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**SETTLEMENTS, PUBLIC FACILITIES AND CUSTOMERS:  
USING GIS FOR FUNDING PURPOSES**

Submitted by Statistics Netherlands <sup>1</sup>

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## **Settlements, Public Facilities and Customers: Using GIS for funding purposes**

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# SETTLEMENTS, PUBLIC FACILITIES AND CUSTOMERS: USING GIS FOR FUNDING PURPOSES

## **Summary:**

*On the 1<sup>st</sup> of January 1997 the Act on the Municipal Fund has been replaced by a new Act. In this new law a very comprehensive list of criteria has been defined for payments to be distributed from this structural Fund to the local authorities. Some criteria are new, such as the criterion described in this paper: the potential of customers of public facilities in settlements within the municipalities - the lowest administrative level in the Netherlands. The paper describes the theoretical model for the criterion, the data sources and the GIS application used to compile the relevant statistics as well as some preliminary results.*

## **Keywords:**

*customers, geographical information systems, gravity models, payments of central government, public facilities, settlements.*

## **1. Introduction**

The administrative structure in the Netherlands consists of a hierarchical system of three levels of government<sup>2</sup>: central (the Netherlands), provincial (12 provinces) and local (municipalities - 572 in 1997). Every level of government has its own tasks and responsibilities. Central, provincial and local authorities are relatively autonomous, since every authority has its own legislative power. This legislative power can only be exercised, of course, for its own territory. There exists, however, another restriction in exercising this power. Regulations issued by a lower level of government, e.g. a local authority, may not conflict with a regulation issued by an authority of a higher level - in this case: a provincial authority and central government.

In order to perform their tasks the provincial as well as the local authorities have their own budgets. Both authorities, however, can not fully meet their expenditures from their own receipts. Although the local authorities, for example, have their own revenues such as local taxes and retributions, the amount of these revenues constitutes only forty percent of their total receipts. The other amount is financed by central government.

There are two ways central government is financing provincial and local authorities: for a specific purpose or based on a lump sum which has a general character. The last way of financing has been institutionalised by two structural Funds: the Provincial Fund and the Municipal Fund. The total amount of the financial contributions from these Funds and the

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<sup>2</sup> Properly speaking there is a fourth level, namely the "District Water Boards". This level falls outside the scope of this paper.

criteria used to determine the share of respectively each provincial or local authority are regulated by law.

On the first of January 1997 the Act on the Municipal Fund of 1984 has been replaced by a new Act. In this new law a more comprehensive list of criteria has been defined for the payments to be distributed from this Fund to the individual local authorities. To put these criteria into practice, concrete figures are needed. At this stage Statistics Netherlands plays an important role, for most of these figures are taken from statistics which are published regularly by our Office. Examples of such figures are: inhabitants - total, 19 years or younger and 65 years or older - minorities, households with a low income, persons claiming social benefits, as well as area land, area inland and coastal waters, housing units and address density of the surrounding area<sup>3</sup>. Figures for some criteria, however, are compiled on special request of the administrators of these Funds - the Department of the Interior and the Finance Department. This is, for example, the case for figures on the potential customers of public facilities - a criterion defined in the new Act on the Municipal Fund, which is the topic of this paper.

The theoretical background of this criterion is described in the next section; the operationalisation of the criterion in section 3. In section 4 the data sources used and the various steps of the data processing are treated. Preliminary results for 1997 are presented in section 5. In the last section future perspectives are given with respect to other criteria for which GIS applications will still have to be developed.

## **2. Settlements and public facilities: the attraction model**

The criteria used in the new Act on the Municipal Fund have been developed taking the principle into account that these criteria should be related to differences in expenditures between local authorities on a certain number of policy fields. One of these policy fields refers to the presence and maintenance of public facilities. The range in public facilities on the local level varies evidently with the size and type of the local community. Cities and towns have, generally speaking, a broader range of public facilities than suburbs or rural areas. Many facilities present in these cities or towns are used not only by the citizens of these communities but also by the inhabitants of suburbs and neighbouring rural areas. From the viewpoint of local expenditures this situation is a peculiar one. The local authorities of cities and towns are financing facilities on their territory for customers outside this territory without getting payments for this service from the respective local authorities.

The research on the development of an appropriate criterion which could take into account this imbalance in expenditures between cities and towns on the one hand and suburbs and rural areas

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<sup>3</sup> The address density of a surrounding area for a municipality is the average of such densities for every address in the municipality. The address density for every address is the address density in the area surrounding that address within a circle with a radius of one km. For more information on this subject see: Vliegen M. and Van de Stadt, H., Measuring urbanisation: a categorial approach, ECE Work Session on Geographical Information Systems, Working Paper no 20, Voorburg, 1994 .

on the other hand, took a long time. The Advisory Body for Local Budgets that conducted the research, has finally chosen for an abstract model to tackle this problem, for models based on levels of actually present public facilities had shown to have too many disadvantages for this aim. The abstract model finally chosen by the Advisory Body has been borrowed from models representing consumer spatial behaviour in order to delineate retail trading areas and to define their potential customers. Particularly the model presented by David Huff (Huff, 1964) has been a source of inspiration in this respect.

Contrary to the models of other market analysts Huff's theoretical model for defining trading areas and estimating the expected number of customers for a particular shopping area focused on the consumer as the primary agent rather than the firm. In addition to the parameters used in the traditional gravity models in this field of research - population masses of areas and the distance between these areas - Huff introduced the element of possible competition between neighbouring areas by introducing the customer's ability to choose between alternatives.

This particular element of competition Huff had introduced was for the Advisory Body for Local Budgets of high importance in order to grasp the potential customers of public facilities in the various kinds of settlements (Raad voor de Gemeente-financiën, 1995). Since the citizens of suburbs, for example, have "intervening opportunities" for excellent public facilities in the cities, a substantial part of these citizens will be oriented in this respect towards the neighbouring cities. Citizens of a settlement as big as a suburb but geographically located in the midst of an extended rural area will, on the other hand, be oriented towards their own settlements in this respect. Huff's model based on the consumer as primary agent, took into account such effects.

The theoretical model for the estimation of the potential of customers of public facilities the Advisory Body has finally chosen for, has been based on the following assumptions:

- Settlements of a bigger size offer more public facilities and will also attract customers from small settlements;
- People will make use of public facilities to a lesser extent, when the distance to be bridged to these facilities increases. Above a certain distance, nobody will make use of the facilities anymore. In this case the distance can be prohibitive or the customers will use facilities which are located nearer to their homes;
- As providers of public facilities settlements will compete with each other in a spatial system of settlements of various size and geographical position. As a consequence the level of public facilities present in a settlement depends not only on the number of its inhabitants, but also on the presence or absence of possible alternatives in its surroundings.

The starting point in the theoretical attraction model chosen can be formulated as follows: the attraction public facilities in settlement  $j$  are exerting on the population of settlement  $i$  ( $A_{ij}$ ) varies with some function  $f$  of the population of settlement  $j$  ( $M_j$ ) and inversely with some function  $g$  of the distance between settlement  $j$  and settlement  $i$  ( $D_{ij}$ ). In formula:

$$(1) A_{ij} = (f M_j / g d_{ij})$$

There are, however, various settlements  $j$  exerting an attraction on the population of settlement  $i$ . From the viewpoint of settlement  $i$   $A_{ij}$  can be expressed as a proportion of the total attraction ( $A_i$ ) added for all settlements  $n$  ( $A_i = \sum_n A_{in}$ ). In formula:

$$(2) P_{ij} = A_{ij} / A_i = (f M_j / g d_{ij}) / \sum_n (f M_n / g d_{in})$$

The proportion ( $P_{ij}$ ) in formula (2) indicates the probability that an inhabitant of settlement  $i$  uses the public facilities of settlement  $j$ . Multiplying  $P_{ij}$  with the number of inhabitants of settlement  $i$  ( $M_i$ ) yields the estimation of the number of inhabitants living in settlement  $i$  using regularly the public facilities of settlement  $j$  ( $C_{ij}$ ). In formula:

$$(3) C_{ij} = P_{ij} * M_i$$

Adding the values of  $C_{ij}$  for all settlements  $i$  yields the total number of potential customers of the public facilities in settlement  $j$  coming from all settlements  $i$  (including those of settlement  $j$ ). In formula:

$$(4) C_j = \sum_i C_{ij} = \sum_i (P_{ij} * M_i)$$

Finally, it is interesting to note that adding the values of  $C_{ij}$  in formula (3) for all settlements  $j$  yields the number of inhabitants of settlement  $i$ , since the sum of  $P_{ij}$  over  $j$  equals 1. The model yields, therefore, a redistribution of the total population of the settlements: from inhabitants of settlements to potential customers of public facilities in those settlements.

### 3. Potential of local and regional customers

Having developed the general attraction model for estimating the potential of customers the Advisory Body has elaborated two variants of this model. As the Advisory Body observed, great differences exist between the various public facilities in scale as well as in geographical range. For the sake of simplicity the Advisory Body made a distinction in this respect between (a) public facilities with a local impact - e.g. public libraries or sports-grounds - and (b) facilities with a regional impact - e.g. theatres or concert-halls. The former can be found in many settlements and they operate on a small geographical range; the latter are found only in settlements of a certain size and their geographical range is much wider.

Based on these differences the Advisory Body proposed two criteria: the potential of local customers of public facilities as well as the potential of regional customers of such facilities. In the *local* variant the range of the public facilities has geographically been limited to 20 km. Furthermore, the function  $f M_j$  in formula (1) has been defined as  $f M_j = M_j$  and the function  $g d_{ij}$  in this formula as  $g d_{ij} = d_{ij}^2$ . The *regional* variant, on the contrary, takes only public facilities on a large geographical scale into account, so that the maximum distance in this model has been extended to 60 km. The function  $f M_j$  in this variant, however, has been defined as  $f M_j = M_j^2$ ; the definition of the function  $g d_{ij}$  remains the same as in the local variant:  $g d_{ij} = d_{ij}^2$ .

The equations used in the general model have subsequently been adapted to the functions defined in the local and regional variant. Thus, the probability that an inhabitant of settlement  $i$  uses the public facilities of settlement  $j$  ( $P_{ij}$ ) is computed in the *local* variant by the following formula:

$$(5) P_{ij} = \frac{M_j / d_{ij}^2}{\sum_{n:d_{in} \leq 20} M_n / d_{in}^2}, \quad \text{if } d_{ij} \leq 20 \text{ km and } P_{ij} \equiv 0 \text{ if } d_{ij} > 20 \text{ km}$$

where:

- $M_j$  = the number of inhabitants of settlement  $j$ ;
- $d_{ij}$  = the distance between the settlements  $i$  and  $j$ .
- the sum in the denominator sees to it that the total potential of local customers from settlement  $i$  equals the number of inhabitants of this settlement

The probability that an inhabitant of settlement  $i$  uses the public facilities of settlement  $j$  ( $P_{ij}$ ) is computed in the *regional* variant by the following formula:

$$(6) P_{ij} = \frac{M_j^2 / d_{ij}^2}{\sum_{n:d_{in} \leq 60} M_n^2 / d_{in}^2}, \quad \text{if } d_{ij} \leq 60 \text{ km and } P_{ij} \equiv 0 \text{ if } d_{ij} > 60 \text{ km}$$

where:

- $M_j$  = the number of inhabitants of settlement  $j$ ;
- $d_{ij}$  = the distance between the settlements  $i$  and  $j$ .
- the sum in the denominator sees to it that the total potential of regional customers from settlement  $i$  equals the number of inhabitants of this settlement.

In both variants the estimation of the number of inhabitants living in settlement  $i$  using regularly the public facilities of settlement  $i$  ( $C_{ij}$ ) is calculated from  $P_{ij}$  and  $M_i$  by formula (3) above. The total potential of local, respectively regional customers of settlement  $j$  ( $C_j$ ) is subsequently obtained by adding the values of  $C_{ij}$  for all settlements at a distance of 20 km or less for the local variant, respectively 60 km or less for the regional variant - using formula (4) above.

Since the distribution of payments from the Municipal Fund is based on figures for the whole territory of the local authorities - i.e. the municipality -, the total potential of local, respectively regional customers of these municipalities ( $C_m$ ) is obtained by adding the values of  $C_j$  for all settlements  $j$  belonging to municipality  $m$ .

## 4. Operationalisation

### 4.1. Supplementary definitions

In addition to the development of the theoretical model and the formulas to be used for the calculations it was still necessary to define (a) the settlement, (b) the inhabitants of a settlement as well as (c) the distance between settlements. These definitions as well as the calculation formulas had to be part of the new Act on the Municipal Fund.

The *definition of the settlement* has been based on earlier work of Statistics Netherlands on the delineation of localities. This work refers to attempts of grouping particular census tracts to localities in a GIS-environment. Within this framework a map consisting of grids of 500 x 500 meters with at least 25 addresses per grid square was used as a yardstick for grouping these tracts. This grid map had been constructed as a proxy for the continuous built-up area<sup>4</sup> - the basic characteristic of a locality. Hence, the continuous built-up area had operationally been defined as a configuration of such grid squares which are contiguous at least at one side or an isolated grid square with 25 addresses or more. After a thorough scrutiny the Advisory Body for Local Budgets adopted this proxy of a continuous built-up area for the definition of the settlement. There was only one amendment made on the proxy: it should not cross the boundaries of the municipalities. Localities extending the territory of two or more municipalities had, therefore, to be split up in more than one settlement.

In applying the criterion the total resident population should be redistributed to potential customers of public facilities. A further specification of the *inhabitants of settlements* was, therefore, necessary in order to take sparsely populated areas into account. It was decided that people living in such areas should be assigned to a particular settlement. The assignment itself occurs proportionally to the size of the settlements at the level of the individual municipality. Inhabitants of a settlement are thus defined as an enlarged population in settlements.

The *distance* between settlements was defined as the beeline from the centre of a settlement to the centre of another one. The centre was operationally defined as the centre of gravity - in terms of a geographic co-ordinate - of the configuration of grid squares mentioned above re-weighted for the number of addresses in every grid. The distance of a settlement to the settlement itself was fixed at 1 km.

## **4.2. Calculating the potentials: data sources and data processing**

The sources used for the calculation of the potentials of local and regional customers of public facilities are twofold: the Geographic Base File (GBF) and the enumeration files from the Municipal Population Registers (MPR).

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<sup>4</sup> The criterion of at least 25 addresses is derived from the guidelines for the delimitation of census tracts in rural areas in the Netherlands by local authorities. In these guidelines it is recommended, among others, that groupings of at least 25 dwellings in a rural area at a distance of each other of less than 100 meters should be considered as a separate census tract. Transformation of this criterion to a grid system implies that there should be a distance of at most 100 meters between pairs of addresses which can be located within the grids concerned. The application of this rule to a grid system of 500 x 500 meters yields the number of 25 addresses or more per grid square. For more information on this subject see: Vliegen M., 1993 Geographical Information Systems and the Statistical System. Examples of applications for small area statistics, Working Paper No. 10, ECE Work Session on Geographical Information Systems, 28-30 September, Ottawa.

The GBF is an automated register with all postal addresses in the Netherlands to which the codes of the municipalities, the census districts and tracts and the postal districts have been attached as well as the geographical co-ordinates of the national system of grid squares of 500 x 500 meter. The GBF is updated annually by a consortium of the Postal Office, the National Physical Planning Agency and Statistics Netherlands.

The GBF is used in two ways in the data processing for the calculation of the potentials of customers. First, it constitutes the basic file for gathering the data required for the delineation of the settlements, namely figures on the number of addresses for every grid of 500 x 500 meter. Since the GBF is also a relational system between small areas with the address as key, it is matched with the enumeration files from the MPR's at the level of the individual addresses. In this process of matching the co-ordinates of the national grid system as well as the codes for the census districts and tracts are attached to the MRP enumeration files. In this way it is possible to compile, among others, figures on the number of persons for every grid square of 500 x 500 meter.

In the further stage of the data processing the file with the GBF addresses per grid square is introduced into a GIS in order to determine the contiguity of grids with 25 or more addresses and, consequently, to delineate the proper configurations of grid squares as proxies for the settlements. The GIS is used, moreover, to assign an unique code to the delineated configurations of grid squares as well as to compute their centre of gravity in terms of a co-ordinate of 500 x 500 meter and the distances between the respective configurations. Subsequently, the file with the number of persons for every grid square of 500 x 500 meter is introduced in the system in order to compute the figures on the inhabitants of the settlements.

Having delineated the settlements for every municipality and computed their inhabitants as well as the distances between those settlements, the potentials of local and regional customers can be computed straightforward using the formulas described above: first for the individual settlements and then for the municipalities.

## **5. Some preliminary results**

### **5.1. Settlements and their inhabitants**

The new Act on the Municipal Fund has taken effect on the 1<sup>st</sup> of January 1997. In view of a timely administration by the Finance Department preliminary figures have been compiled on the potentials of customers. These figures have been derived from a provisional version of the GBF 1996 and from estimates of the number of persons per grid square. These estimates have been based on the addresses in the GBF of which the characteristics indicate that they might be inhabited.

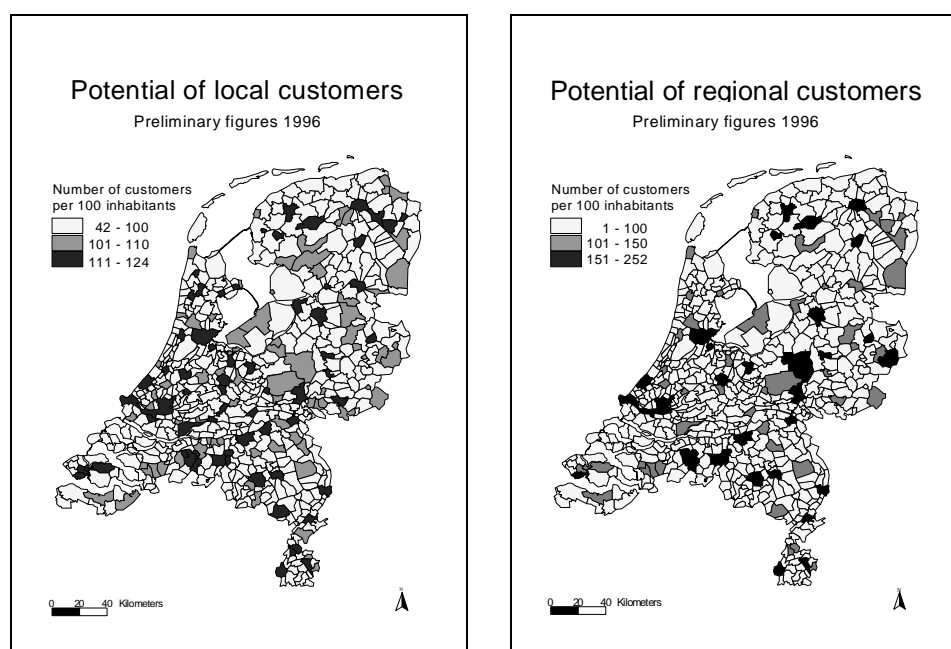
The map in Annex 1 of this paper shows the result of the first stage of the data processing, namely the delineation of the settlements. Somewhat more than 3 100 settlements within municipalities have been identified in the process. Some characteristics have been summarised in table 1 of Annex 2. These figures as well as the map show that The Netherlands are highly urbanised. Applying the ECE definition of an urbanised area - i.e. settlements with 2 000

inhabitants or more - it can be deduced from the figures in table 1 that about 88 percent of the population in The Netherlands is living in such an urban area. Only four settlements within the municipalities, however, have more than 200 thousand inhabitants, namely Amsterdam, Rotterdam, The Hague and Utrecht - the only four big cities in the country.

## 5.2. Potentials of local and regional customers

Table 2 in Annex 2 summarises the results of the calculations with regard to the potential customers of public facilities in settlements of a various size. With respect to the figures in this table two general observations can be made. First, the presuppositions made in the theoretical model are clearly reflected in those figures. Bigger settlements are relatively attracting more potential customers than smaller ones. This applies for potential customers of both local and regional facilities. The figures for the first type of potential customers vary from 115 for the biggest settlements to 48 per 100 inhabitants for the smallest ones; for the second type from 251 potential customers to 1 potential customer per 100 inhabitants.

The second observation to be made refers to the difference in 'break-even point' between the two variants of the attraction model. The figures show that - generally speaking for local facilities this point is situated at settlements with 20 thousand inhabitants. For facilities with a wider geographical range, however, this break-even point seems to be situated at settlements with 50 thousand inhabitants. Above these break-even points the number of potential customers of settlements exceeds the number of their inhabitants. The two maps below give an insight in the geographical distribution of this phenomenon at the level of the municipalities. The municipalities belonging to the highest category in those maps can be considered as occupying a more or less central position in relation to their neighbouring areas.



## 5.3. Payments to be distributed

The payments distributed in 1997 from the Municipal Fund to the local authorities amount to more than 21 billion guilders, i.e. approximately 10.3 billion U.S. Dollar. About twelve percent of these payments - 2.6 billion guilders or 1.3 billion U.S. Dollars - is based on the criterion of the potential of customers: 1 778 million guilders for the potential of local customers and 869 million guilders for the potential of regional customers.

The figures on the potentials of customers lead to big differences in the receipts based on this criterion obtained by individual local authorities from the Municipal Fund. These receipts vary from 273 to 50 guilders per inhabitant. Remarkably, the big cities do not receive the highest amount per inhabitant with respect to this criterion. Amsterdam, for example, is ranking at the seventh, Rotterdam at the fourth and The Hague at the tenth place. It seems as if these cities - all of them located in the most urbanised part of the Netherlands: the so-called Randstad Holland - have more competitive cities in their neighbourhood than cities like Groningen (first position in the ranking), Eindhoven (second position) and Nijmegen (third position) located peripherally to the Randstad in the Northern, respectively the South-eastern and Eastern part of the country.

## **6. Future developments**

It is expected that in the near future GIS will have a still stronger impact in the compilation of statistical figures for the payments to be distributed from the Municipal Fund. On request of the Finance Department and the Department of the Interior Statistics Netherlands recently carried out a pilot project with regard to a possible replacement of an already existing method for the calculation of figures on the total residential and industrial areas at the level of the municipalities by a GIS-application. The basic input for such an application is the digital topographic map, scale 1 : 10 000. The results of this pilot have been qualified by both Departments as useful for payments to be distributed from the Municipal Fund. Meanwhile the Finance Department has commissioned Statistics Netherlands to develop and to maintain a GIS-application for this purpose.

In a later stage the GIS-system which at the moment is developed for this purpose, has probably to be extended for other applications. One of the priorities on the list of both Departments is a diversification of the total residential and industrial area by type of soil on which the respective buildings have been constructed. Building on peat, particularly on bog, for example, is more expensive for local authorities than building on sandy soil.

A stronger impact of GIS for funding purposes makes the need for standards still more important. In addition to the digital boundaries of the municipalities the digital topographic map mentioned above can be also one of such standards. It is, therefore, the policy of Statistics Netherlands in the long run to derive all kinds of area related figures from this map.

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