)

Due to the constraints of the trial, it was not possible to modify the Software A system to include the capability of joining pedestrian and driving distance as a regular feature. So the important saving have only been shown with manual entries and manual combination of delivery addresses. Manual entries into the system are time consuming, not very user friendly, and cannot be performed daily.

The tested Software A solution remained below expectation even after adaptation but the path forward became clearer. The most beneficial effect, the reduction of the total number of stops by using centralised loading bays, could only be implemented after a long manual procedure. In the day-to-day business, this would take too much time. The positive results of >50% distance reduction might not withstand further testing in different business situations, after the software would have include the new features. At the end of the trial, the functionality of the route optimisation in Software A offers the possibility in future developments to link pedestrian and van driving routes, and to combine different areas to optimise the overall delivery situation, saving time, distance and cost. However further software adaptation and demonstration projects are needed to achieve this.

Software B trial

Software B is a pure trip planning and routing system for freight transport. The software provider is based in UK and the system offers the possibility to calculate the shortest itinerary and combination of stops including timing and distance driven.

Typically, a scheduling manager would obtain a delivery list in the morning and would upload this list into the Software B system, which is available online. This order list would then be processed and the function ‘optimise’ is used to obtain the shortest distance for each trip. It is also possible to combine different destinations and routes and to optimise multiple routes all together.

The objective of the trial was to adapt the current Software B system to the specific business of Gnewt Cargo, aiming at obtaining optimised routes and plans that would be better and shorter in distance and in time compared to what a driver would do manually.

During the Software B trial:

1. Software B developed a conversion program to take the courier report data arriving at operator from the main Client (via their IT provider Software D) after deliveries have been made. This then creates to see the actual routes taken, and the sequence that they were taken in. This is the baseline data for routing, without optimisation.
2. The operator experimented with timings for parcels, in order to calibrate the Software B routing software system and match the system with the recorded route times in Central London as closely as possible. All systems had to be educated to work on predefined rules for example: How long does it take to complete a delivery on average? This type of information needs to be calibrated in order to create viable outputs.
3. The operator optimised the individual driver’s work and generated a comparison between Software B-optimised routes and effectively driven routes.
4. Software B provided a conversion to take data from Software C report (i.e. the orders listed in original the main Client sequence, before deliveries are made) and create input to Software B that produce optimised routes. This was done in April and May 2016.
5. The operator was not experimenting with a small number of rounds based on the Software B routing, because the routing results were never reaching the point where the Software B route would be better, shorter and quicker than the drivers’ knowledge.

Figure 8, below, shows the optimised routes tested in early 2016. The period was suitable for a trial because it corresponds to an average business situation without peaks or lows in goods volume. The total distance of the routes effectively driven on 22nd January 2016 by the operator’s drivers for the main Client is available as baseline. The operator uploaded the main Client’s round data obtained after the deliveries on 22 January 2016. The data are based on the manual tour planning data for 15 delivery rounds performed by the operator for the main Client on that day. These routes were uploaded into the system. Figure 8 shows the results of the optimisation of the routes with Software B. Instead of 15 routes, the system proposes 12 routes, during the same total time.

These preliminary results indicate a reduction in total distance of 25% after optimisation compared with the distance as given by the original list. Moreover, 3 vehicles can be saved, reducing the number of trips and the number of vehicles on the road by 20%, compared to the original list of routes driven on 22nd January. This result had to be validated with further refined runs of Software B. The previous set of routes was calculated afterwards, and not on a real business situation in the morning before delivery start. It was not possible to effectively test-drive all these routes again, and verify the exact distance and practicalities of these results.

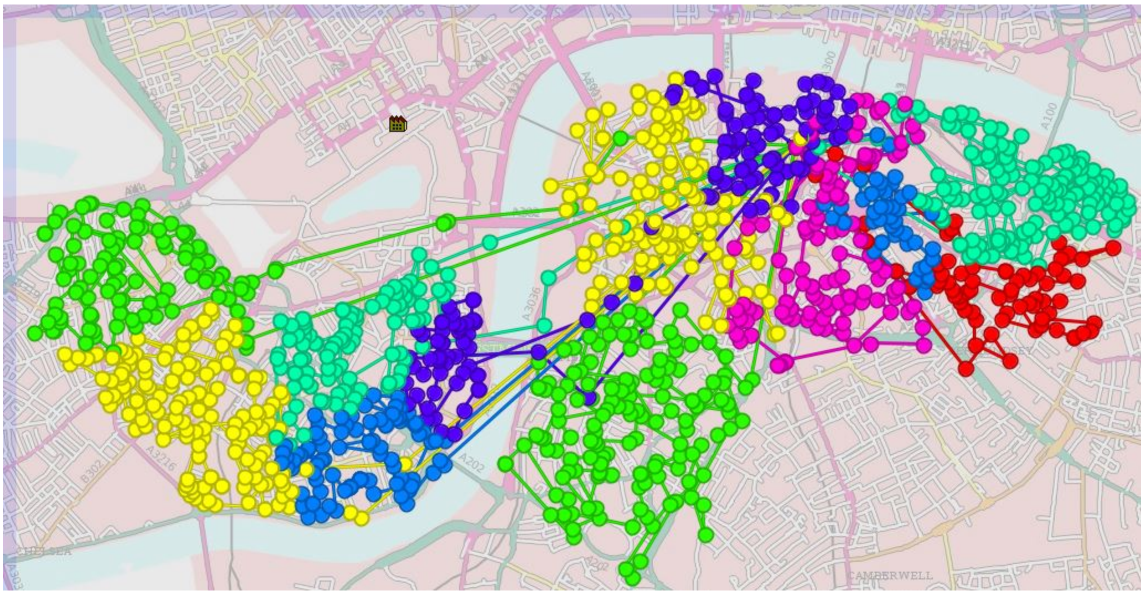


Figure 8: Software B optimisation routes for the main Client

Source: Software B and operator data

As of June 2016, all further trials to obtain routes that would have been effectively shorter than manual routing after Software B optimisation, were negative. None of the optimised routes were shorter than what a driver would have done anyway. The improved Software B software was not found suitable for future business implementation at this stage.

DISCUSSION

Multiple tests were performed for the IT trials. For the main client, final results of software A and B tests indicates a high potential for future routing and scheduling optimisation. It is too early to claim that the 50% improvement attained with Software A would be replicable. However, the trial was successful and expectations are that targets could be reached in the long term, when the software solution will be further developed. The sample used only a part of the data collected on 15,000 round trips.

Limitation of technology, technical barriers, constraints and challenges experienced during the project were drawbacks for future implementation. Drawbacks are linked to following points: (1) quality of the geographical data, especially the missing link of loading bays and entrance doors for delivery addresses; (2) difficulties of providing accurate customer data, and to relate the address data of multiple clients to the routing system (3) the design of optimization algorithms was not visible, but it is unlikely that the algorithms were including variables linking pedestrian and driving trips (4) the way that the routing systems are used by depot and fleet managers: when parcels and data arrive in the morning hours all at the same time, there is no time to insert a routing optimisation before departure of the first vans.

Trials were also constrained by the quality and small set of IT solutions tested. Unfortunately, the market did not provide a solution for urban freight delivery routing that would be better than a trained driver. All the routing systems are designed for long distance freight traffic. Intensive exchange occurred with the software providers, to adapt current products to the Central London situation, characterised by short distances, small delivery areas, high density of customers, different on-street and off-street loading bays, parking duration allowance and access restrictions.

The data provides evidence that the IT solutions can be scaled up and provide quantifiable results in the ability to increase fundamental efficiencies by applying ‘smart’ technology to the tracking of vehicles, route optimisation and the scheduling of routes on a daily basis. Scalability is relatively straightforward because whether a business choose to optimize 50 routes or 5000, the logic remains the same, meaning if these systems work on a micro level they could be expanded to the improvement of the whole industry and for other cities. However, whilst scalable they must be cost-effective and competitive, otherwise there is a risk of scaling a problem rather than a solution.

As main legacy on future IT technology use in urban logistics, the software A solution was found to be potentially very powerful in its beneficial impacts on business. To achieve this, another development to improve the software is needed. Such a development could see the software implemented, and deliver a public database on London’s most convenient stopping points, linked to final postcode addresses, and providing relations between pedestrian and driving parts of the delivery trips.

Theoretically, the routing software is able to provide better results, as long as it has the same quality and quantity of information as inputs as the delivery drivers do, since the algorithms for optimisation built-in the software are generally superior to the drivers’ brain for it. With the increased number of customers, the algorithms cannot produce exact solutions (i.e., exactly optimal routes) but approximate solutions using the optimisation techniques called heuristics or metaheuristics. However, even such approximate techniques are very likely to yield better results within reasonable computation times than the drivers’ brain, since the latest progress of the heuristic techniques is remarkable, including genetic algorithm, tabu search, and particle swarm optimisation. Consequently, it is crucial to incorporate the detailed information on delivery areas that the drivers hold (i.e., drivers’ knowledge and experience) within the software, unless it has low-quality approximate techniques built-in.

Intelligent Transport Systems (ITS) may also have the potential to supplement the necessary information, for example, precise travel times, and provide better routes (e.g., Qureshi et al., 2012). However, ITS focus more on the information on arterial roads but less on narrow streets within city centre. Data collection on such narrow streets would be possible using probe cars and GPS, but it would be more promising to embed the drivers’ knowledge and experience within the software as electronic information and inputs.

Furthermore, it would be effective to develop the optimisation software that can more precisely consider the linkage between the street van driving and the pedestrian delivery trip from the loading bays to the final customer addresses. This type of routing and scheduling algorithms is emerging in the field of VRP and VRPTW.

CONCLUDING REMARKS

Some systems showed up to 50% distance reduction and a 10% time reduction per parcel. None of the systems would be good enough to be implemented in the daily business, due to a high number of failures to optimise most routes. On most cases the driver routes effectively driven are shorter and faster than the system would do. This makes it impossible to obtain a return on investment when purchasing such a system.

But it was possible to identify specific features of the systems that could lead to future optimisations and practical applications. Weaknesses were identified, and this continues to hinder implementation and wider uptake of the routing solutions, but these identified problems can all be the starting points for future software developments and improvements. In one example, it was possible to reduce the total number of stops down to 5 key locations, and link the van trips with the pedestrian parts of the trips. In this case, a more advanced routing system would be able to produce an optimum, linking the street van driving optimisation with the pedestrian delivery trip from the loading bays to the final customer addresses. Findings suggest this optimum, as mix of pedestrian, unloading stops locations, and van routing optimisation, can lead to distance reduction of more than 50%, and time savings of 10%.

The theoretical part of this paper analyses the IT solutions and the results of this survey and points out the weakness and potential of IT-based routing and scheduling software. As a result, an outlook to future potential improvements was derived from both observations, and theoretical analysis.

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