MUNICIPAL WASTE COLLECTION FLOW PLANNING ISSUES

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Abstract
In Hungary, municipal waste collection plays a key role in the waste management sector. The common interest of the sector is to increase the efficiency of waste collection and minimize costs. It is also important in terms of material expenditure and environmental impact that this collection system works as efficiently as possible. In the presented work we tried to illustrate the currently operating system, the division of the Waste Management Regions, and the linking of the settlements and landfills. In addition, we examined the design of one other theoretical collection system that appears to be more efficient than the existing one and to present the influencing factors which have an effect the practical implementation of the theoretical model, their incorporation into specific flight plans.

Keywords: *waste management, waste collection*

1. The quantity of the mixed waste generated in Hungary

In 2019, 2,677,000 tons of municipal solid waste was collected in Hungary. A significant part of this was realized with the help of waste collection flights going to house in 3155 settlements of the country at least once a week. Regarding the territorial distribution it is proportional to the population density (see Figure 1). A larger quantity is generated in the cities than in the case of the settlements, highlighting the outstandingly high value of Budapest, which is approximately ten times higher than the second largest "producer" which is Debrecen (Figure 2). From a collection point of view, a more concentrated quantity is obviously more favourable, if we consider only the specific transport work need.

2. Waste Management Regions of Hungary

In Hungary 25 Waste Management Regions (WMR) have been established, in the territory of which 33 Public Service Providers (PSPs) perform waste collection and treatment tasks. Areas of operation have developed or are developing in the course of complex legal and economic processes in the midst of continuous changes. Figure 3 shows the WMR boundaries and the areas of operation of Public Service Providers in 2019. It is conspicuous, and it also follows from the numbers that several Public Service Providers operate in one WMR area, and one Public Service Provider provides services in several WMR areas. From the above it is clear that there is a key role of continuous review and optimization of collection systems for the sake of efficient operation.

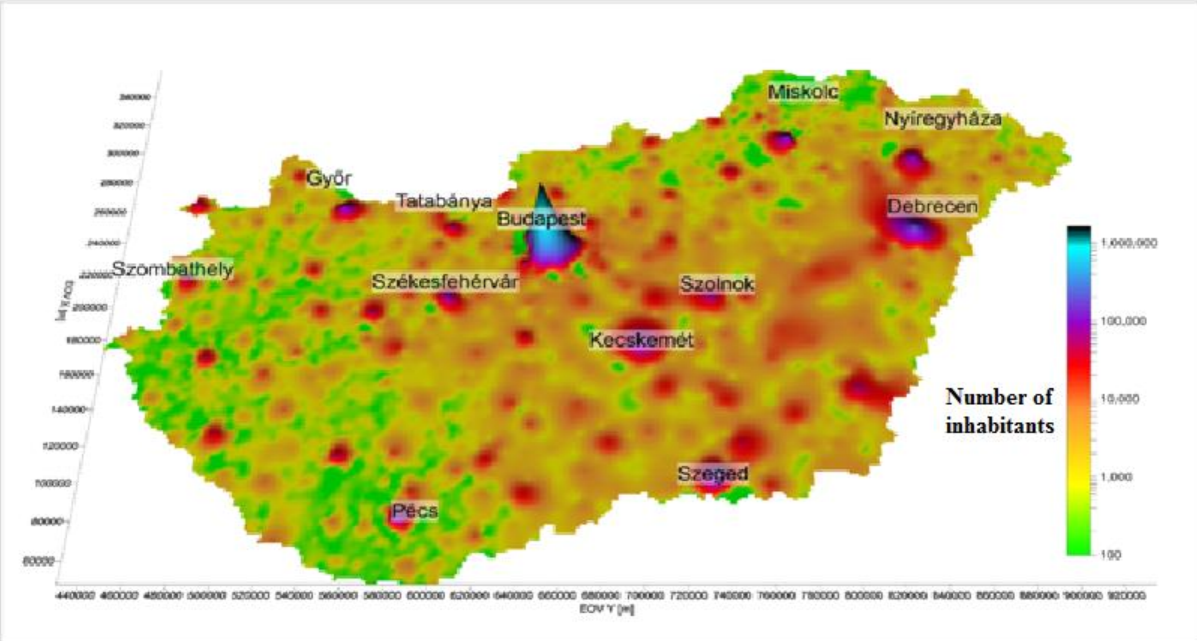

Figure 1. *Population distribution in Hungary (Central Statistics Office)*

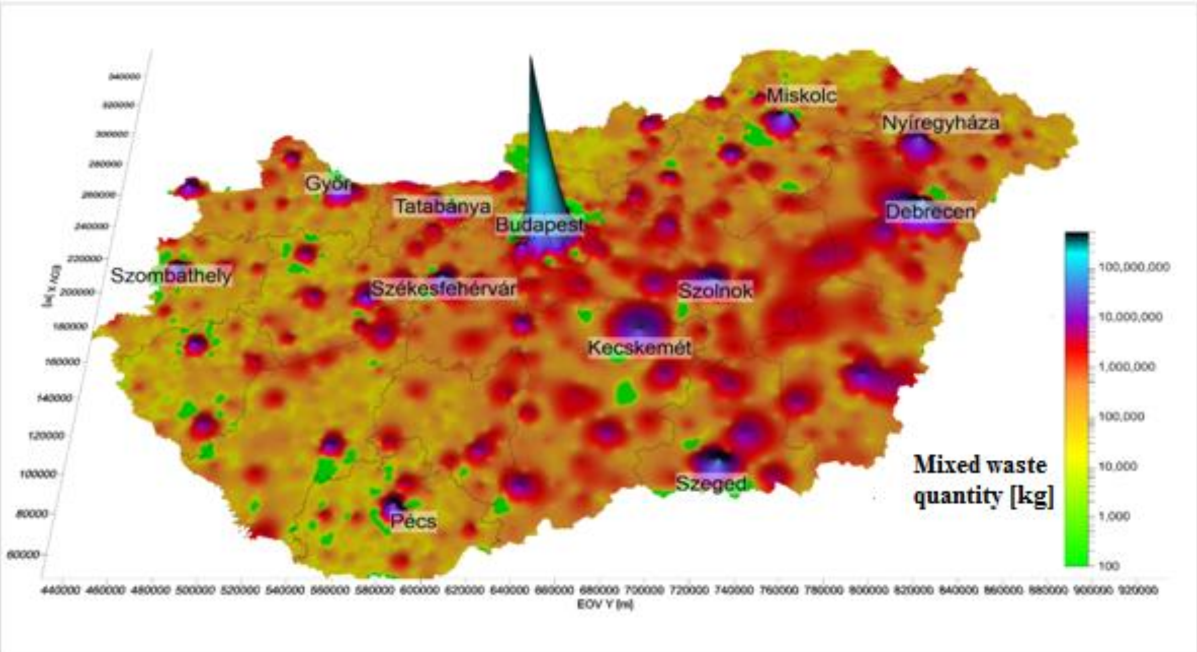

Figure 2. *Distribution of resulting municipal waste in Hungary (IWMIS)*

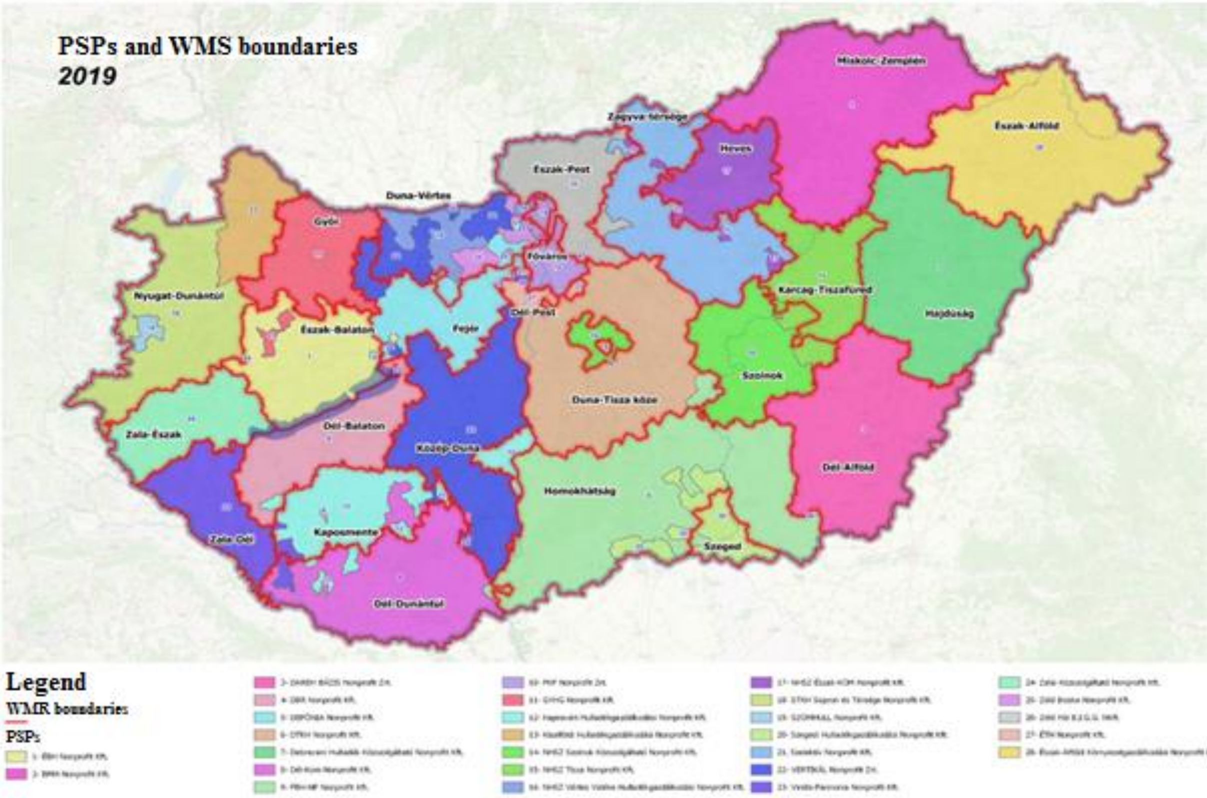

Figure 3. *Public Service Providers and WMR boundaries (National Waste Management Public Service Plan, 2021)*

3. Mixed communal waste collection facilities

In terms of facilities there are 60 landfills operating in the country. It is not really possible to build new ones depending on the set out goals and EU expectations. A significant reduction in landfills is expected. In terms of collection, therefore, landfills and transhipment stations are used to reduce long transport distances. Transhipment stations are most often mobile facilities, where the collected amount of waste collection flights is transferred to a larger storage container, which is then transported to the landfill after it is full. 5-6 vehicle waste can fit in such a container, thus reducing the transport distance. In return, the transhipment station also has maintenance and operating costs. Figure 4 shows the location of landfills, transhipment stations and settlements relative to the WMR boundaries. It can be clearly stated that there are fewer settlements in the Great Plain region considering that they are further apart than the denser settlements of Southern Transdanubia. At the same time it can be seen in the previous figures that the larger generated quantity is more typical in the Great Plain region than in Southern Transdanubia. The distribution of landfills, however, does not follow the density of the settlements or the quantitative distribution. A higher density of transhipment stations can be seen near the more complex settlement layouts, where even topographic conditions affect the efficiency of collection.

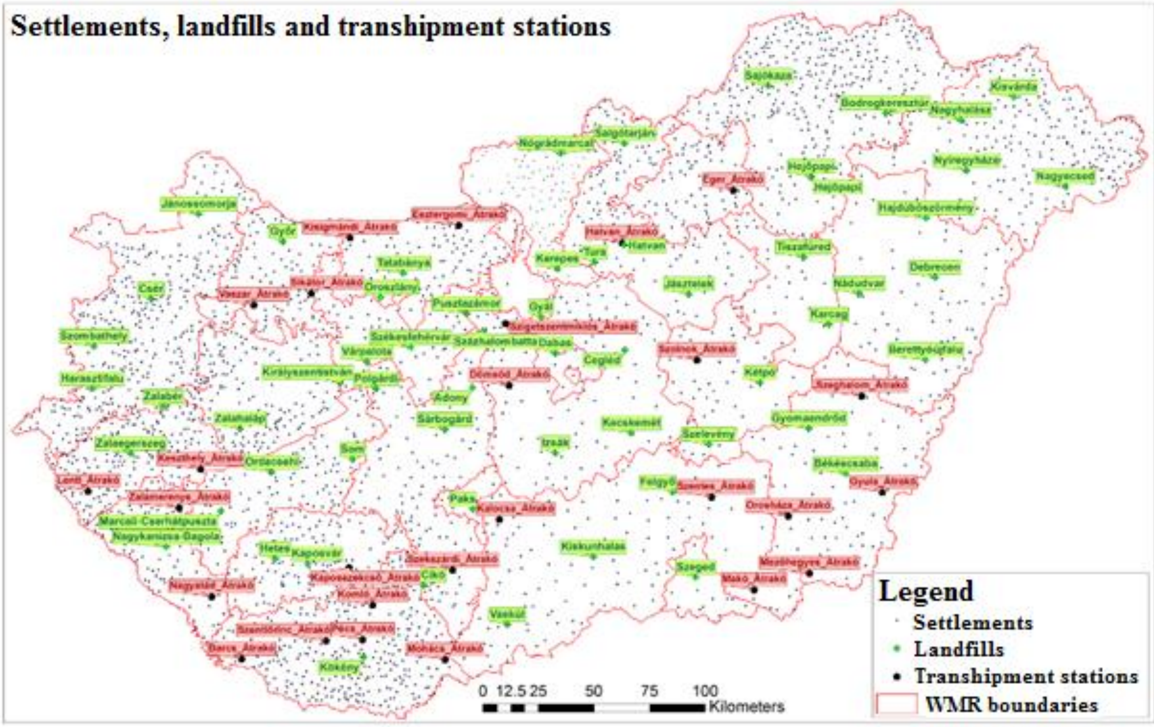

***Figure 4.** Hungarian settlements with landfills and transhipment stations; WMR boundaries*

4. Assignment of settlements and facilities within Waste Management Regions

The waste of the settlements within the area of operation of the given WMR must be transported to the corresponding landfill. This is the basic organizational principle. It is true that there are more landfills than WMR, but the spatial distribution of landfills and the geographical definition of WMR boundaries are not uniform and do not match the population. According to this there are WMRs without landfills and other ones with more landfills in other cases. Collection efficiency is greatly impaired by the situation where the landfill is close to the WMR border because the waste from a settlement which is very close to the landfill but belonging to another region is already transported to a more distant landfill. We tried to display the 2019 settlement assignment for transhipment and waste landfill in a map form, which is shown in Figure 5. The assignments in the North Pest region will be detailed later. You can see which facility contains the waste of a given settlement, and it is marked with blue straight lines. The information available on the website of the Public Service Providers is the collection schedule for each waste stream at the settlement level (which type of waste is transported on which day or days in the given week).

It can be clearly stated that in regions with higher settlement density there is a complicated transport system, many line intersections can be seen, somewhat confirming the above statements. We can therefore assume that the system is not operating as efficiently as possible.

For this reason we have created a model or solution that assigns each settlement to the nearest landfill that can be measured on the road. Regional boundaries were not taken into account, nor were transhipment stations included. The result map is shown in Figure 6.

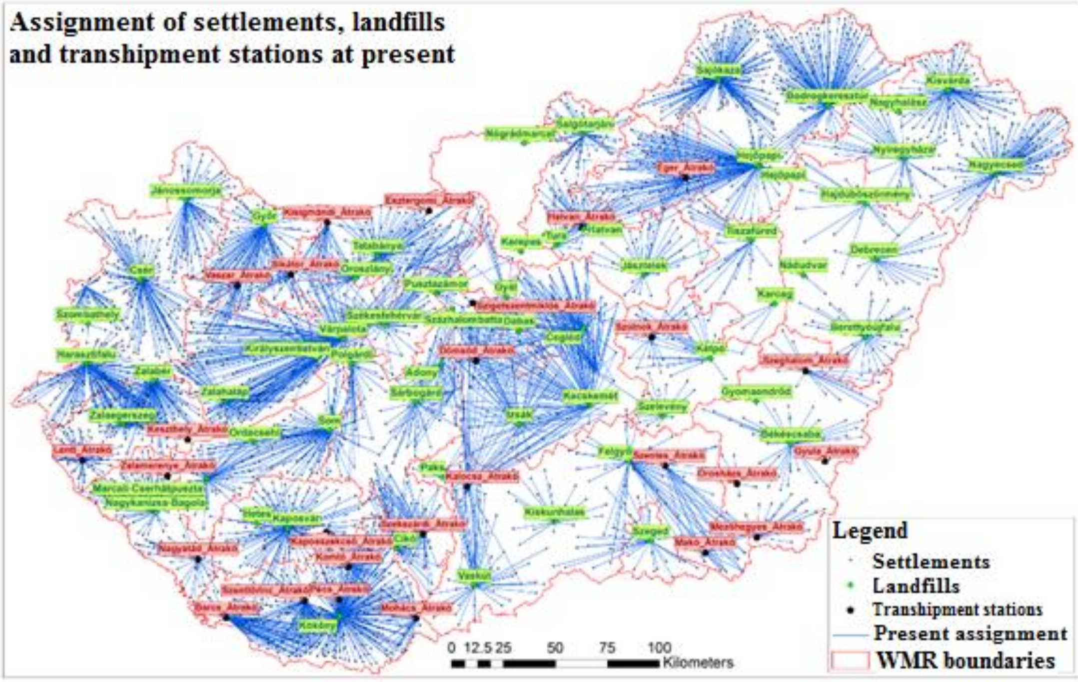

Figure 5. *Settlement and facility assignment in WMR boundaries*

The assignment based on the shortest road distance shows a much clearer picture. To compare the two systems we formed a distance-based value which is in the given assignment the sum of the distances measured by road between the facilities and the settlements assigned to them. It is important to emphasize that this is not the same as the transport distance required for collection, on the one hand, each distance was considered only once (not there and back). On the other hand, the collection takes place in the form of round trips, i.e. a collection vehicle collects waste from several settlements or parts of settlements and there is no flight to all settlements from the landfill and back. It can be concluded, however, which solution is more effective and to what extent. It is also important that the collection of mixed communal waste takes place in settlements with family houses, their parts once a week and in parts of housing estates twice or three times a week at the same weekly rate.

In our case the mapping of the current state yielded the following numbers (we did not take into account additional shipments from a transhipment station to a landfill, which further increase the distance):

- Total settlement-landfill road distance: 180,000 km;
- Maximum distance: 209 km;
- Average distance: 35 km.

<u>The least road distance assignment numbers</u>:

- Total settlement-landfill road distance: 84,000 km;
- Maximum distance: 75 km;
- Average distance: 27 km.

In order to get a more accurate picture of the collection efficiency in each assignment variant, it is necessary to make detailed flight plans for each assignment that can be implemented in practice and to form the sum of them. This is a huge task for which little reliable information is available.

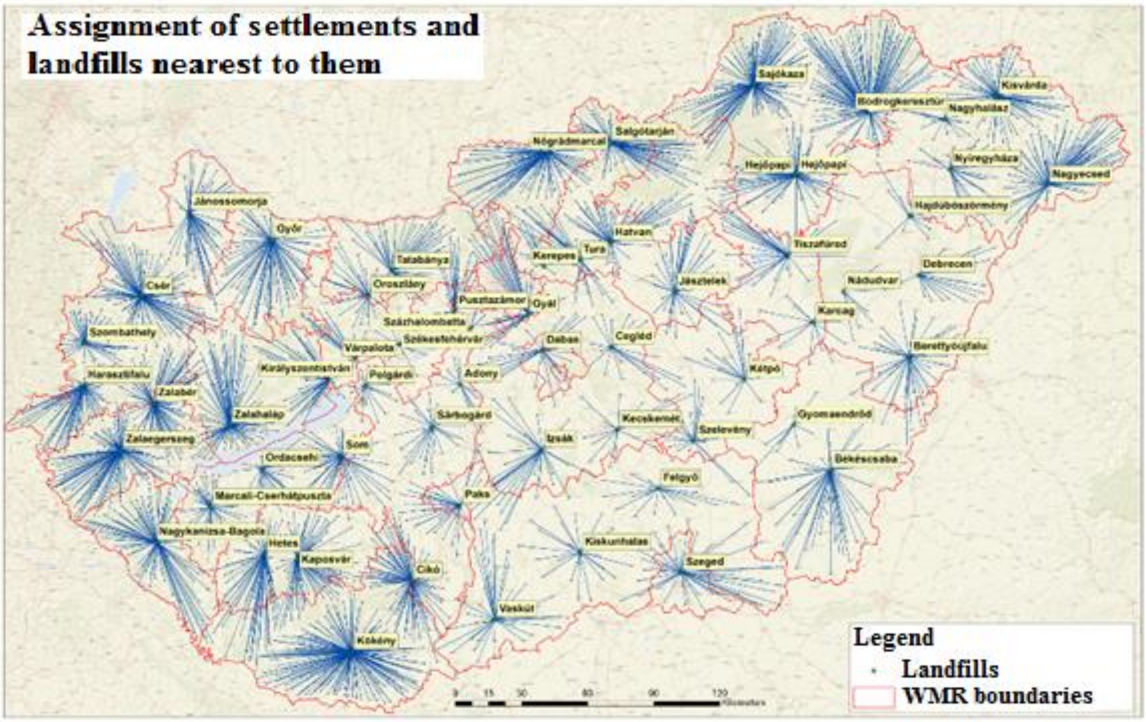

Figure 6. *Settlement and landfill assignment based on the least road distance*

5. Waste collection flight plans in each region

Let’s start with some thoughts on flight plans. There are basically two types. One of them is the flight plans within a settlement. These show the route along which each address point can be optimally served in each settlement. Their significance lies primarily in optimizing the time required for collection and secondly in optimizing the transport distance. The other type is inter-settlement flight plans which are very important primarily in terms of transport distances.

In order to prepare an inter-settlement flight plan, a number of parameters must be taken into account, the most important of which are as follows:

- The quantity of weekly waste generated in each settlement. This is obviously an average figure from which there is some deviation every week. The deviation should be taken into account due to the finite capacity of the collection vehicles. One of the reasons for the discrepancy is in the form of seasonal waste, which can be traced back to the season, but it appears differently in different economically developed regions. For example: periods of leave. Due to the COVID situation more people stay at home.
- The time required to collect the resulting quantity in the given settlement or a settlement part. It is important what the structure of the settlement is like, how far the buildings are from each other, and how often the vehicle has to stop. It is also essential how many times a week the container should be emptied and on what fixed days the container should be emptied.
- Parameters of collection flights, such as load capacity, axle load and physical dimensions. These largely determine the speed at which the vehicle can travel. Weight restrictions, narrow streets

make work very difficult.

- The employees' working hours, which include the time of morning inspection, travel, collection and emptying and, in some cases, return time after unloading at a landfill, if the vehicles are not located in the landfill area. Attention is also needed for determining the amount of overtime.
- The geographical location of each settlement and facility, moreover, position of each landfill, transhipment station and garage.
- The capacity of the facilities which is especially important in the case of transhipments.
- The road network with traffic rules, weight and size restrictions, speed limits.
- The condition of the roads is also important because full vehicles are very vulnerable on pothole roads. Dirt roads can be used only temporally and in dry weather.
- Terrain features. Winding forest roads with large level differences, especially in winter, greatly affect the efficiency of collection.
- Weather.

In the following we will demonstrate how a detailed flight plan is put together for a region. The North Pest region to be presented, which is not shown in Figure 5, included 111 settlements in the period under review, as well as two landfills and one transhipment station. There are also garages for vehicles in the area of the landfills, and due to the large area, there are two more sites from which flights depart and then return here after collection and emptying. A fleet of vehicles can be found at the landfills and sites, and it consists of 38 cars with a load capacity of 4-12 tons and 6 cars with a l oad capacity of less than 3.5 tons.

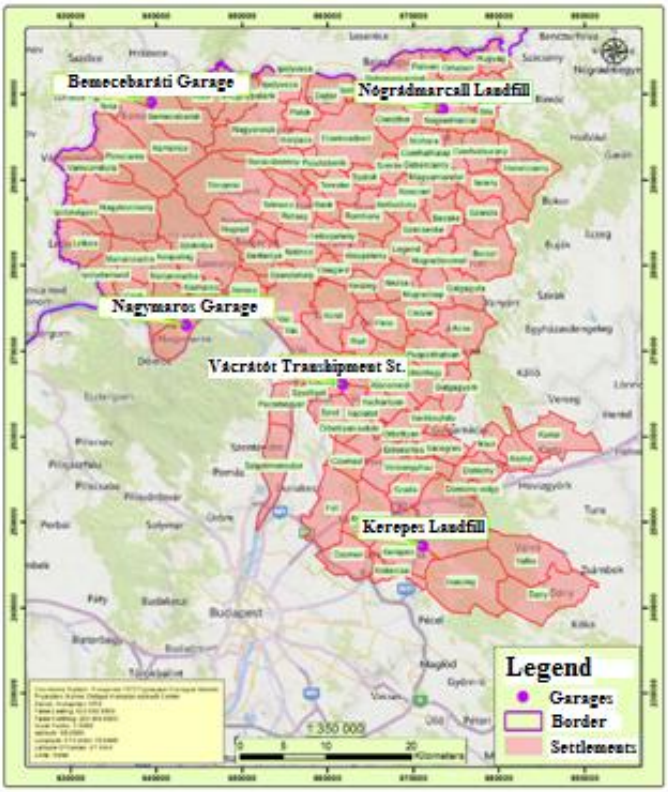

Figure 7. *Map of the region with settlements and facilities*

The settlements in the region are illustrated in Figure 7. A total of approximately 1,400 tons / week of waste is generated in the region.

An important boundary condition of the studies was that all settlements must be collected within one day, with the exception of the housing estate zone, where this had to be done twice or three times a week in case of specific settlements.

In the first step of the study, which was basically performed using the Network Analyst module of the ArcGIS 10.5 for Desktop software package, we divided the settlements into collection districts based on their minimum road distance from the landfills and the transhipment stations and the maximum transhipment capacity. Settlements close to the transhipment stations generate more waste than their equipment can handle. For this reason, it is an important task to determine which of the surrounding settlements should be the ones whose waste needs to be transported directly to the more distant landfill, not through the nearest transhipment station.

To this end, in the distance matrix describing the waste collection system, the distances belonging to the settlements were weighted by the collection quantities. As a result of the research aimed at minimizing the resulting logistical work, we determined the settlements where the waste can be delivered to the landfill more efficiently compared to the use of collection vehicles by compressing it into high-capacity transport vehicles and containers.

As a result of the first phase of the flight optimization, the list of settlements belonging to each collection district was formed, which is shown in Figure 8.

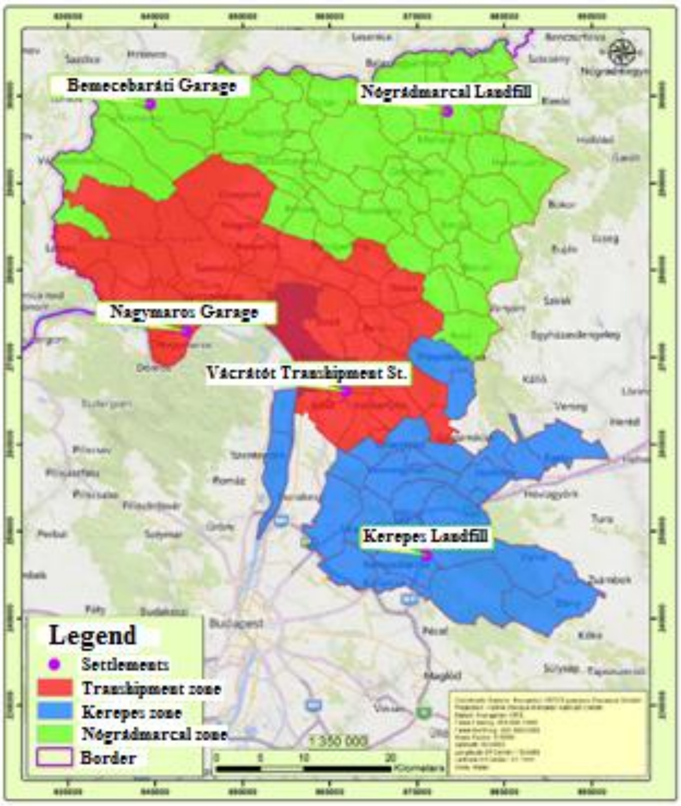

Figure 8. *System divided into collection zones*

In the second phase, the settlements in each district were divided according to collection days, in such a way that the quantity of waste per day and the associated collection time (collection, emptying and transport) were as equal as possible. We formed acceptable ranges for each parameter, within which we made several daily schedules. From these, we selected our solution that took into account not only theoretical considerations but also practical ones during the optimization. From a practical point of view, it is more advantageous if the settlements served one day are close to each other, or if several vehicles travel on a common route, because the occurrence of possible technical problems or excess quantities can be more easily handled. The available vehicle capacity can be used more efficiently with a load equally distributed over the days (in quantity and time). The resolution by days is illustrated in Figure 9.

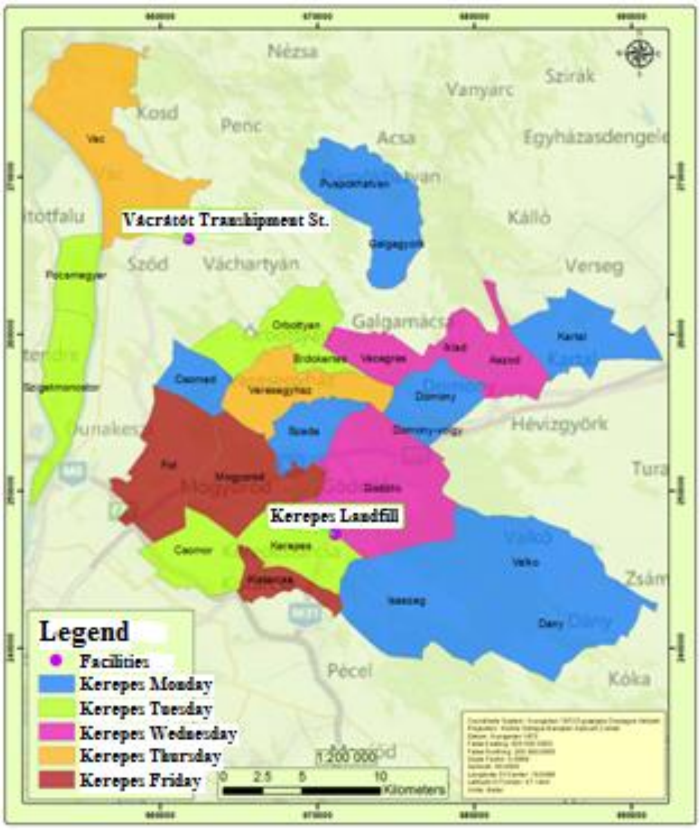

***Figure 9.** Resolution of a collection area by days*

In the third and final step, we prepared the intraday flight plans, taking into account the quantities generated in the settlements assigned to the given day, the vehicle capacities, and the time required for transport, collection and emptying, furthermore, the parameters which we listed earlier and could be quantified in the design software. In addition, we took the observance of working hours into consideration. In special cases when, due to external conditions, the daily work does not fit into the eight hours on average, we tried to minimize overtime.

The purpose of the completed flight plan is to operate the entire system in the most efficient way. Of course, in the study we took into account that the quantity of waste generated can even change significantly from period to period, so we also tried to provide a reserve for the collection capacity of each flight. As a result of the multi-stage logistical analysis process the division of the region into districts and collection days within the districts and the concrete flight plans for each collection day in each district was completed. The result provides a complete collection plan covering 155 flights for the region. The flight plans include, in part, the concrete route plan for the whole day, as well as the quantity planned for collection, the required working time and the distance to be covered.

6. Summary

In our opinion, it is necessary to increase the efficiency of the municipal waste collection system but it must be seen that it is influenced by a huge number of parameters. The necessary data is scarce and a huge amount of work needs to be done to justify a new idea that will not be more reliable than the data used. It is essential to build a database at the national level that quantifies the many parameters that influence flight planning. Some of this information can be obtained from the experience of the current system operators, and the database can be built in cooperation with them.

The flight plans of the presented study cover only one region in the country in terms of mixed waste collection. In addition to mixed waste, however, other waste streams are also collected, such as packaging waste, green one, and glass one. There is waste disposal, and in addition to public collection, the collection of waste from the industrial sector and hazardous waste as well.

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