# Raster based GIS for Urban Management: a Low-Cost Solution for Developing Countries – Case study: Analysis of the city of Warsaw

## 1 Background

Previously to this study, the author developed a medium scale analysis and a tool with similar technical features in Glasgow, Scotland, focusing on the regeneration of the Glasgow canals (R. Schuett[1], 2007). The study in Glasgow opened the idea to increase the scale of both study area and spatial data range because it delivered fairly consistent results compared to previous studies (British Waterways Scotland and Glasgow City Council[2], 2003)

Among the strengths of the study in Glasgow are the facts that results were made available in a relatively short time and to a very low cost, given the fact that all information was either provided free of charge by the stakeholders (15%), downloaded from public institutions websites (70%) or collected or generated on site (15%).

For the present case study, there are various aspects about this site that make it opportune and interesting to develop a similar analysis in Warsaw.
Since the fall of the Berlin wall and the political transition of Poland, but especially since Poland's membership in the European Union, Warsaw is experimenting major transformations in all sectors, from district regenerations (for example in Srodmiescie and Praga Poludnie), through major infrastructure (Metro line, new bridges and motorway circuit around the city, the suburban railway EKD, the new Frédéric Chopin Airport terminal, etc) from the public sector as well as outstanding key developments by private investors (retail, business and residential estates like the Blue Tower, Warsaw Trade Tower, Metropolitan, Rondo 1B, Zlote Tarasi, fair and exhibition centres like the Millennium Plaza Centre, only to mention some).

Existing projects under study prove that Warsaw's redevelopment and modernisation is an ongoing process, ratifying Poland's capital city as one of todays economic centres in modern Europe.

## 2 Objectives of this study

Primarily, the objective of this study is testing the capabilities of the used tool (raster based GIS analysis for planning) for a large city, using a large range of attributes from multiple sources.
As suggested in the paper title, this tool is meant to be a low-cost alternative for planning wherever time and financial resources are limited, especially in developing countries. Therefore part of the main objective is to feed the database used in this tool with freely accessible data, such as the one provided by public institutions and media, provided they have reliable references and sources.

Further, the author expects to identify locations with potential for investment and development and areas that represent constraints in the urban context.

Other objectives are the interpretation of development policies and initiatives in Warsaw according to the existing potentials for investment and today's urban planning currents from the point of view of integral development and sustainability.

The applied methodology should enable to pursue these targets with objective analysis and reliable data.

## 3 Methodology

*Creating the geographic data base*

A GIS database was created with spatial information acquired from an extensive survey undertaken before March 2006 by the Warsaw Municipality (2006, Prezydent Miasta Stolecznego Warsawy[3]) which was digitised by the author. Information contained in maps in a scale 1:20 000 display current infrastructure and resources regarding topics like “functional structure”, “cultural heritage”, “natural heritage”, “land property”, “road categories configuration”, “public transportation”, etc. Other web based sources like Google Earth, Wikipedia and the official Warsaw municipal government website provided spatial and tabular data about density, built environment, political boundaries, landmarks, etc.

Both the Warsaw municipality study and the data collected from Google Earth have in common a UTM projection and the WGS84 geographical datum, so that all data can be scaled to the same coordinate system and map unit. In the case of Google Earth, data was not collected from aerial photographs but only from street maps.

All data was digitised with AutoCad using either raster images laid under or by means of exporting selection paths of colour ranges from a graphic processing software into Adobe Illustrator before being it inserted into AutoCAD. Using the latter method, considerable time can be gained when digitising the images but accuracy is lost. Depending on the purpose and size of dataset or data object, this trade off can be either less than beneficial or irrelevant and this has to be considered.

*Creating a raster of cells*

In addition to the data, a raster of cells was created, covering the entire municipal area of Warsaw. Each cell represents 1 Ha and 52184 were necessary.

After the data and the cells raster were transferred into the GIS software environment, it was distributed into representative datasets. The total number of datasets was around 53 (see table No 1). The datasets were then interpreted as attributes for a better understanding of their meaning in the urban planning context.

Table 1
List of attributes

| Name | Type of representation | Weighting factors Mix (1) | Pub (2) | Envir (3) |
|---|---|---|---|---|
| areas with commercial function | polygons | 4 | -2 | -1 |
| areas with administrative, scientifical, health or cultural function | polygons | 2 | 5 | 2 |
| green areas (amenity space) | polygons | -4 | -2 | 4 |
| areas with industrial use | polygons | -4 | -3 | -4 |
| areas with agricultural use | polygons | -4 | -3 | -2 |
| derelict area | polygons | 5 | 4 | -1 |
| residential areas (tenemental style) | polygons | 3 | 2 | -3 |
| residential areas (semi detached style) | polygons | 2 | 1 | -2 |
| residential areas (detached with own garden) | polygons | -3 | -3 | -1 |
| allotment areas | polygons | -3 | -3 | 3 |
| green areas (sports and recreation) | polygons | -3 | -3 | 3 |
| green areas (planned forest) | polygons | -3 | -3 | 3 |

| | | | | |
|---|---|---|---|---|
| green areas (natural forest) | polygons | -4 | -4 | 5 |
| cemetery | polygons | -3 | -2 | 3 |
| water (rivers, lagoons, lakes, ponds) | polygons | 3 | 2 | 4 |
| utilities infrastructure | polygons | -3 | 1 | -2 |
| transportation infrastructure/ facilities | polygons | -3 | 1 | -3 |
| City boundary | polygons | 1 | 2 | -1 |
| Borough boundaries | polygons | 0 | 0 | 0 |
| Unesco World Heritage Site area | polygons | 2 | 3 | -1 |
| Other registered heritage sites outside | polygons | 2 | 3 | -1 |
| Sites under consideration for protection | polygons | 2 | 4 | -1 |
| Buffer zones to heritage sites | polygons | 3 | 4 | 0 |
| Skarpa Warszawska ("Slope of Warsaw" along Wisla River) | polygons | -2 | -2 | 2 |
| Area of airport noise pollution (high) | polygons | -3 | -2 | -3 |
| Area of airport noise pollution (medium) | polygons | -2 | -1 | -2 |
| Area of landfill | polygons | -5 | -5 | -5 |
| Buffer area around landfill | polygons | -3 | -3 | -3 |
| Area of activity with major environmental impact | polygons, points | -5 | -5 | -5 |
| Fresh water reservoir | polygons | -5 | -5 | 5 |
| Areas on state ownership | polygons | -3 | 5 | -1 |
| Areas on municipal ownership | polygons | -3 | 5 | -1 |
| Areas on state ownership, for sale | polygons | 3 | -3 | -1 |
| Areas on municipal ownership, for sale | polygons | 3 | -3 | -1 |
| Areas transferred to army institutions | polygons | -3 | 3 | -1 |
| Private property | polygons | 4 | -3 | -2 |
| Highway | lines | 1 | 2 | -2 |
| National Road | lines | 4 | 3 | -2 |
| Municipal Road | lines | 4 | 3 | -1 |
| Internal Road (speed restriction) | lines | -2 | 1 | -1 |
| Landmarks (representative infrastructure) | polygons, points | 4 | 3 | -2 |
| Future landmarks (memorial, castles in project) | polygons | 4 | 3 | -2 |
| Public transportation nodes (stations) | points | 4 | 4 | 2 |
| Major shopping precints | polygons, points | 4 | 1 | -2 |
| Traffic key locations (bridges over Wisla) | points | 4 | 0 | -2 |
| Parking houses in city centre | points | 4 | 3 | -2 |
| Restricted parking zone (city centre core) | polygons | -2 | -2 | 3 |
| Restricted parking zone (city centre) | polygons | -1 | -1 | 2 |
| Tram routes | lines | 3 | 4 | 3 |
| Metro stations | points | 4 | 4 | 3 |
| Metro stations in construction | points | 4 | 4 | 1 |
| Train stations | points | 3 | 4 | 3 |
| City morphology (built density) | polygons | 3 | 0 | -3 |

Basically, the cells are used to segregate the study area into small units, which can be assessed independently in relationship to the attributes and their implications for planning.

This is a relatively quick process when using the GIS tools. It consists in assigning a compliance value to each of the cells, according to their location in the study area, in relationship to the attributes. That means, each cell received 53 compliance values (the total number of data sets or attributes).

A compliance value can be between 0 (not applicable to the attribute) and 1 (fully applicable). Intermediate values between 0 and 1 were applied in case of partial compliance with an attribute, for example to cells within buffer zones, areas of impact or areas of influence. For example: a train station is considered to serve users in a radius of 500m distance. In this case, the dataset “train station” will imply that all cells within a radius of 500m distance were assigned the value 1 under the attribute “train station existing within 500m”. However, cells located within a radius of 800m outside the radius of 500m were assigned the value 0.5 and cells located within a radius of 1000m but outside the radius of 800m were assigned the value 0.1. All other cells in the study area outside a radius of 1000m from a train station do not comply with this attribute and therefore were assigned the value ‘0’.

The same operation was undertaken 53 times for each one of the 52184 cells, that means more than 2.76 million operations.

*Defining analysis focuses for this case study*

The raster based system developed in this case study can be applied for a large number of analyses. It may be applied for example for environmental impact analyses, analyses of potential sites for the development of a certain infrastructure, suitability analyses for investment in a certain location, etc.

In this case study the author wants to focus on (1) identifying potential sites for development of mixed areas (combined residential, retail and business developments) and (2) potential sites for public infrastructure development (buildings for cultural or administrative use). As well, the author wants to (3) identify areas with “environmental stress” as suggested by the collected data.

*Assigning weighting factors*

Once the focuses of analysis were defined, the author created a matrix of weighting factors for each attribute and each focus of analysis (See table No 1, right columns ‘weighting factors’).

The intention is to qualify each attribute for or against a particular investment choice (mixed or public development) or its environmental impact (positively or negatively). It brings also the possibility to assign a weighting factor ‘0’ to take out from consideration irrelevant attributes.

The factors chosen have a range between -5 (very disadvantageous/ most negative impact) and +5 (very advantageous/ best contribution), and 0 is chosen for not relevant attributes. The compliance values of each cell were multiplied by the chosen weighting factors in each of the three analysis intentions.

The products of all “qualified” compliance values were added up into a final “balance” for each cell in each analysis. These “balance” values would be within a range between a minimum absolute value (for the cell representing the worst conditions) and a maximum absolute value (for the cell representing the best conditions). Minima and Maxima would then be translated respectively into 0 and 100, in order to obtain a standard rating of relative values (see formulae)

Weighting factors are flexible and the author chose them in most cases according to his experience and personal perception. When assigning weighting factors, an integral scope is required and multidisciplinary discussion is required. The author believes that this is a strength in the system. It implies as well that when applying this system in a professional environment, all interested parties have a say and decisions are made in a bottom up approach and integrated fashion.

The GIS tool used permits to display the calculated value ranges translated into colour ranges for easier understanding.

Formulae used

(1) $\text{cell}_n$ $\text{value}_{abs}$ (analysis α) = $\Sigma_1^{53}$[Compliance Attr. $\text{Cell}_n$ x weighting factor Analysis Type α]

(2) $\text{cell}_n$ $\text{Value}_{rel}$ = 100 {cell value abs - Min [cell value abs]} /(Max [cell value abs ] – Min [cell value abs ])

Example of calculation, Analysis “α” for Cell ‘n’:

Attr. 1 [cell compliance (0 … 1) x weighting $\text{factor}_1$ (-5 … 5)] +
Attr. 2 [cell compliance (0 … 1) x weighting $\text{factor}_2$ (-5 … 5)] +
…
Attr. 53 [cell compliance (0 … 1) x weighting $\text{factor}_{53}$ (-5 … 5)]
= absolute Cell value for Analysis “α”

figures obtained from sums (example):

Min Max
- 4.5 ………………… +7.0
| |
0% …………………..100%

## 4 Analysis of the model results

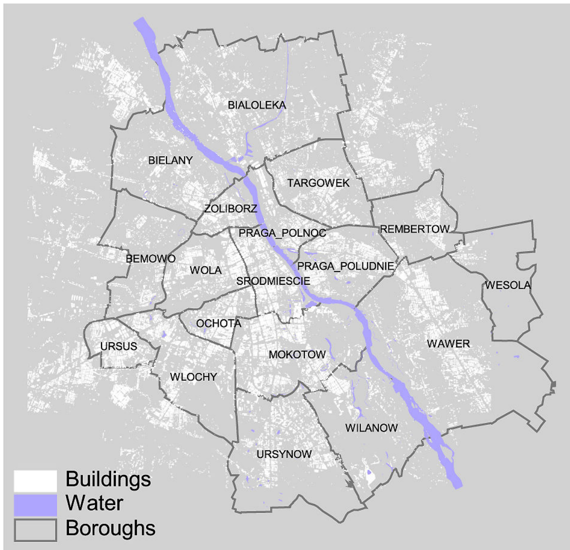


**Fig 1** *City of Warsaw and its boroughs*

Accepting as true that the model shows realistic results, due to the large number of representative and reliable data considered, two assumptions arise as a first impression. First of all, the areas considered by the city council as valuable for investment[4] are confirmed by the model, which at the same time shows widespread opportunities in all Warsaw boroughs. Secondly, the model also shows that the vast urban area contains abundant land with a low profile for investment. These areas are mostly outside the city centre, mainly in boroughs with low density like Targowek, Wilanow, Ursynow, Wlochy (see Fig. 1).

*Opportunities for mixed development*

Not surprisingly, the figure (Fig. 2.1) showing areas with opportunities for mixed development does underline the existence of prime areas in the city centre (Srodomescie), mainly along the most important streets around the Palace of Culture at Defilad Square, Central Station, etc. but it also shows important areas on the eastern side of the River Wisla in the borough Praga Poludnie, which contains a large number of industrial brown fields. As well there is a remarkable concentration of cells with high values in the northern borough of Bialoleka, which is currently mainly underused farmland and a fairly large concentration of cells with high value in the area of Ursus, which contains at the moment mostly residential areas with medium density.

*Opportunities for public development*

The model (Fig 2.2) confirms that the city is still very centralised, because mostly the central boroughs appear to fulfil the framework conditions for successful development of public infrastructure. Exceptions to this seem to be the boroughs of Ursynow, which is served by the Warsaw metro and the southern part of Bielany, which will be connected to the metro network in the near future. In the case of Bielany, there is as well a strong contrast between the mainly residential southern part and the industrial north, which is clearly pointed out by the model results.

The boroughs of Wawer and Wilanow however are clearly underrepresented. Main reasons may be their scarce road communication to the rest of the city and low population density.

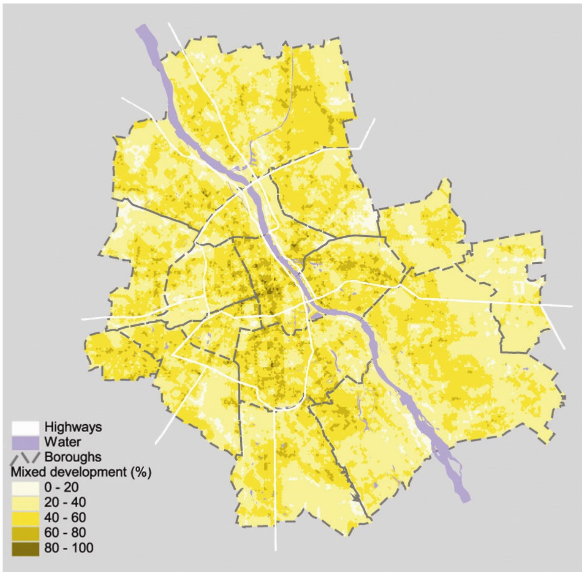


Fig 2.1

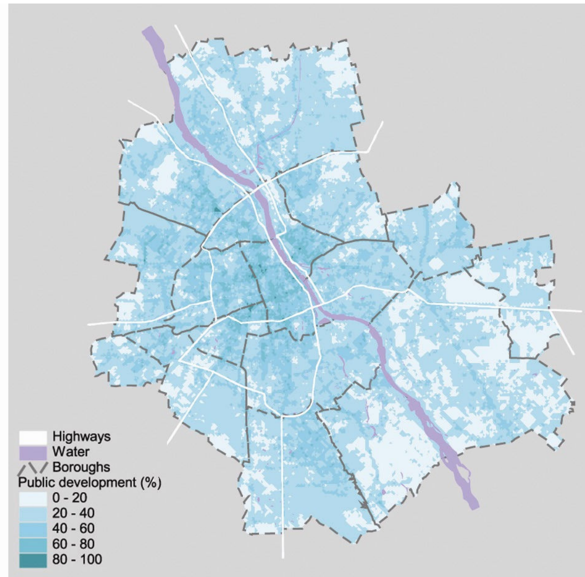


Fig 2.2

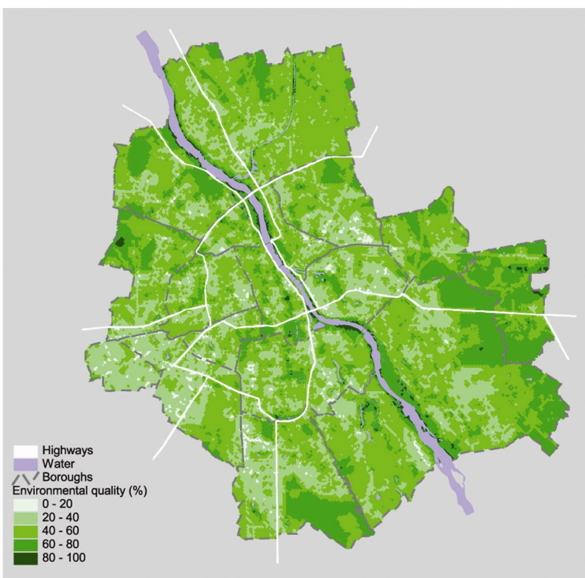


Fig 2.3

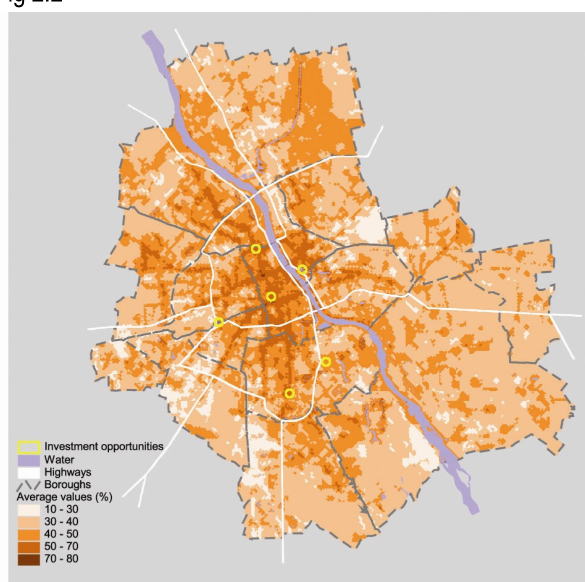


Fig 2.4

**Fig 2** *Model results (2.1) Analysis of mixed development opportunities, (2.2) Opportunities for public infrastructure, (2.3) Analysis of environmental quality and (2.4) Average values*

*Environmental quality*

This model (Fig 2.3) shows a twofold in the existing environmental conditions of Warsaw. There are on the one hand extensive areas at low risk. These are mainly areas with less built density and areas that are already protected, for example in the districts of Wawer and Wesola, which contain important forests and fresh water sources. The river Wisla would also count to this category, excepting in the vicinity of the city centre and of a landfill area south of Wilanow. On the other hand, there are throughout the city many "green" spots with environmental importance but which are disconnected from each other. This suggests the opportunity to create wildlife corridors for fauna, as well as networks of amenity space for pedestrians, cyclists, etc, which should be analysed closer.

*Average values and currently promoted areas*

The model showing average values (Fig. 2.4) is representative for the other 3 estimations. The image shows as well the location of six potential locations identified by the Warsaw city council. These are confirmed by the model. The model as well confirms that some areas mainly in the south of Warsaw lack of appropriate framework conditions for investment. These areas are mainly in Wilanow, Ursynow, Wlochy and Ursus.

## 5 Conclusions and recommendations

It is certainly interesting to identify in some cases or confirm in other cases that certain areas in Warsaw will undoubtedly face major transformations in future years, because of their positive conditions. A recent survey by the economy consultants Ernst & Young confirms that Poland is one of the most preferred countries for foreign investment, only after China, India, Russia, and USA[5]. However, it is perhaps more important to identify the areas in significant locations that do not qualify among the upper values and find out which conditions should be improved. An example is the model displaying environmental quality. The identified critical locations intersect with existing areas in which people live or work. A closer analysis would also identify schools, hospitals, nurseries and similar facilities in these areas, suggesting to verify their environmental conditions.

With a land-use layout influenced by Poland’s communistic town-planning times, Warsaw contains more than 30% of industrial brown-fields inside its city centre boundaries. This is a great potential and an advantage for planning, which should be considered carefully in this times of abundant investment from abroad. However, it can be as well clever to assess with an approach like the one presented here, where to support transformations and where to rather slow them down. Space in a big city gives flexibility now and in the future, and a city will always need to adapt to future changes of the dynamic economy of modern times.

It is also important to make sure that any transformations are included in the geographical database, because they will influence the “real-time” conditions. Also the weighting factors change for users of different disciplines and generations, also depending on the time and economical conjuncture.

In the previous experience in Glasgow, the author had access to a proposed master plan developed by an architecture office in cooperation with the stakeholders. Using this master plan as a scenario, the values were calculated again and an impact could be measured in comparison to the real conditions. When calculating the difference of the cells’ values, it could also be foreseen if and in which extend the conditions would be improved or worsen with the chosen scenario. The same exercise could be done in Warsaw’s model if a master plan were available.

The system could also be used for more detailed observations, monitoring of changes, querying of the perception of users about their space and community participation as a basis for discussion.

Last but not least, it is important to remember that, as any alternative technology, this model offers a different manner to observe the urban landscape and its results should not be understood as definitive, but only as a suggestion. Interdisciplinary discussion as a tool and our ideas as a software should always be the first option when taking any decision.

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**References and Endnotes**

[1] Schuett, Rolf (2007) GIS based planning support system in Glasgow. Case study: The Glasgow Canals regeneration. In: CUPUM 07 : proceedings of the 10th international conference on computers in urban planning and urban management, 11-13 July, 2007 Iguasso Falls, Brazil. ISBN 978-85-85205-77-5

[2] Glasgow City Council and British Waterways Scotland (2003) The Glasgow Canals Regeneration Framework, published PDF report - http://www.glasgowcanal.co.uk/vision/

[3] Warsaw City Council (2006) Studium Uwarunkowan i Kierunkow Zagospodarowania Przestrennego Miasta Stolcznego Warszawy, Warsaw.

[4] Official Website of Warsaw, http://e-warsaw.pl/2/index.php?id=583 – Sections ‘property market’ and ‘Construction opportunities’ Visited 05.06.2008

[5] Kreiler, Korina (2008), “Standort-Ranking, Der Glanz des Westens verblasst”, Der Spiegel Online, published 05.06.2008 http://www.spiegel.de/wirtschaft/0,1518,557939,00.html