location problems; maximal covering problems; optimization; simulation; geographic information system (GIS); urban freight transport

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RECONSTRUCTION OF DELIVERY POSITIONS IN THE CITY OF CELJE, SLOVENIA

Summary. The paper addresses the problem of the reconstruction and allocation of delivery positions in the urban area. The aim is to achieve the optimal reorganization of urban freight transport in old town core in the municipality of Celje. Optimal allocation relies on optimization based on the Monte Carlo simulation and represents a first stage of a two-stage optimization approach to re-design the existing urban freight transport. The number of optimal delivery positions is required to be as minimal as possible, which can still assure a maximal service area within the prescribed radius, while keeping the minimal walking distances of delivery personnel between the nearest delivery position and the customer's physical location. The main issues of the used heuristic allocation algorithm and the presentation of calculated results are provided. In the near future, the calculated delivery positions are going to be used for the purpose of physical implementation in order to improve the existing delivery transport.

WIEDERAUFBAU VON DEM LIEFERPOSITIONEN IN STADT CELJE, SLOWENIEN

Zusammenfassung. Der Artikel behandelt das Problem der Wiederaufbau und Allokation von den Lieferung Positionen in einem städtischen Gebiet. Der Zweck ist die optimale Reorganisation des städtischen Güterverkehrs im alten Stadtkern in der Gemeinde Celje zu Erreichen. Die optimale Allokation basiert auf der Optimierung auf Basis der Monte-Carlo-Simulationen und stellt die erste Stufe einer zweistufigen Optimierung Verfahren zur Re-Designs der bestehenden städtischen Güterverkehrs. Die Anzahl der optimalen Lieferpositionen sollte so wenig wie möglich sein, aber trotzdem einen maximalen Service-Bereich innerhalb des vorgeschriebenen Radius gewährleisten. Gleichzeitig sollte die Entfernung zwischen den nächstgelegenen Lieferpositionen und Kunden Positionen kleinstmöglich sein. Die wichtigsten Themen des verwendeten Heuristic Zuordnungsalgorithmus und die Darstellung der berechneten Ergebnisse sind gegeben. Die Standorte der berechneten Lieferung Positionen werden zum Zwecke der physikalischen Implementierung genutzt, um den bestehenden Güterverkehr zu verbessern.

1. INTRODUCTION

Cities are locations having a high level of accumulation and concentration of economic activities and are complex spatial structures that are supported by transport systems. The larger the city is, the greater is its complexity and the potential for disruptions, of course if this complexity is not effectively managed. Managing of city complexity is closely connected to urban productivity, which is highly dependent on the efficiency of its transport system that enables the moving of labor, consumers and freight between multiple origins and destinations. Additionally, important transport terminals such as ports, airports, and railways are often located within or near urban areas, also contributing to a specific array of urban transport problems.

Among the most notable urban transport problems are [18]: the problems of urban freight transport, the problems related to the private vehicles transport, the problems of non motorized transport and the problems of public transport (c.f. figure 1). These transport categories in urban areas are marked with circles and most typical urban transport problems are marked with blocks in figure 1. Naturally, some of the urban transport problems are related with more transport categories simultaneously. For example: longer commuting between citizen’s residences and workplaces concerns the public transport and private vehicles, respectively. On the other hand, traffic congestion, environmental impacts and energy consumption concerns three types of transport categories (public, freight and private vehicles transport). Of course, accidents and safety are connected to all types of urban transport.

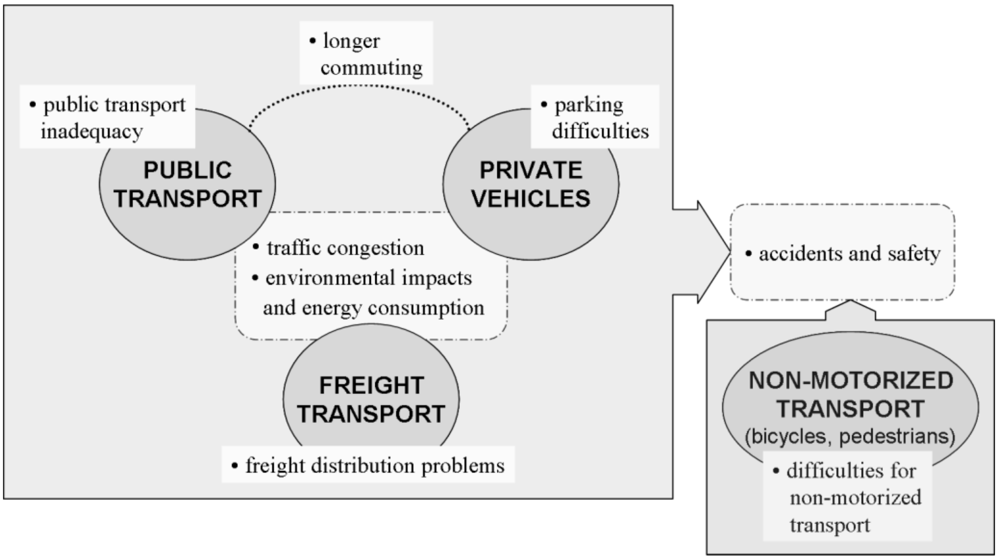

Fig. 1. Basic configuration of different urban transport categories and typical city logistics problems
Bild. 1. Die Grundkonfiguration von unterschiedene Kategorie der öffentliche Verkehrsmittel und typische Probleme der Stadtlogistik

During last years, there is a strong tendency around many world cities, how to solve the problems of urban transport. The appropriate solutions to achieve more efficient urban transport planning have been introduced in many papers and books in the existing literature [10, 15, 18]. In these contributions, there have been also many good practices included, which were already successfully implemented in several cities worldwide.

This paper deals with re-design of existing urban freight transport in the old town core of city Celje, Slovenia. As it is known, the freight transport has a significantly large impact on pollution, noise and congestions in urban areas, which can noticeably influence on the quality of life and health of urban population. So it is natural for every responsible city personnel to organize delivery transport as optimal as possible.

The work represents the prototyping design of heuristic algorithm for (sub) optimal allocation of delivery positions, which should be organized in the sense that the delivery personnel would have to overcome as short delivery distances as possible. Since this problem can be treated as a maximal covering problem, an optimization approach, based on Monte Carlo simulation, has been developed for this purpose. When the allocation is finished, it is supposed that the minimum possible number of delivery positions covers as much customers (users of delivery services) as possible within the prescribed radius.

The calculated delivery positions could be in the further procedure of freight transport optimization also used as a basis for optimization of delivery routes and time schedules of delivery vehicles. Since this kind of optimization is not finished yet, this paper is focused only to represent the procedure and results of the allocation of delivery positions.

The paper is further organized as follows. Section 2 presents a brief overview of the area of urban freight transport. The literature review of existing algorithms for solving maximum covering problems is given in section 3. The definition of problem and the description of treated data in the municipality of Celje are represented in section 4. The proposed optimization procedure for the purpose of optimal allocation of delivery positions is described in section 5. Finally, the presentation of calculated numerical results and the statistical analysis of achieved delivery distances are provided in section 6.

2. URBAN FREIGHT TRANSPORT

At present time, when competitive situation is sharpening and the economic crisis is in progress, the efficient organization of the delivery traffic in cities also becomes more and more topical. In general, the urban freight transport consists of the following segments: supplying stores with the goods, supplying of restaurants, delivery of reproduction material to craft and similar workshops, supplying of other business entities, etc. Of course, the globalization and the materialization of the economy have resulted in growing quantities of freight moving within cities. As freight traffic commonly shares infrastructures with the circulation of passengers, the mobility of freight in urban areas has become increasingly problematic. The mentioned situation can become even worse, since the current production and distribution practices are more and more based on low inventories and timely deliveries. In addition, the explosive growth of business-to-consumer e-commerce generates significant volumes of personal deliveries, which definitely increases the negative influences of the freight transport in the cities, since the joint travelled distances of freight vehicles are becoming much longer.

Also, optimizing the delivery traffic is necessary for the full set of some other undesirable consequences, such as: additional pollution of urban air, additional burden of city traffic, additional noise in the cities, reduction of parking places for cars and other personal vehicles, an obstruction of cycling and pedestrians traffic, etc. So, messy delivery traffic can bring a whole range of consequences that can significantly reduce the quality of life in the cities.

Delivery traffic problems generally can be resolved in several ways. Very modern trend is to develop the so-called integrated logistic system, where shippers, carriers and movements are coordinated and loads of different customers and carriers are consolidated into the same “green” delivery vehicle [2]. Therefore the consolidation and coordination activities represent a fundamental concept of city freight transport. Naturally, the consolidation activities usually take place at city distribution centers (CDCs), which are located on the outskirts of the urban zone. The proper location of the CDC should be calculated with respect to some suitable scientific approach, which should take into consideration the space topology of freight traffic flows and the corresponding amount of cargo. On one hand, the main idea is to direct heavy freight trucks to the corresponding distribution centre in order to prevent their presence in the urban area, which naturally worsen the traffic conditions in the cities. On the other hand, the freight can be consolidated, suitably sorted and loaded to smaller vehicles (little trucks, vans, etc.) in the CDC and then delivered to the prescribed locations in the city. Since the small delivery vehicles burden the city traffic flows much less than the heavy trucks, obviously here could be achieved a huge progress in the sense of relieving of the treated city.

Another interesting way to improve the urban freight distribution is the implementation of so-called automated underground system (capsule pipelines). In this kind of system, there is a specific underground infrastructure built, which is structured with the whole set of conveyor belts. The cargo is appropriately consolidated in the distribution center at first, and then sent to the final destination with respect to some predetermined algorithm. Within this framework, an interested research has been done [4]in the case of city of Groningen (170 000 inhabitants). In this case, the comparison analysis for the traditional distribution with trucks (case 1), CDC with vans (case 2), and underground logistic system with pallet size vehicles (case 3) was done. As it turned out, the total mileage in case 3 is much higher than in cases 1 and 2, because we are dealing only with one-way directions in case 3. On the other hand, the local emissions of certain gasses within the city centre are completely eliminated in case 3, global impacts of CO2 are reduced to the lowest possible level, and also the energy use is maximally reduced [4]. Despite of very environmentally-friendly effects of underground pipelines system, the weakness of this system is a very huge financial investment that makes this concept quite unrealistic in most cases [2]. Naturally, there are also some other modern approaches, how to deal with the freight movement problems in urban areas, which concern curb spaces and alleys, pedestrian interaction, building entrances, loading docks and signage, and so on. They can be studied in the existing literature [13, 14, 16, 17].

The municipality of Celje is also confronted with numerous freight transport problems mentioned above that affect the effectiveness of delivery traffic in the old town core (OTC). It was therefore necessary to adopt certain measures to solve such problems and achieve more optimal freight transport. Due to the lack of financial resources and because of specific demographic characteristics in the case of the city of Celje (only 50 000 inhabitants), none of the approaches mentioned above is not acceptable at the current moment. Therefore, instead of applying some most modern trends mentioned above, it is decided to introduce a slightly different approach to achieve the optimal reorganization of the existing freight transport. For this purpose, the two-stage heuristic optimization mechanism is adopted in order to apply as efficient optimization of freight transport as possible. The main idea is to calculate the (sub) optimal delivery positions in the first stage, and then calculate the optimal delivery routes and time schedules (second stage) with respect to results, calculated in the first stage (c.f. figure 2).

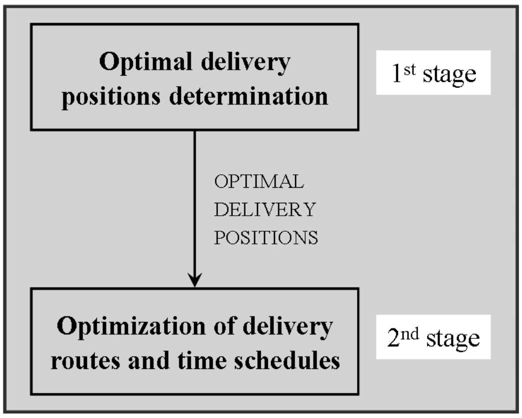

Fig. 2. The two-stage optimization approach to re-design the delivery traffic
Bild. 2. Das zweistufig Aufstiegoptimierung zu Umgestaltung der Lieferbewegung

In the first stage, the determination of optimal delivery positions should be executed, which must take into account many specific criterions and constraints. Besides the topology and characteristics of the treated city, an important criterion is also to minimize the distance of freight transport from every individual customer to its nearest delivery position. Naturally, the delivery positions can not be located at any place in the area under study, so that their number can not be chosen completely arbitrary. On the contrast, they must be determined in such way that as much customers as possible should be serviced from an individual delivery position, while the total number of delivery positions must be reduced to the lowest possible level. Obviously, this problem is similar to the so-called “maximum location covering problems” (MLCPs), where the minimum fixed number of facilities must be located, which should maximize the service area [6].

During the second stage of optimization approach, the optimal delivery routes and time schedules can be also calculated with respect to results of the first stage. For this purpose, the software tool ESRI ArcLogistics [8] can be used, which is suitable for solving of such type of problems. When the second stage of optimization procedure is finished, the distances of calculated delivery routes between optimal delivery positions are supposed to be as minimal as possible, while simultaneously all the predefined delivery restrictions and constrains, like time window restrictions, etc. are going to be also satisfied.

Since this paper deals only with the representation of first stage of optimization approach in figure 2, the following section will provide a brief overview of the existing literature for solving maximum covering problems [5-7, 11, 19].

3. EXISTING ALGORITHMS FOR SOLVING MAXIMUM LOCATION COVERING PROBLEMS

The MLCP seeks the maximum population that can be served by a limited number of facilities within a stated service distance or time [5]. It represents a typical problem in the so-called facility location theory. Facility location is a set of resource allocation problems that deals with a placement of different types of facilities, which should be provided to the customers on demand [5, 6]. Beside MLCP, facility location theory also includes some other significant location problems, like set covering problem, p-centre problem, p-median problem, etc [6].

The MLCPs arise in a variety of public and private sector problems [6, 7]. For example, state governments need to determine locations for bases for emergency highway patrol vehicles. Similarly, local governments must locate fire stations, police stations and ambulances. In all of these cases, poorly chosen locations can increase the possibility of damage or lost of life. In the private sector, industry must locate offices, production and assembly plants, distribution centres and retail outlets. Poor location decisions in this environment lead to increased costs and decreased competitive position [6].

At the beginning of research of maximum covering problems, the relaxed linear programming approach, supplemented by occasional use of branch and bound procedure, was used [5, 6]. Since then, a number of new algorithms and heuristics have been derived for this purpose. For example, the Greedy heuristic algorithms [5, 6] are often used to solve facility location problems. Some of most typical greedy algorithms are: Basic Greedy Adding (Add) algorithm, Improved Greedy Adding algorithm with Substitution, Greedy Dropping (Drop) algorithm, etc.

Of course, besides Greedy algorithms, there are many other more advanced heuristics like Genetic Algorithms, Simulated Annealing, Tabu Search, etc. [11, 19]. Some other significant methods, which have been also proposed for solving of maximum covering problems are: Lagrangean relaxation, Lagrangean/Surrogate heuristics, Heuristic concentration, etc [11,19]. Detailed reviews of the solution procedures for the maximum covering problems can be found in [6, 11, 19].

In the sequel, let us introduce how a maximum covering problem appears in the context of efforts to apply an optimized re-design of existing freight transport in the city of Celje.

4. PROBLEM DEFINITION AND INITIAL ROAD DATA REDUCTION

Figure 3 shows the observed area in the OTC, where optimal allocation of delivery positions should be adopted. From figure 3 the external borders can be also noticed, which surrounds the observed area. As it can be seen from figure 3, the intersection of two roads, where the delivery traffic is entirely prohibited because of specific reasons, is also presented.

Within the observed area, 799 customers (companies, institutions, etc.) are located on 34 streets. These customers present the main subject of our research, which means that we are interested about the optimization of their delivery traffic. Since in several cases, the different customers are located on the same physical location (address), the total number of their physical locations is naturally lower than the number of considered customers.

For the purpose of urban freight transport optimization it is desired to collect as much information about the treated customers as possible. Therefore the questionnaire has been organized, which enabled the acquisition of all necessary attributes about the observed customers. The questionnaire included the customer's name and its address, the customer's activity, the number of deliverers, the frequency and time schedules of deliverers and also the types of delivery vehicles and packaging types. As it turned out, 514 customers, located on 197 physical locations in OTC, were willing to cooperate in this study, which means the 64% of all treated population. The spatial locations of collaborating customers were obtained by means of software tool Geographic Information System (GIS) [8] and can be noticed from figure 4a.

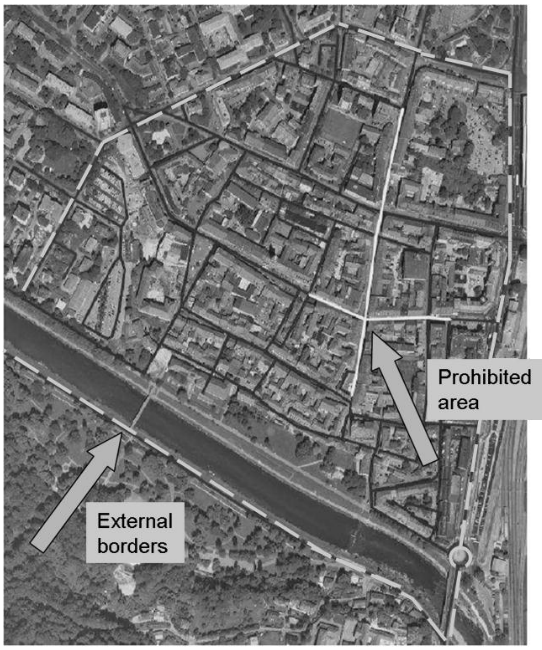

Fig. 3. Observed area in old town core of the municipality of Celje
Bild. 3. Der beobachtener Raum im Zentrum der Altstadt in der Stadt Celje

Figure 4a also shows the positions of entire set of road data points located on 34 streets within the observed area in the municipality of Celje. Those road data points represent possible candidate's points for delivery positions and have been generated by 5 metres segmentation of every single road within the treated surface. The total number of segmented road data points, which were also collected by use of software tool GIS, is 1198.

Since, the number of candidate's points for the delivery positions (candidate's points) is enormous in the treated case (1198 possible points), the initial road data reduction must be applied at first. For this purpose, certain heuristic rules can be applied [7]. First rule takes into consideration those road data points, which are not too close to the nearest neighboring road data points. On the other hand, second rule takes into consideration only those data points, which are close enough to the customer's data points. When these heuristic rules are applied, the reduction of the initial number of 1198 possible road points leads us to the more acceptable number of 453 candidate's points (c.f. figure 4b). Since the reduced number of 453 road data points is still too big in the sense of the optimal allocation of delivery positions, the further reduction of these points is somehow needed in order to lower the total number of optimal delivery positions to the acceptable level. For this purpose, the optimization based on Monte Carlo simulation must be used.

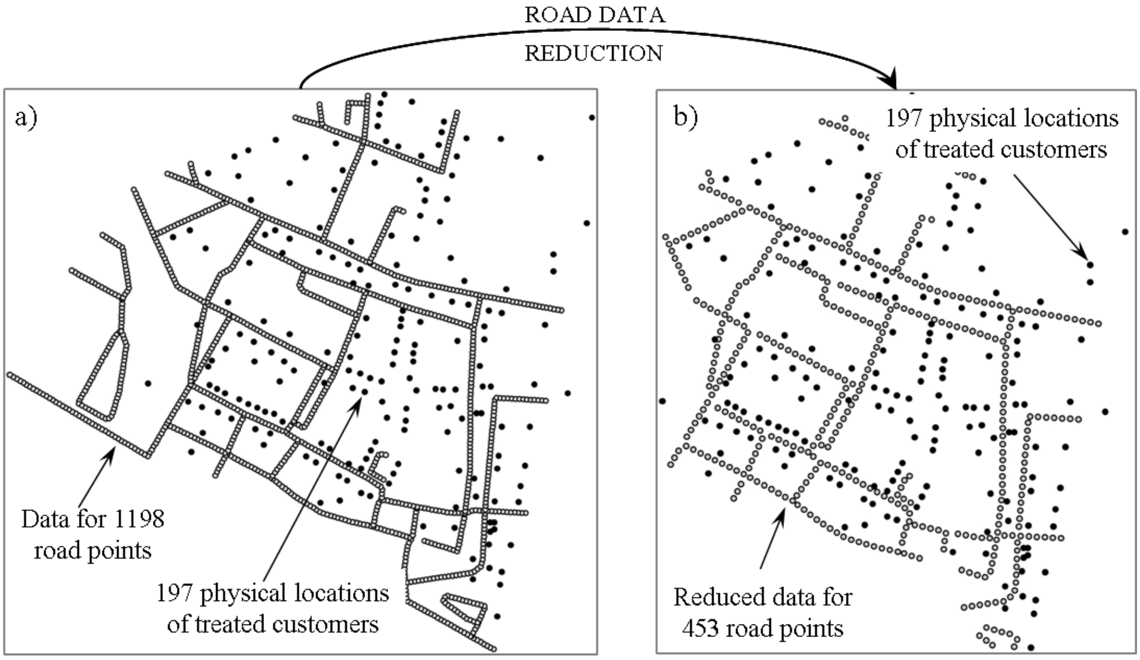

Fig. 4. a) 197 physical locations of treated customers and 1198 road data points as possible candidates for delivery positions; b) 197 physical locations of treated customers and reduced set of 453 road data points as possible candidates for delivery positions

Bild. 4. a) 197 Lokalisierungen von Kunden und 1198 Straßenpunkten als die mögliche Plätze auf die Lieferung; b) 197 Lokalisierungen von Kunden und verkleinerten um 453 die mögliche Plätze auf die Lieferung

5. OPTIMAL DETERMINATION OF DELIVERY POSITIONS BY MEANS OF OPTIMIZATION PROCEDURE BASED ON MONTE CARLO SIMULATION

The methodology, which has been used to determine the optimal delivery positions, in certain sense works similarly as so called “Simulation-Optimization” (or “Simulation-based Optimization”) approaches [1, 3, 9, 20]. Simulations enable the testing of a large number of scenarios, while the optimization is used to find the best scenario, where the specific criterion function reaches the best result. Although the “Simulation-Optimization” approach is not new and can be noticed in the different areas, it can be very effective, as observed in the existing literature (for example look at [3,20]). Since the approach in the suggested form, proposed in this paper, has not been detected in the existing literature for the case of maximum covering problems, when urban freight transport is treated, we have decided to use this approach in our case.

Since we are dealing with the maximum covering problem, for which its NP-hard nature is well known [12], the final solution in principle can not be totally optimal, but only sub-optimal. This is particularly true when some of the heuristic approaches are used, as in our case, where all possible scenarios obviously can not be tested during the run of simulations and the truly optimal solution can not be found. But as it turned out, the proposed sub-optimal solution is still acceptable for the customer (municipality).

Naturally, the optimization procedure based on Monte Carlo simulation [7], which has been used in this contribution, is slightly different from the existing MLCP algorithms [11,19], explained in section 3. The working mechanism of optimization based on Monte Carlo simulation has been for earlier versions of development of this algorithm already explained in contribution [7]. Since then, the further development of algorithm led us to its modified version, adapted to the specific characteristics of urban freight transport, which is going to be briefly explained in the sequel of this section.

During the procedure, the observed surface with 453 candidate’s points must be firstly divided into the certain number of subsectors, otherwise some serious computational problems could occur. The partition of area into subsectors relies on testing different partitioning scenarios in order to obtain the best number of subsectors, which can assure the most reasonable optimization results. As it turns out for the case of treated city, partition into 8 subsectors provide the most efficient use of the Monte Carlo optimization procedure. When the partition of observed area is done, naturally each subsector covers certain number of candidate’s points and certain number of customer’s data points.

In the sequel, for each subsector must be determined, which candidate’s points provide most efficient service to the maximal possible number of customers in the sense that the minimal walking distance of delivery personnel lie within the prescribed radius r. As it turns out, this problem can be efficiently solved by the use of Monte Carlo procedure. During the running of simulations of this procedure, a set of equal number of randomly chosen candidate’s points, surrounded by circles of prescribed radius, is generated for each subsector at every iteration. For these candidate’s points, the distances to covered (assigned) customers (which lie within the circles) are also measured in each simulation iteration, and the number of uncovered (unassigned) customers (which lie outside the circles) is enumerated. In other words, the algorithm for each subsector calculates the shortest (Euclidian) distances from the customer’s address to the nearest chosen candidate’s point, which means that all customers in the observed subsector tried to be assigned to the nearest candidate’s point, if the calculated mutual distance is shorter than the prescribed radius r.

From the explanation described above it can be concluded, that the main focus of this allocation procedure is based for each subsector on the following two criteria (criterion functions). Within the first criterion function, the sum of distances of assigned customers to the nearest candidate’s points must be lowered as much as possible. Within the second criterion function, the number of uncovered customers must be simultaneously lowered as much as possible.

Naturally, during the execution of Monte Carlo simulation iterations, the situation persistently changes, since the set of randomly chosen candidate’s points is different at every repetition. Consequently, the assigned and unassigned customer’s points are different at every repetition and also both criterion functions continuously changes. So, when running a certain number of N iterations during the simulation procedure, the whole set of values of both criterion functions is calculated for each subsector.

Now, the two-criterion optimization procedure must be somehow applied, where the combined optimum of both criterion functions is trying to be found for each subsector. The latter means searching for that “best” set of randomly chosen candidate’s points for each subsector, where the first criterion function reaches the minimal value, while simultaneously keeping the second criterion function on the lowest possible level.

The combination of calculated results for all subsectors, which are the “best” sets of randomly chosen candidate’s points for each subsector, represents the locations of optimal delivery positions. In this conception the following assumption can be given. If the optimal delivery positions are calculated by means of the procedure described above, the latter covers as much customers as possible within the prescribed radius, while the delivery personnel have to walk (on average) from delivery positions to the customer’s locations as little as possible. Also, the remained number of unassigned customers is supposed to be as minimal as possible.

More detailed description of the delivery positions allocation is presented in the following pseudo-code of procedure called Allocation of delivery positions:

Algorithm 1: Allocation of delivery positions

Input:

- number of subsectors S
- reduced set of candidate’s points for delivery positions
- customer’s points
- prescribed radius r
- number N of randomly chosen road points (RCRP) inside each subsector
- number of Monte Carlo simulations M

Output:

- locations of optimal delivery positions G in all subsectors (results)

Local variables of notice:

- criterion function 1: sum of distances of assigned customers to the nearest RCRP
- criterion function 2: number of uncovered customers

```
Function Optimal_delivery_positions
Begin
Divide observed surface into S subsectors
For each simulation do
For each subsector do
Randomly choose N road points
For each customer's point inside subsector do
Calculate distances between customer's point and the nearest RCRP
If distance is shorter than prescribed radius
Consider customer's point as assigned
Increase criterion function 1
Else
Consider customer's point as unassigned
Increase criterion function 2
End If
End For
End For
End For
For each subsector do
Find the best random set of randomly chosen RCRP, where criterion functions 1 and 2 reach combined minimum among
M simulations
Add the best random set of randomly chosen RCRP to the set of results G
End For
Return the set of results G, which represents the locations of optimal delivery positions
End Function
```

6. NUMERICAL RESULTS AND STATISTICAL ANALYSIS

The development of algorithm for determination of optimal delivery positions and all the computations of the optimization procedure were carried out in Matlab. The prescribed radius, which was used as an additional constraint during the computations, is 80 meters. The latter was not chosen arbitrary, but was demanded as a maximum possible radius, which is still acceptable for the municipality of Celje. Thus, the delivery personnel in principle should not walk more than 80 m from the delivery positions to the customer's physical locations. Besides the prescribed radius, the municipality has also given a demand regarding the costs of the reservation of the space to be used as load zones. Namely, the demand about this question was that there should not be more than maximally 50 delivery places (but rather less).

6.1. Optimal delivery positions

When the optimization procedure based on Monte Carlo simulation is finished, the coordinates of 40 optimal delivery positions (8 subsectors, 5 randomly chosen road data points in each subsector) are calculated. The latter are marked in figure 5 with stars and are surrounded with circles of prescribed radius. It can be seen from figure 5, that the optimal delivery positions are capable of covering of 192 customer's physical locations (black points) within the prescribed radius of 80 m, while 5 physical locations remain uncovered. So the algorithm obviously managed to cover 97.4% of customer's physical locations. Hopefully, unassigned 5 physical locations are not very relevant, since 4 of them are already located outside the observed area (near the external border), while one uncovered customer is located in the area of intersection of two roads, where the delivery traffic is entirely prohibited (c.f. figure 3).

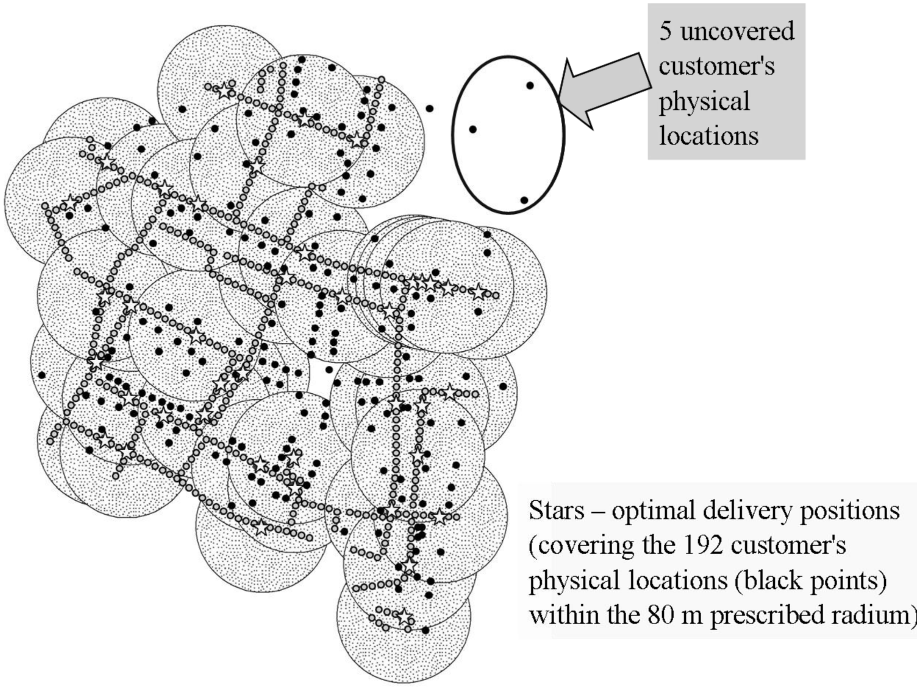

Fig. 5. The locations of 40 calculated optimal delivery positions (stars), surrounded by circles of prescribed radius of 80 m. 192 covered and 5 uncovered physical locations of customers (black points)
Bild. 5. Lokalisierungen von 40 optimal berechnet Lieferungplätze (Sterne), die sind umstellt von allem über das Kreis mit der Radius 80m. 192 bedeckte und 5 unbedeckte Lokalisierungen von Kunden (schwarzer Punkt)

Even a better view of the calculated delivery positions can be represented as shown in figure 6. The latter was also equipped with a realistic topology of the old town core of Celje, which means that also the concrete streets and roads with corresponding names were added to the observed figure.

Coordinates of the optimal delivery positions have been submitted to the Celje municipality responsible personnel in order to trigger all necessary procedures for the purpose of delivery positions physical implementation. As it looks at the current moment, about 20 of 40 calculated delivery positions will be actually finally implemented in the practice. There is a whole spectre of reasons for this decision, but the main one is connected with the problem of architectural obstacles. In any case, the space distribution of implemented delivery positions will be planned in such a way that they will be capable of covering as many customer's locations within the prescribed radius 80 m, as possible. Therefore, the municipality will try to provide the minimal possible freight transport walking effort to the maximal possible number of customers.

6.2. Statistical analysis of distances from the customer's physical locations to the nearest optimal delivery positions

According to the obtained results in the previous section, we can derive the distance distribution between 192 assigned customer's locations and the nearest calculated delivery positions, and, in addition, the corresponding histogram. As it turns out, most of the physical locations (19) reach the delivery distance of 34 meters to the nearest delivery position. It can be also noticed that 128 customer's physical locations (66% of all covered) reach the delivery distance to the nearest delivery position, which is shorter than 40 meters. For the other 64 physical locations (34% of all covered), the delivery personnel have to travel across the distance, which is longer than 40 meters, but still shorter than prescribed 80 meters.

From all shown results it is evident that the calculated delivery positions cover the maximum possible service area and provide the minimal possible freight transport walking effort to the maximal possible number of customers. So, the obtained results of the first stage of optimization in figure 2 obviously represent a good basis for the development of further optimization of freight transport, which means the application of optimal delivery routes and corresponding time schedules (second stage of procedure in figure 2).

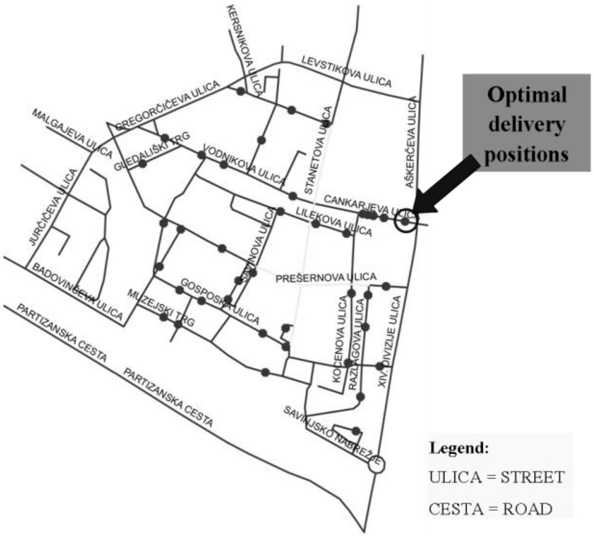

Fig. 6. The space distribution of calculated 40 delivery positions and the real topology of old town core
Bild. 6. Der Vertriebsraum für 40 berechnete Stellungen und die reale Topologie von das Zentrum des Altstadtes

7. CONCLUSION

Transport has a major impact on the spatial and economic development of cities and regions. But in many cases, the links between transport and urban development are not adequate, particularly in the context of the changing nature of cities and the globalization of the world economy. Within this framework, urban freight transport also represents a very polemical issue for most of the municipalities worldwide. Namely, this kind of urban transport has a significantly large impact on pollution, noise and congestions in urban areas, which significantly influence on the livability and accessibility of every city.

Since the old town core of municipality of Celje, Slovenia, has been also faced with the problem, how to improve the existing urban freight transport, the two-stage optimization approach has been developed for this purpose. The latter represents more “traditional” re-design of urban freight distribution with respect to certain other approaches, which can be already noticed in some bigger cities worldwide.

The main idea of used heuristic approach is to calculate the optimal delivery positions in the first stage, and then with respect to these results, calculate the optimal delivery routes and time schedules in the second stage. This paper is focused only to the results of first stage, which are obtained by the optimization procedure based on Monte Carlo simulation.

When the optimal delivery positions are calculated, it is supposed, that the minimal number of these positions cover as much customers as possible within the prescribed radius, while the delivery personnel have to walk from delivery positions to the customers locations as little as possible.

As it is evident from the results, the total number of calculated optimal delivery positions is capable to cover the majority of 97.4% customer’s locations within the prescribed radius 80 meters. Only 5 customer’s locations remain uncovered, but even in those cases the delivery personnel should walk only several tens of meters more, than the prescribed radius is.

In future work, some additional corrections of achieved results are going to be applied, if the municipality will express an interest for this modification. For example, the Manhattan measures could be employed instead of Euclidian measures for the calculation of distances between the delivery positions and customer's locations. This would probably reflect the streets topology in the old town core more authentically than in the case of Euclidian distances. Naturally, the second stage of optimization procedure, which means the determination of optimal delivery routes and time schedules, is also planned for the future research work.

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