# Microzoning: A grid based approach to facilitate last-mile delivery

Boukje Schellens MSc[1], Dr Frans Cruijssen[2]

[1]ArgusI, Breda, the Netherlands
[2]ArgusI, Breda, the Netherlands
Corresponding author: b.schellens@argusi.org

***Abstract:*** *Microzoning is a method which makes (last-mile) road transport more efficient and sustainable. The method generates small compact areas, called microzones, which can be used as building blocks to design efficient service zones. The innovative methodology uses a grid of an area, heuristic methods and routing algorithms to develop the service zones. Stakeholders' preferences can be incorporated into the model to generate industry or company specific microzones. This methodology has been applied by Argusi during a project for a parcels delivery company located in the Netherlands to facilitate their last-mile transport.*

***Keywords:*** *service zone, microzone, last-mile delivery, Physical Internet*

## 1 Introduction

The current growth in e-commerce marked a new era in last-mile delivery. Consequently, route planning for last-mile delivery is becoming more and more difficult. To facilitate the daily route planning this paper introduces microzoning. A method which divides an area into small pieces, called microzones, and consecutively generates efficient service zones based on them.

Microzones can be seen as basic units, which are the building blocks of a service zone. Creating service zones is also called districting or territory design. Districting is applied in a wide variety of applications such as emergency districting or political districting (Kalcsics, Nickel, & Schröder, 2005). The innovation introduced in this paper, however, focuses on the transport sector.

Currently postal codes are often used as basic units to generate service zones for transportation. But postal codes have inefficient shapes and are highly unbalanced with respect to geographical properties such as population density, driving time and travelled kilometres. Figure 1 shows three examples of inefficient PC5 areas in the Netherlands. Where PC5 refers to the four numbers and first letter of the Dutch postal code. Another problem of postal codes is the size of the area which it covers. The Dutch postal code system is very detailed, so one postal code covers a relatively small area, but postal codes in other countries in Europe and America cover a much larger area. One postal code in Belgium for example, covers a whole municipality. This is in many applications already too large for a service zone, so definitely not suitable as basic unit. Microzoning can overcome those inefficient situations. Efficient microzones can be developed for case specific situations and stakeholders' preferences can be incorporated.

The service zones resulting from a combination of microzones are robust and therefore only have to be generated once. Based on the service zones daily routes can be created. All demand points which belong to the same service zone also belong to the same route. So, on a daily basis only the shortest or fastest route which visits all delivery locations within one service zone has to be determined, which reduces computation times significantly. Another advantage of this approach is that truck drivers serve the same area every day so they become familiar with the regions and customers will recognize their carriers.

An initial version of the microzoning method has been applied by Argusi during a project for a parcels delivery company located in the Netherlands. Currently there exists an improved version of this method, which has been tested on parcel delivery data in Belgium. The next section provides an overview of this improved version of the microzoning approach.

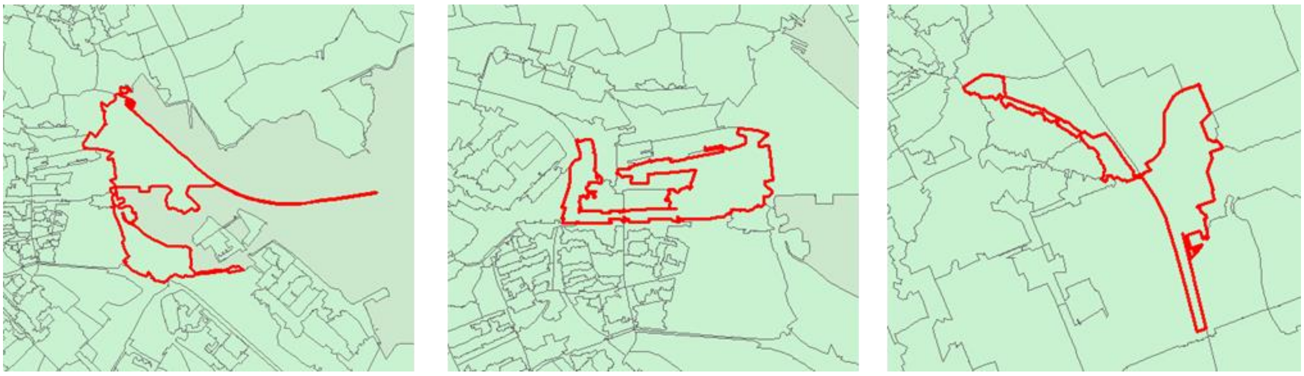

*Figure 1: Example of inefficient postal code areas in the Netherlands*

## 2 Methodology

By interviewing stakeholders and a literature study, the properties of a microzone were defined. The microzones should satisfy the following hard criteria, therefore they occur as constraints in the developed model:

1. Complete and exclusive assignment: Every piece of land should belong to exactly one microzone.
2. Contiguity: a microzone should consist of a connected aggregation of land.
3. Compatible with natural and physical barriers
4. No holes: a microzone cannot be located completely within another microzone.

Besides hard criteria also three soft criteria were determined. Those criteria should be optimized and therefore occur in the objective:
1. Minimize the number of microzones
2. Minimize workload (e.g. in case of parcel delivery driving and stop time)
3. Compactness: a microzone should be spatially compact

The importance of each objective might differ among stakeholders or per application therefore the model has the flexibility to assign priorities to each of the objectives.

In order to generate the microzones, a grid of an area is used as starting point. Besides the modelling advantages of a grid, this can also be beneficial for future standardisation since recently European countries are providing statistics based on squares of 100 by 100 meter.

Since microzones should be compatible with natural and physical barriers polygons are generated based on geographical boundaries. The following boundaries were taken into account to determine the polygons: country borders, highways, railways and main waterways. For each polygon a grid was generated. The size of the grid cells depends on the purpose of the microzoning. Together with historical demand data this is used as input for the model.

An iterative model has been created which exist of two phases. In the initiation phase, an initial solution is generated which fulfils all the predefined constraints. Besides the four fixed constraints mentioned above the model can incorporate other application specific constraints such as a maximum workload or a maximum surface per microzone. The initial solution is obtained by merging grid cells until every cell is assigned to a microzone and no more merges can be made.

The initial solution is used as input for the optimization phase. The goal of this phase is to obtain the best possible objective value. The objective function consists of the sum of the three soft criteria mentioned above where each criterion has its own weight function. To determine compactness a perimeter-area measurement has been applied. A square is considered as the optimal shape of a microzone. The workload is simply the sum of the workloads of all microzones. Optimizing the objective function is done by means of a heuristic approach. Two types of heuristics are used: simulated annealing (Kirkpatrick, Gelatt, & Vecchi, 1983) and Tabu Search (Glover, Tabu search part i, 1989; Glover, Tabu search part ii, 1990). In every iteration of this optimization phase two connected microzones are selected and grid cells are moved from one microzone to the other. Due to the simulated annealing heuristic movements which lead to worse objective values are accepted with a higher probability in the beginning to escape from local optima, but this probability decreases in every iteration. The optimization phase terminates when a predefined end temperature has been reached.

## 3 Case Study

The method described in the previous section has been applied on historical demand data of a parcel delivery company. Two areas in Belgium were considered; one densely populated area with many demand points and one rural area. For polygons located within the dense area a grid with cells of 300m by 300m was generated. The size of the grid cells in rural areas was set at 500m by 500m. The research has been applied on one month of historical demand data, consisting of 22 workdays.

Besides constraints mentioned in the previous section an additional workload constraint was added to the model, the restriction was that microzones could have a maximum workload of 30 minutes. Where the workload consists of driving time and stop time. This restriction was determined in collaboration with the stakeholders. Microzones with 30 minutes workload leave enough flexibility to generate service zones. If this workload would be significantly higher the possible combinations to generate a service zone decrease, resulting in less efficient service zones. Whereas reducing the workload per microzone increases complexity and computation time and results in less robust microzones.

Four scenarios were calculated to simulate stakeholders' preference regarding to the three objectives mentioned in the previous section. Table 1 gives an overview of those four scenarios, where $\rho_i$ indicates the priority value of objective *i*. In the first scenario each objective is considered equally important, while the other three scenario's simulate cases where one objective is more important than the other two.

Once the microzones were generated the service zones were determined. A service zone consists of an aggregation of microzones. The service zones were restricted to a maximum average daily workload of 480 minutes (8 hour workday). The workload of a service zone consists of the sum of the workloads of all microzones located within that service zone and the driving time from and to the depot. In the determination of the service zones the geographical boundaries were no longer taken into account, meaning that microzones of different polygons can belong to the same service zone.

Based on the service zones the daily routes were calculated. A route is simply the shortest route which starts at the depot then visits all demand points located within one service zone and finally returns at the depot. To calculate those routes a TSP algorithm has been used.

*Table 1: Overview of the four scenarios with corresponding priorities*

| Scenario | $\rho_1$ | $\rho_2$ | $\rho_3$ |
|---|---|---|---|
| 1. equal priority | 1 | 1 | 1 |
| 2. priority minimizing number of microzones high,<br>priority minimizing workload low,<br>priority compactness low | 2 | 0.5 | 0.5 |
| 3. priority minimizing number of microzones low,<br>priority minimizing workload high,<br>priority compactness low | 0.5 | 2 | 0.5 |
| 4. priority minimizing number of microzones low,<br>priority minimizing workload low,<br>priority compactness high | 0.5 | 0.5 | 2 |

## 4 Results

In total nine polygons were considered in the study of which four were located in the dense area and five in the rural area. Figure 2 shows an example of a polygon located in the dense area and the seven microzones which were generated within this polygon.

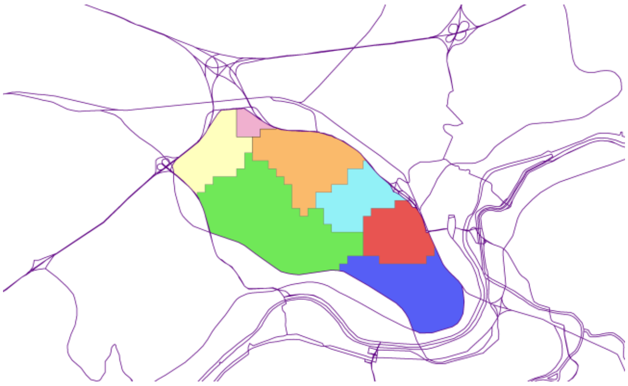

*Figure 2: Polygon with seven generated microzones*

The outcomes of the study showed that all four scenarios resulted in compact zones for every polygon. Minimizing the number of microzones and minimizing workload turned out to have a high correlation since scenario 2 and 3 obtained similar results in most of the polygons. In general both scenarios obtained low values for workload and the number of microzones. Giving higher priority to compactness on the other hand comes at the cost of the number of microzones and leads in the majority of the cases to more workload, while the compactness score only slightly improves. Those results can also be observed from Figure 3 which shows the outcome for each of the four scenarios for the polygon shown in Figure 2. In this case scenario 2 and 3 resulted in seven microzones, while scenario 1 and 4 resulted in nine and eight unique microzones respectively. It can be observed that each of the four scenarios for this case resulted in compact microzones assuming that a square is the most compact shape of a microzone. According to the numerical results represented in Table 2, scenario 1 turned out to have the best compactness score but this is hardly visible in Figure 3. Unlike the results of all other polygons, scenario 1 also achieved the lowest workload score for this polygon. For all other polygons considered in this study, scenario 2 or 3 obtained the lowest workload. This also indicates the unpredictability of the outcomes of scenario 1 where all objectives are considered equally important.

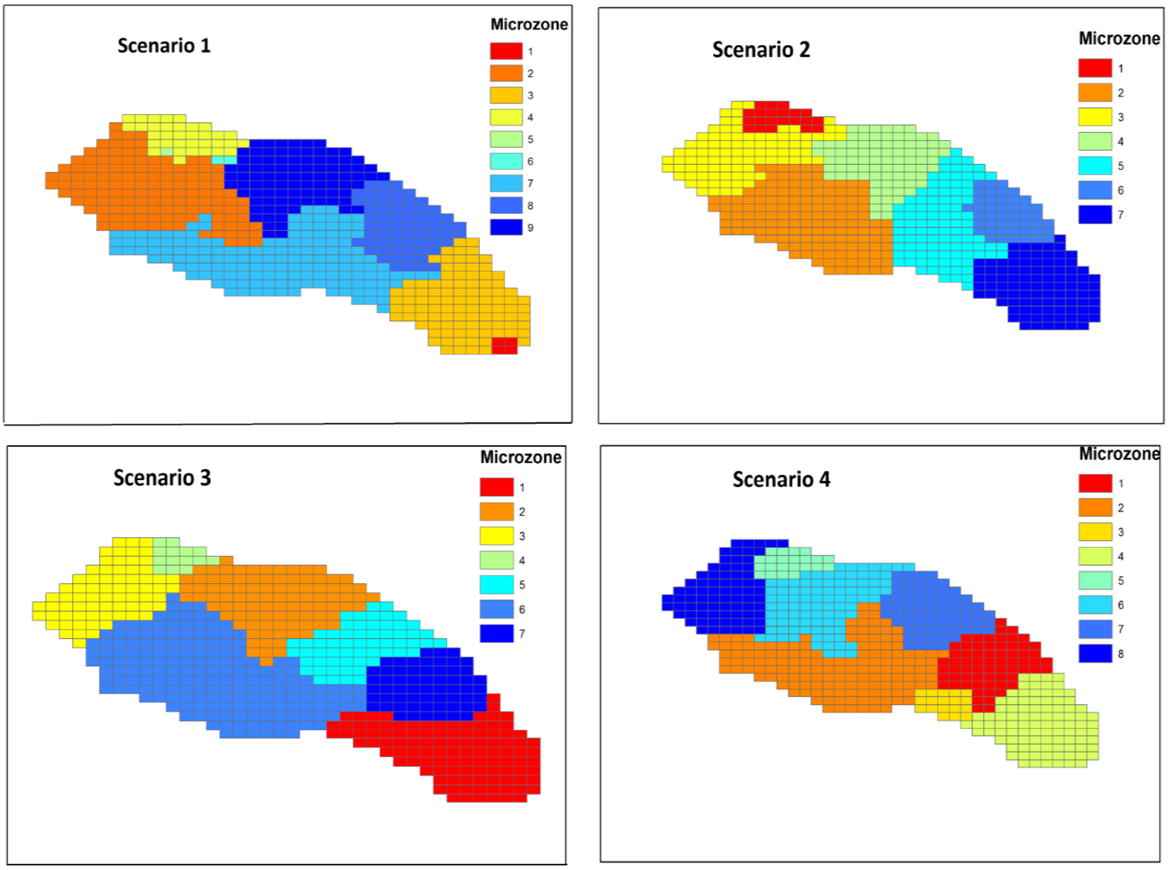


*Figure 3: The microzones resulting from the four scenarios for a polygon located in the dense area*

*Table 2: Numerical results of the four scenario's shown in Figure 3*

| Polygon 1 | Microzones | Total Workload | Compactness | Average Compactness Per Microzone |
|---|---|---|---|---|
| scenario 1 | 9 | 4134.162 | 2.020564 | 0.775493 |
| scenario 2 | 7 | 4167.718 | 1.805535 | 0.742066 |
| scenario 3 | 7 | 4140.67 | 1.667751 | 0.76175 |
| scenario 4 | 8 | 4218.144 | 1.823981 | 0.772002 |

In total six service zones were developed based on the generated microzones, two for the rural area and four for the dense area. For each zone the daily routes were generated. It turned out that the routes were quite robust with a coefficient of variation between 0.1 and 0.17 for all service zones.

Even though the microzones which were developed for this case are company specific, Argusi is aiming for standardised microzones, just like the standardised $\pi$ containers in physical internet (Montreuil, Meller, & Ballot, 2010). Possible improvements of this approach are the incorporation of public data such as population density and land use. Also, the generation of microzones with different levels of detail needs further investigation. One can think of different layers of microzones, like the NUTS classification (EUROSTAT, 2013) only with significantly smaller areas and specifically designed for logistic purposes.

## 5 Conclusion

This paper introduced microzoning, a method which develops basic units which can be used to create service zones for last-mile delivery. The microzones provide a solution to the current lack of efficient basic units that can be used for logistical purposes. Furthermore the use of microzones reduces computation time in daily route planning. The developed method introduced in this paper generates efficient and compact microzones and can incorporate stakeholders' preferences. A case study has been carried out based on data of a parcels delivery company. This study proved the effectiveness of this method in the daily route planning. More research should be done on standardization of the microzones and possibly the generation of different layers such that they can become the standard for all logistics applications and facilitate the physical internet.

## 6 References

EUROSTAT. (2013). Eurogeographics for the administrative boundaries. EUROSTAT: Statistical office of the European Union.

Glover, F. (1989). Tabu search part i. *ORSA Journal on computing*, *1*(3), 190-206.

Glover, F. (1990). Tabu search part ii. *ORSA Journal on computing*, *2*(1), 4-32.

Kalcsics, J., Nickel, S., & Schröder, M. (2005). Towards a unified territorial design approach—Applications, algorithms and GIS integration. *Top*, *13*(1), 1-56.

Kirkpatrick, S., Gelatt, C. D., & Vecchi, M. P. (1983). Optimization by simulated annealing. *science*, *220*(4598), 671-680.

MachEachren, A. M. (1985). Compactness of geographic shape: Comparison and evaluation of measures. *Geografiska Annaler. Series B. Human Geography*, 53-67.

Montreuil, B., Meller, R. D., & Ballot, E. (2010). Towards a Physical Internet: the impact on logistics facilities and material handling systems design and innovation. *Progress in material handling research*, 305-327.