

# The use of anamorphic images in the development of transit maps

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## 1. Introduction

### *1.1. The scope of contents of an urban transportation network map*

An urban transportation network map is designed to illustrate the user information about availability of modes of transport – types of communication lines and their distribution – on a specific area. The map should be designed in such a way that passenger (user) is able to identify its location and select appropriate route to the chosen destination.

The main element of the map is the connections network of all types of modes of transport (e.g. buses, trams and trains). A map designer should also mark locations of stops and add necessary descriptions. The network is usually presented as polylines in different colours depending on types of modes of transport (bus and tram routes); moreover railroads and underground routes can be additionally specify by different pattern. If in the city there are a few kinds of specific mode of transport (e.g. express bus, night bus), they can be extra distinguished using different colours. (Cain, 2008). This increases the functionality and legibility of the map as regards presentation of individual communication lines, especially in the case of large metropolitan areas.

Because of the fact that the audience of an urban transportation network map in addition to citizens are also tourists, the map should present orienting elements, such as rivers, monuments or hotels. Using these, a visitor would be able to locate its position faster and easier, and use the map in a wider range, setting routes to points of interest. In addition, in the case of big cities and due large number of tourists, it is very important to provide information in different languages. More and more visitors come from abroad and therefore it is worth to allow them exploring foreign (for them) city in easier way.

## ***1.2. Anamorphic maps***

Development of transit maps for large metropolitan areas encounter difficulties related to the limited capacity of maps, especially those which are produced in analog version. For this reason, the maps often do not establish constant scale. Increasing it lead to automatic increase of an area on the map to present interesting objects or stops' names (Avelar, 2002). The most important thing is to preserve of the topology in network distribution and associated point objects. Because of a large number of communication lines, designers often develop a few maps – e.g. tram network scheme, bus network map and night transport system diagram. The adverse effect of this is the difficulty in planning the trip for passengers, because they have to use several maps.

One way to solve the problem with limited capacity of a transit map is, presented in this paper, proposal of Authors to apply anamorphosis. It is a geometric transformation of map's grid and content, using defined parameters, in such a way that elements presented on the map could be more visible (Šimbera, 2011). In other words, it is a procedure of increasing the scale of the map in areas of high density of selected objects and decrease it where these elements have a low density or are absent. This allows to visualize the content which can be invisible on a conventional base map (Gregory et al., 2009).

Two main groups of anamorphic maps are distinguished: cartographic models in which an area or distance is a transformation function argument (cartograms) and, analyzed in this paper, variable-scale maps (Krzywicka-Blum and Michalski, 2009).

## ***1.3. Area of study and objective***

The study has been conducted on the example of Wrocław which is the capital of Lower Silesian Voivodeship in Poland. Three modes of transport are present in this city: buses, trams and rail.

The main objective of the study is to present possibilities of producing transit maps in CAD software on previously generated anamorphic images. Authors have tested different tools to develop variable-scale models. Eight of them have been produced and analyzed in terms of usability in the development of Wrocław's transportation network map. In this paper, two approaches of making an anamorphic image has been depicted: transformation of a raster file and a vector file.

## 2. Development of an anamorphic image

### 2.1. Anamorphic images in the raster form

The best-known method of execution an anamorphic image based on a raster file is fisheye transformation. The use of this approach makes a defined area enlarged in such a way that the scale in the focal point is the largest and it is successively smaller in the remainder of the image (Sarkar and Brown, 1994).

Nowadays, many image editing applications offer a fisheye transformation module. This paper shows operations that have been carried out using the function “Sphere” in CorelDraw X6 to show opportunities it gives. By applying “Sphere”, the image is wrapped around a sphere. An user can set a focal point (a central point) and control the process with a defining distortion level (from  $-100\%$  to  $100\%$ ). The image is wrapped outside of a sphere when positive values are set or inside of it when they are less than  $0\%$  (Corel Corporation, 2014).

In this study, transformation was applied to the Wrocław city map (Fig. 1.) which contains: streets (black dotted lines), rivers (blue lines), tram tracks (red lines) and railroads (black solid lines) with a pole (marked with letter A) located on the corner of Oławska street and Świdnicka street (Fig. 2.). The distortion level has been chosen arbitrarily, so that the scale in the city center has been enlarged enough to make this area more visible.



Fig. 1. The map of the city of Wrocław – source raster file



Fig. 2. Anamorphic raster image with one focal point

On a transformed map, objects in the city center are much more visible. However, deformations on edges of the image are so large that they cannot be accepted. Therefore, the second attempt was executed in order to make a fisheye transformation on the previously generated anamorphic image. A second focal point (marked with letter B) was taken at the central point of Powstańców Śląskich Roundabout because it is an area of equally large density of communication lines as in the city center (Fig. 3.).

In Authors' opinion, the effect of those transformations is not satisfactory. Distortions of edges of generated image are too large and it cannot be used as a base to draw a public transport network map on it. Moreover, these procedures do not take into consideration all places in the city with high density of communication lines (e.g. Psie Pole district). Therefore, produced image would not be useful to draw Wrocław's transportation network map.

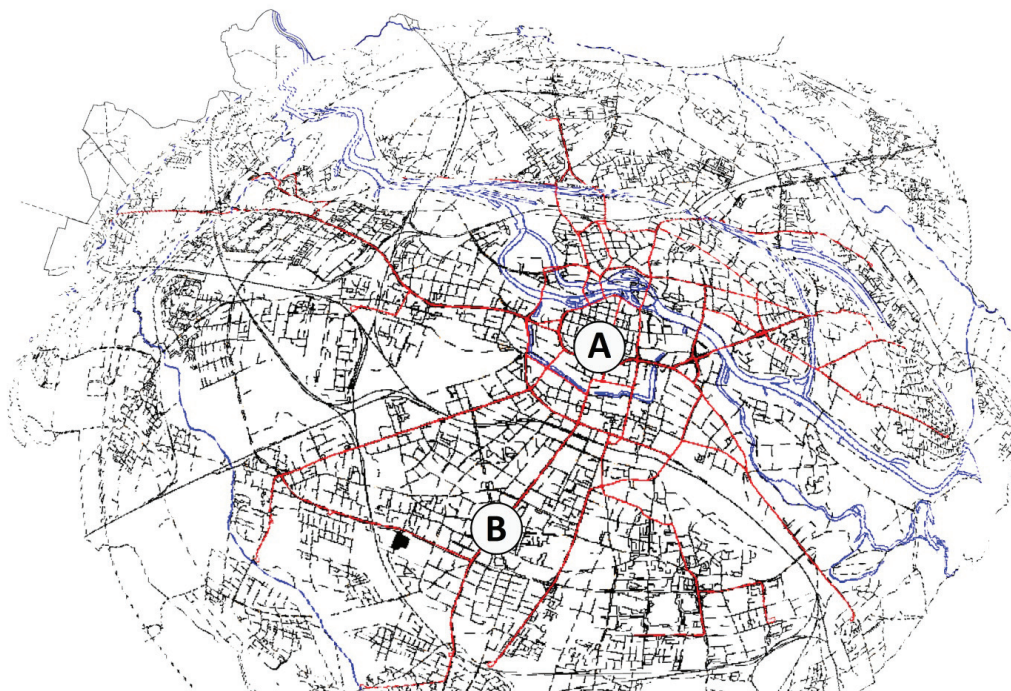


Fig. 3. Anamorphic raster image with two focal points

## 2.2. Anamorphic images in the vector form

Vector files transformations are more complicated than operations with raster files. First of all, to make a variable-scale image appropriate software is needed. In this paper, works were carried out in ArcMap 10 and application MultiFocal Anamorfosis written by Michalski and Tymków (Michalski and Tymków, 2011). They proposed a method which consists of placing regular focal points based on significant points (objects relevant to the purpose of the map) and generated grid. In each square there is counted number of selected point objects and, based on it, calculated their barycenter (focal point). The algorithm also takes into account the range of the impact of each pole which is moderated by the number of selected elements in each field of the grid. A value of displacement of each point relative to each focal point is expressed by the formula (Michalski and Tymków, 2011):

$$r = R + (A \cdot R) \cdot (1 + C \cdot \mu \cdot R^2)^{-1}$$

where:

$$A = \arctan(n)$$

$C = 0$  – if there are no significant objects in a field of the grid

$C = (\arctan(0,5 \cdot n))^{-1}$  – if there are some significant objects in a field of the grid  
and:

$n$  – the number of significant objects in a field of the grid

$R$  – a distance from a point to a barycenter of a field of the grid on a base map

$A$  – a parameter which has influence on the size of distortion;

$C$  – a parameter which has influence on the range of distortion;

$\mu$  – a scale parameter which was chosen arbitrarily by Michalski and Tymków

The original vector image (file format \*.shp) is shown in Fig. 4. It presents the distribution of tram and bus stops (marked with dark dots) within the city boundaries (red lines).



Fig. 4. Distribution of bus and tram stops in Wrocław

The expected result of a modification should be similar to a base map as much as it is possible with simultaneous good visibility of all significant objects.

Taking into account the objective of study, in the first attempt variable-scale images have been made taking bus and tram stops as an transformation function argument. Different sizes of grids have been selected, respectively with sides equal

2000 m, 1500 m and 1000 m (Fig. 5.). Red lines present city boundaries and dark dots – tram and bus stops. Grids are marked with a blue colour.

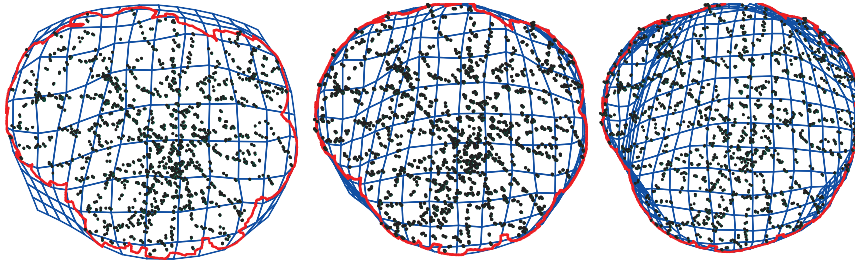


Fig. 5. Anamorphic vector images with tram and bus stops as a transformation function argument

Fig. 5 presents the effect of selection different sizes of a field of the grid on distortion size (the smaller square, the greater distortion of the image). Based on visual analysis of generated maps, it can be said that a large number of objects (1649) caused significant deformation of the image. The resultant anamorphic maps cannot be used for further studies.

The second attempt to make an anamorphic map in MultiFocal Anamorfosis it was transformation based on points of interest which Authors would like to place on the final transit map. Those are: hospitals, sports facilities, hotels, shopping centers, police stations, museums, tourist information points, churches and other tourist facilities (Fig. 6.). To reduce the size of distortion during generating of an anamorphic image, a side of the field of the grid equal 2000 m was chosen (Fig. 7.).

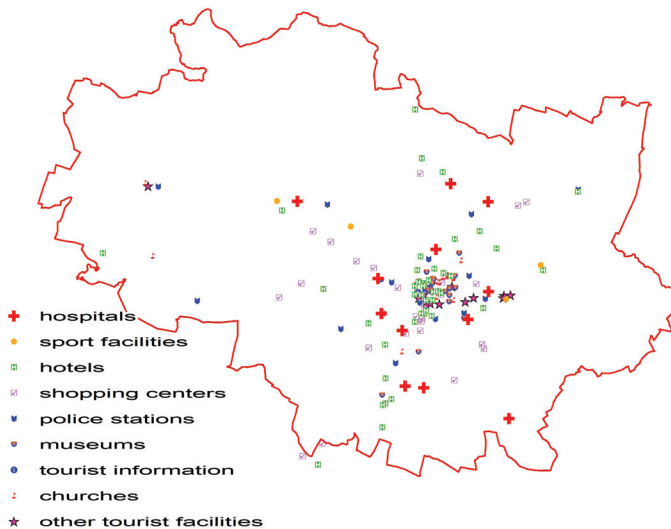


Fig 6. Points of interest in Wrocław

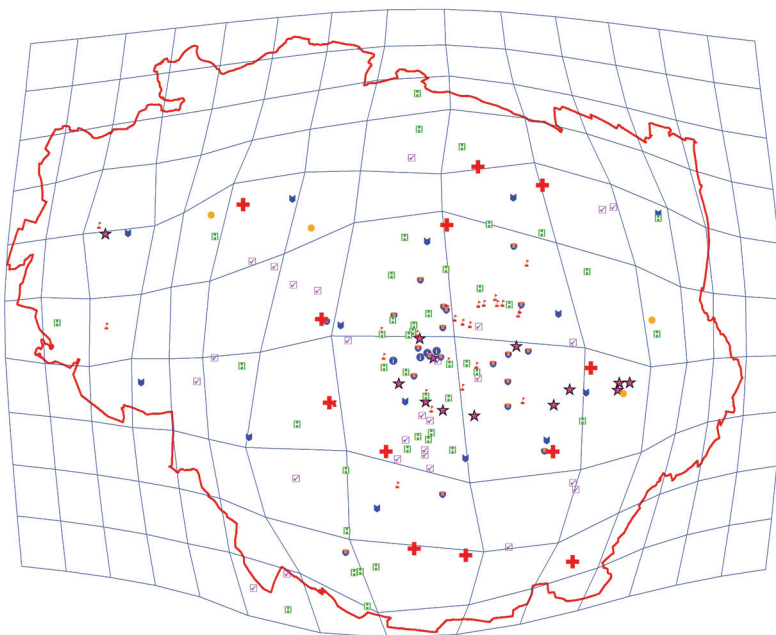


Fig. 7. Anamorphic image with points of interest as a transformation function argument

The result is much better anamorphosis than in the case of transformation based on bus and tram stops, due to the much smaller number of objects.

Another tested option was to generate a variable-scale image where junctions of communication lines (marked with red dots on Fig. 8.) were a transformation function argument. To transform the map, it was also chosen a grid with a side of each field equal 2000 m. The result (Fig. 8.) is very similar to the previously generated anamorphosis (Fig. 7.). For this reason, it can be concluded that points of interest are in areas where many communication lines cross.

The final urban transport network map should present elements relating to communication and orienting elements. Therefore, it was proposed another transformation in which it was taken into account junctions of communication lines as well as selected points of interest (Fig. 9.). Thanks to this it was achieved as a result a variable-scale map on which scale was enlarged where a high density of communication lines and important objects for citizens and visitors are present. By applying a grid with a side of each square equal 2 km, the influence of distortion was limited. Therefore, the map is distorted in such a way that it is clearly similar to the source image. For this reason, it was decided that this anamorphic image can be a base map to draw Wrocław's transportation network map.



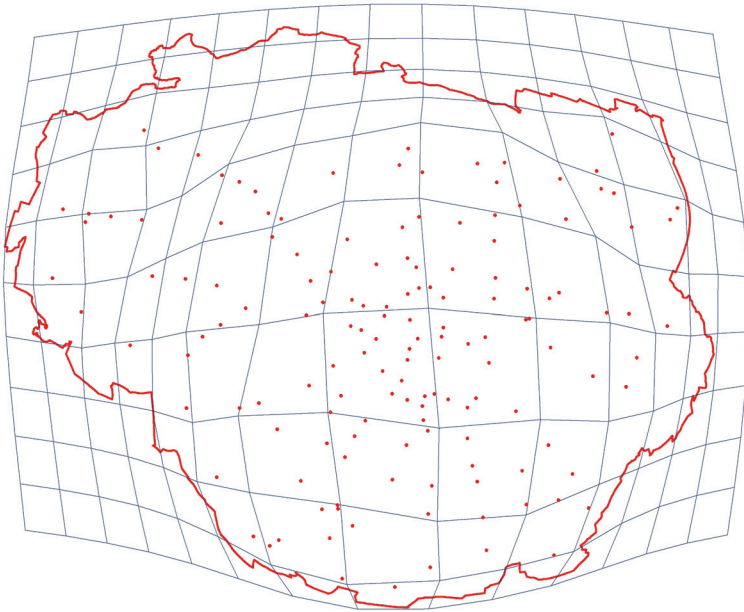


Fig. 8. Anamorphic image with junctions of communication lines as a transformation function argument

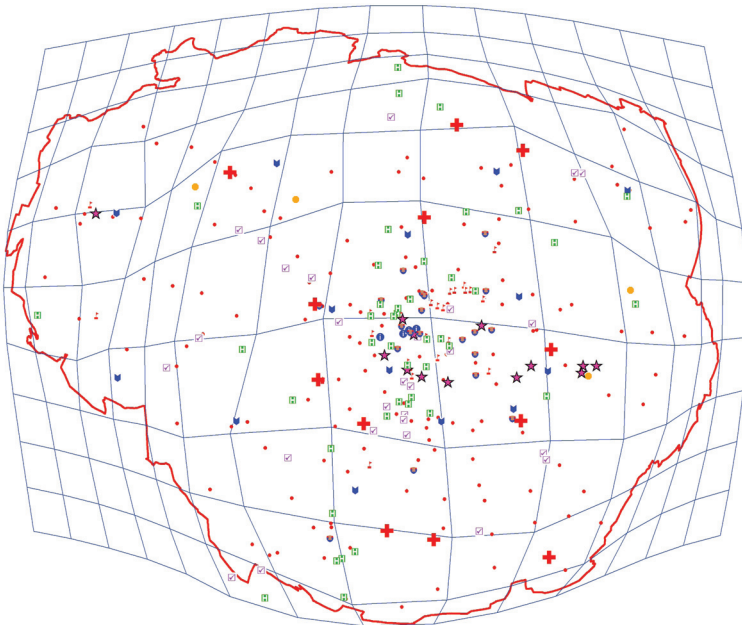


Fig. 9. Anamorphic image with points of interest and junctions of communication lines as a transformation function argument

### 3. The use of generated anamorphic image

The next stage of the study it was exporting all vector data from ArcMap 10 to MicroStation PowerDraft V8i in which further works were carried out.

The first thing while drawing urban transportation network maps is to simplify communication lines (e.g. to polylines) and then move them relative to their original position and add appropriate symbols (Avelar and Hurni, 2006). These schematic maps are characterized by a very high legibility – communication lines are presented using straight sections which change directions and intersect at fixed angles (Cain, 2008). Due to the fact that Wrocław's public transport network is very complex, it was decided to take an angle of courses of communication lines as a multiple of an angle equal 15°. Appearance and sizes of all elements constituting the content of the map – communication lines, stops (with marking “request stops”), orienting elements and any descriptions – were chosen arbitrarily. Every kind of modes of transportation was marked with a different colour (blue – trams; red – normal buses; green – express buses; grey – night buses). Furthermore, it was selected a lot of objects to put them on the map. Therefore, they were described with numbers and the list of them was presented on the reverse of the sheet. Cain proposes to additionally mark which communication lines passenger can reach each facility with – and that was realized in this study (Fig. 10.).

## Lista obiektów

list of facilities / Liste der Objekte

### Kościoły

churches / Kirchen

-  **Archikatedra św. Jana Chrzciciela**  
cathedral / Dom | Plac Katedralny | U10  

-  **Bazylika św. Elżbiety Węgierskiej**  
ul. Św. Mikołaja | S11  

-  **Cerkiew Św. Cyryla i Metodego**  
ul. Św. Jadwigi | T10  


### Muzea

museums / Museen

-  **Arsenał Miejski: Archiwum Budowlane Miasta Wrocławia,  
Muzeum Archeologiczne, Muzeum Militariów**  
ul. Cieszyńskiego 9<sup>o</sup> | E4, S10  

-  **Dom Edyty Stein**  
ul. Nowowiejska 38 | F3  

-  **Muzeum Akademii Sztuk Pięknych**  
ul. Traugutta 19/21 | F4  


### Hotel

hotels / Hotels






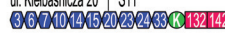
-  **AKIRA Bed & Breakfast**  
Pl. Szrelecki 30 | E3  

-  **Ami Hotel**  
ul. Rychalska 8 | F3  

-  **Art Hotel**  
ul. Kiebaśnicza 20 | S11  


Fig. 10. List of facilities shown on the reverse of the sheet

During the development of the map, it turned out that, in spite of anamorphic transformation, there is too many objects in the city center to present them all. For this reason, this area was marked with yellow colour and presented in a separated frame on the reverse of the sheet (Fig. 11.).

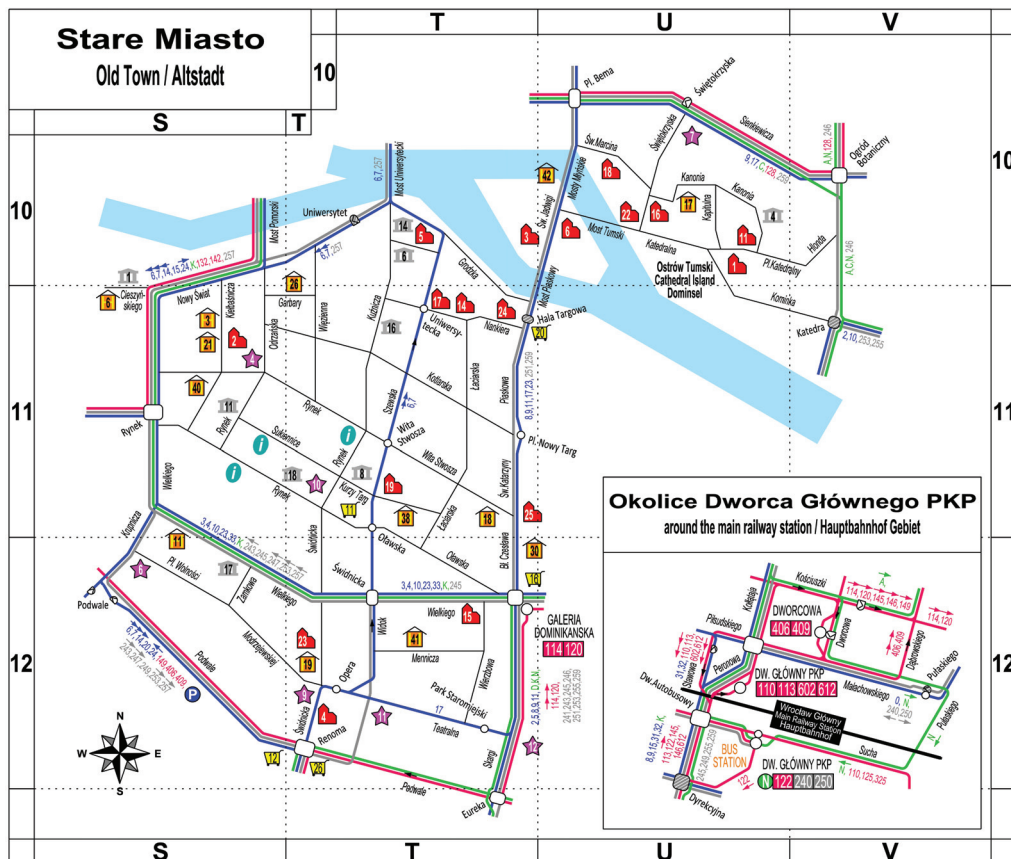


Fig. 11. A fragment of the transit map – city center shown in a separated frame

Nowadays, a distance between two points on a transit map is measured using the number of stops rather than number of kilometers (Guo, 2010) and sometimes it is a better solution. Nevertheless, the sheet presents the distribution of the scale (Fig. 12.). Thus, a user would have general concept how to perceive the distance in various parts of the map and not to treat it as a constant scale map.

Note - the map is not drawn to a fixed scale  
 Anmerkung - diese Karte hat keinen festen Maßstab

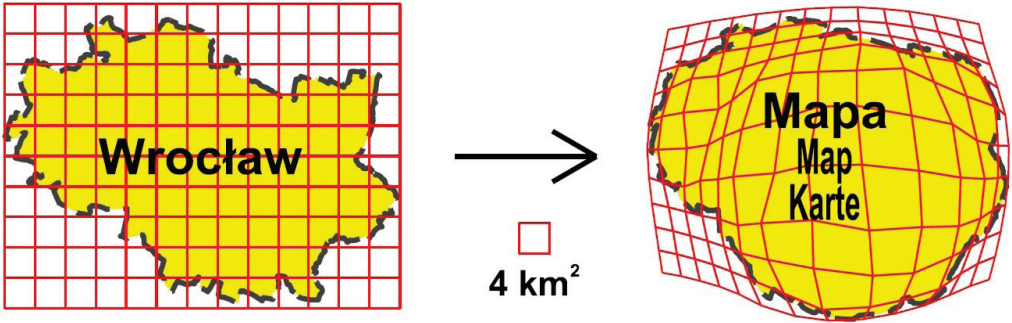


Fig 12. Information about distribution of the scale

Not all chosen facilities are located near streets which constitute also routes of communication lines. Therefore, in addition it was drawn the course of some streets to allow the user determine how to reach a point of interest. A fragment of final urban transport network map is shown in Fig. 13.

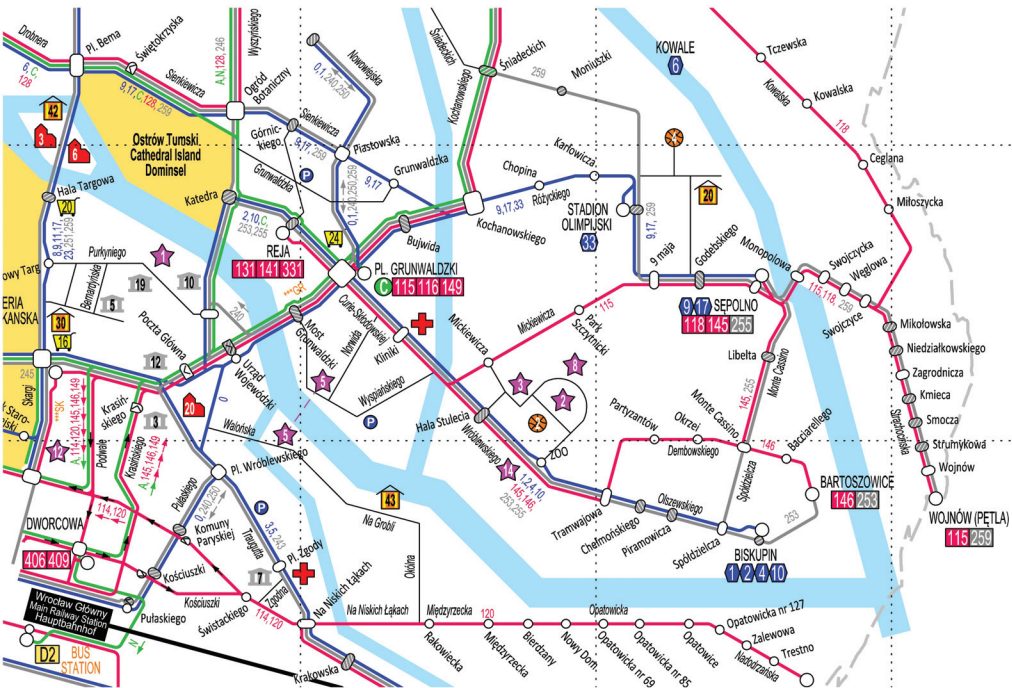


Fig. 13. A fragment of the transit map developed on an anamorphic image

## 4. Conclusion

The choice of the method to generate a variable-scale image to develop a transit map depends on the size of metropolitan area and density of a public transportation network.

The transformation of a raster file is characterized by large deformations on edges of the image. Furthermore, designer should make a subjective choice of just one focal point and optionally repeat the process on the sequentially generated images. On the other hand, raster operations are an alternative for those users who do not have the possibility of using the programs carrying out different GIS analysis and generating professional anamorphic maps.

Making variable-scale vector images gives significantly better results. This process has a high computational complexity (depending on the number of objects). However, it is compensated by the quality of a resulting product. By applying appropriate algorithms, a scale of the map is enlarged where it is necessary (in areas with high density of interesting objects). By selecting the size of a field of a grid, designer is able to determine the satisfactory size of distortion.

Transformations of shape files make the possibility to carry out further works in subject investigated in this paper. By obtaining an image in a vector form, it will be possible to make an attempt to write an algorithm which would automate the process of generalization courses of communication lines and streets, and eliminating unnecessary information from the map. Such an application would allow to develop an urban transportation network map much faster, particularly in cities with the size of Wrocław.

The study showed the practical application of variable-scale images. The result, which in this case is a transit map, has an utilitarian feature which motivates Authors to do further studies on this topic. Other solutions might be considered, e.g. algorithm based on fisheye views of vector images described by Haurert and Sering (2011), or new ones developed.

## Acknowledgments

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