

# **GEODETTIC CONDITIONS OF WARSAW UNDERGROUND EXTENSION**

**Marek Woźniak, Cezary Budrewicz\***  
**Institute of Applied Geodesy, Warsaw University of Technology**  
**\*Warsaw Underground**

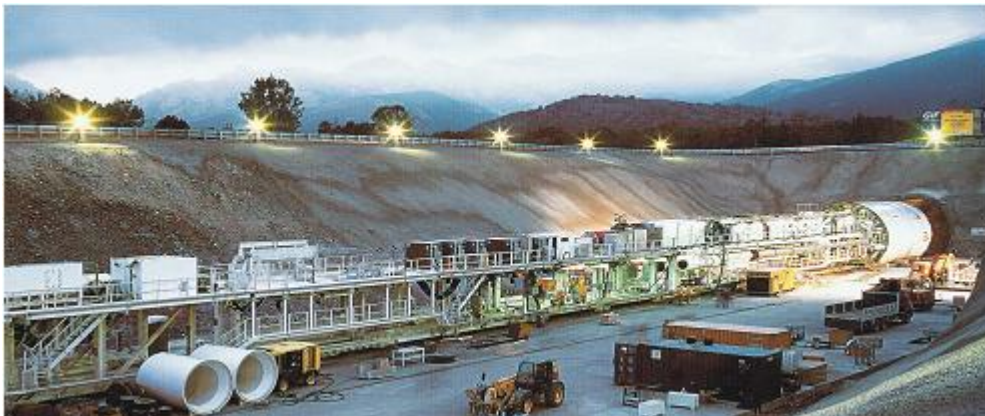
## **ABSTRACT**

The construction of an underground railway system is a very demanding building investment. It requires great concentration of a building potential over an exceptionally vast area. On the one hand, the building site covers a vast densely built-up urban area and on the other, a tunnel is actually excavated over a small space covered by its “front” and interior. The above conditions are extraordinary both because of the technical difficulties of the works to be carried out and high precision required by individual construction elements. Another problem is the disturbance of geotechnical stability of the ground and the ensuing dangers posed for the adjacent buildings.

The paper presents all basic elements of geodetic activities connected with the underground construction, from the designing stage up to construction works.

## **1. INTRODUCTION**

The extension of the existing underground railway system in Warsaw will be carried out in a completely new fashion. It concerns not only the new tunneling and station building technology but also special conditions of the urban project. The TBM system is going to be used to excavate new tunnels. It is supposed to speed up the underground construction considerably. It is planned to excavate a 20-30 m tunnel a day.



**Fig. 1. Construction of a shield of the TBM system.**

## 2. CONDITIONS OF NEW UNDERGROUND LINES CONSTRUCTION

New underground lines will be built in entirely different conditions from now on:

- crossing the River Vistula with a high embankment and its buildings, a water-course,
- building a new underground line in a built-up area, inevitably under the existing buildings, characterized by their poor construction,
- construction linking the existing underground line and other urban arteries.

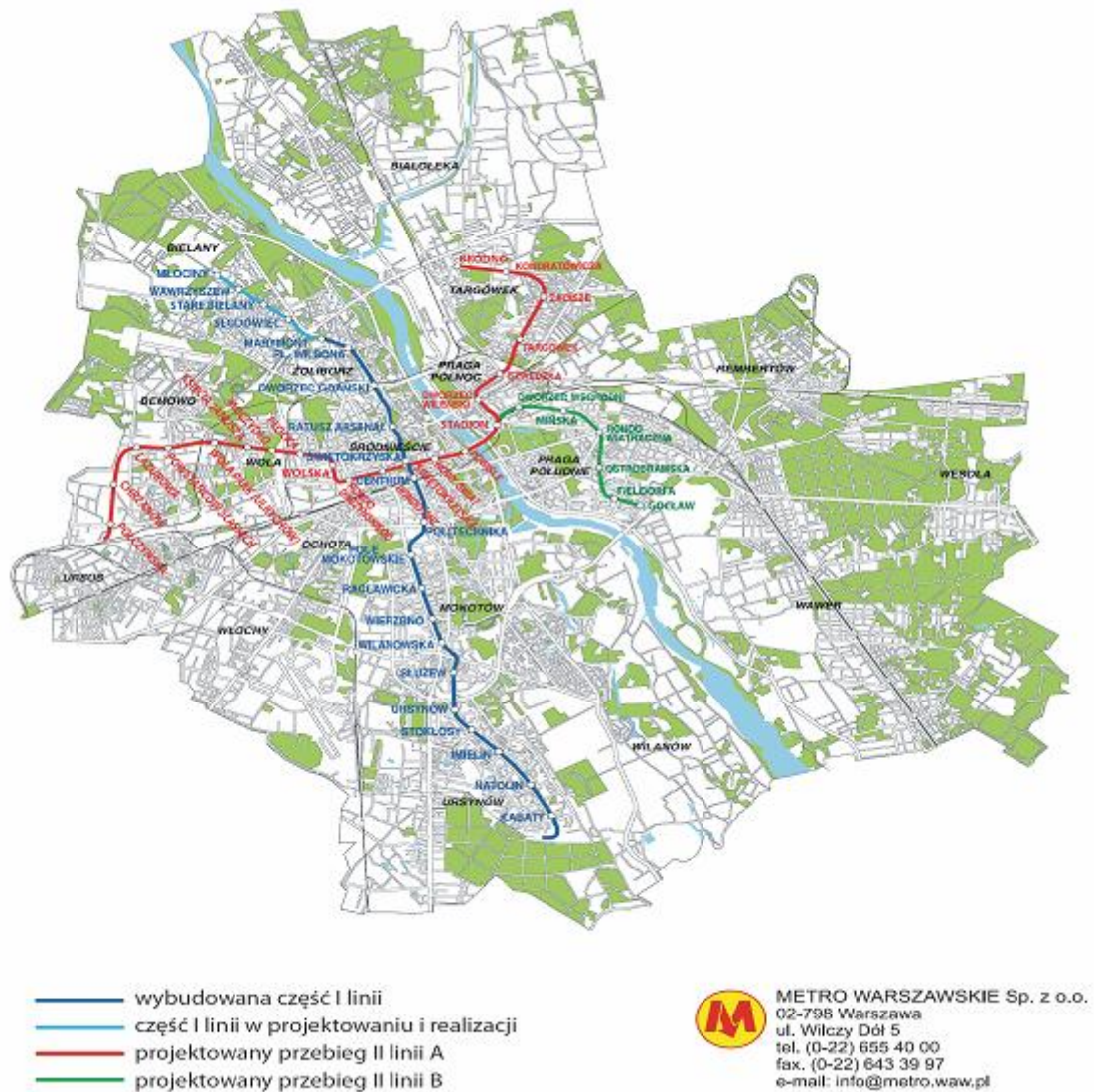


Fig. 2. Schematic diagram of a new underground line project.

The extension of an underground network requires that numerous geodetic tasks be done:

- preparing cartographic documentation for the development of alternative route concepts and maps for design purposes,
- analysis of real estate ownership structure and acquisition of new land for investment,
- preparing a precise control network,
- preparing a “stand-by basic map” in a digital form,
- preparing documentation to obtain a building permit,
- developing a geodetic technology to service the construction project,
- developing principles of monitoring the displacements of endangered objects.

Alternative concepts of localizing individual lines are developed on :

- topographic maps,
- general maps,
- orthophoto images,
- basic map.

All the above elements are used in their digital forms.

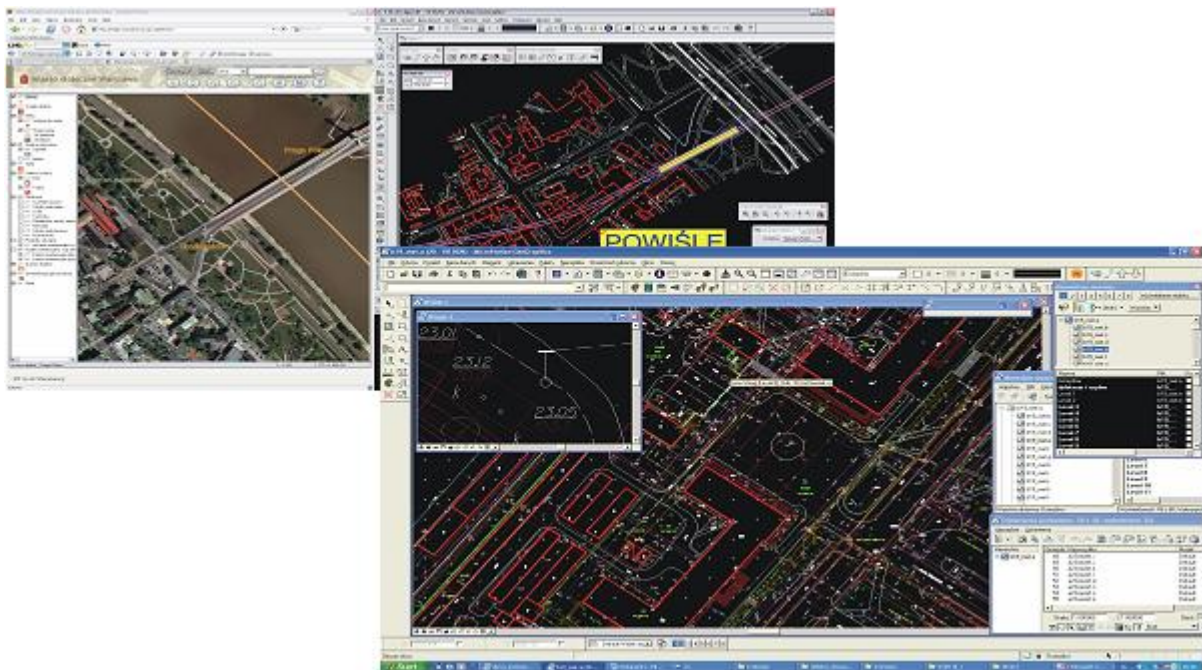


Fig. 3. Screen images of CAD software used.

### 3. LAND LEGAL REGULATIONS

The basic element of an investment project is the acquisition of land for future development. The solution of this problem is very difficult and time-consuming.

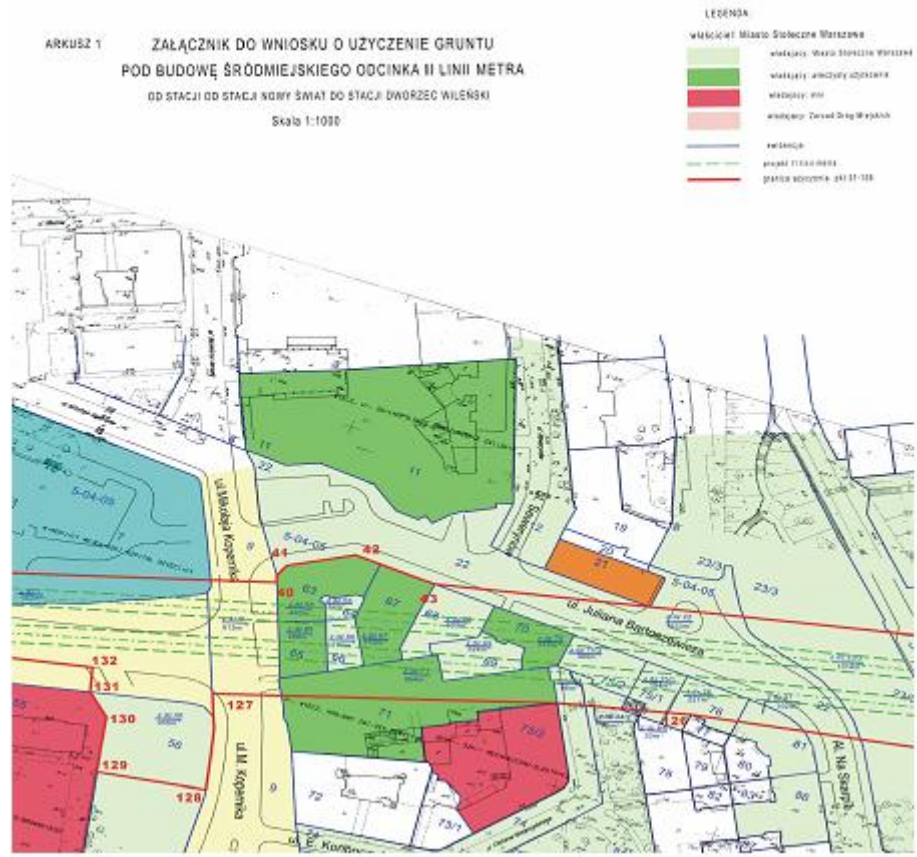


Fig. 4. Map illustrating the legal status of land along the designed route.

Construction affected zones are defined for individual route designs. Object displacements along the underground line are to be monitored.

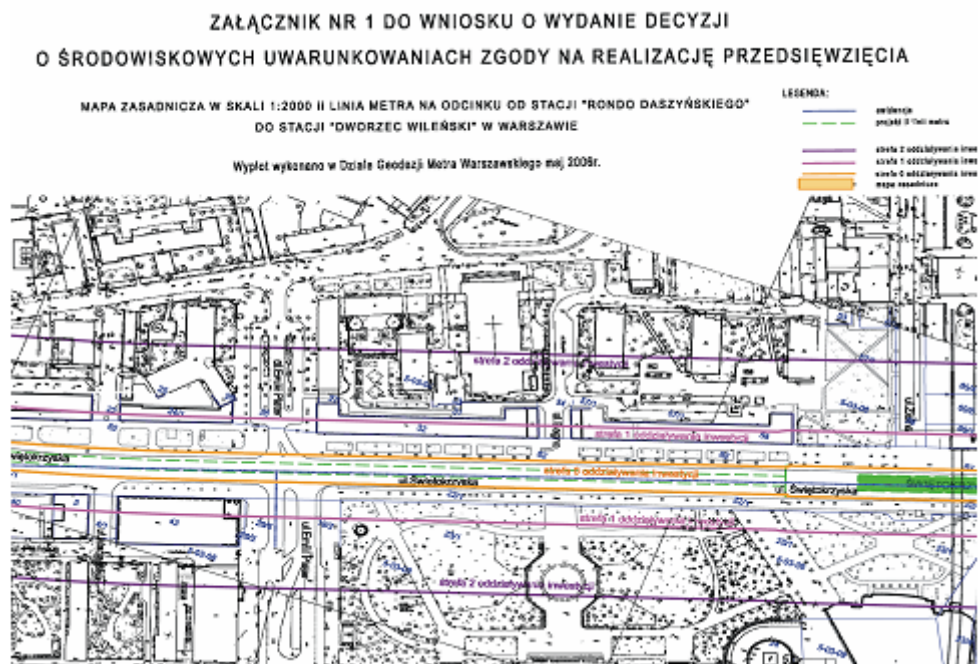


Fig. 5. Map illustrating the conditions affecting the building project.

#### 4. DISPLACEMENT MONITORING

Due to the existing buildings in the construction affected areas, building displacements have to be monitored. Control measurements are going to be made with all the latest technology:

- stability control with hybrid systems including GPS signals,
- measurements with motorized tacheometers equipped with the ATR system,
- measurements of surface structures with laser scanners,
- observations with digital photogrammetric and photographic surveying techniques,
- leveling and inclinometric measurements,
- obtaining information from geotechnical sensors.

In order to process all the above knowledge, a Monitoring Control Centre is going to be built, where all geodetic, geotechnical, environmental and other data are going to be gathered. These data will be made available to all specialists for further analyses



Fig. 6. Modern geodetic instruments.

#### 5. THREATS TO UNDERGROUND TUNNELS POSED BY URBAN BUILDINGS

Contrary to the situation discussed above is that of underground tunnels which have to be protected against the results of other investment projects. This case can be best exemplified by the construction of a building adjacent to the underground tunnel, directly above the ventilation tunnel (Madalińskiego Street/Niepodległości Avenue).

To assess the influence of building investments on the existing underground structures, structural deformation control is carried out throughout the entire construction process.

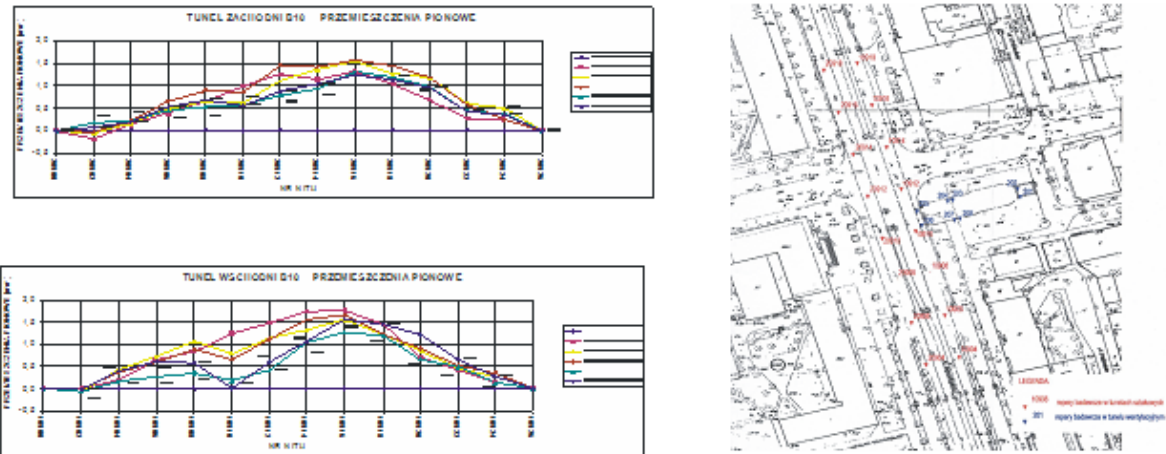


Fig. 7. Diagram of vertical displacements of the underground structures.

## 6. ESTABLISHMENT OF A GEODETIC CONTROL NETWORK

The basic function of a control network is to ensure a precise system of coordinates to implement all elements of the underground objects.

These requirements are not met by the geodetic control network of Warsaw. So a separate network is needed, related to the coordinate system used for the basic map of Warsaw 1925.

In the area of the planned investment it is necessary to establish a new control network using hybrid technologies combining GPS satellite technology with that of angular-linear measurements.

The control network has to ensure the following:

- proper dense coverage of the investment area,
- proper precise definition of coordinates in a uniform system,
- easy access to control network points,
- precise recovery of a survey control station.

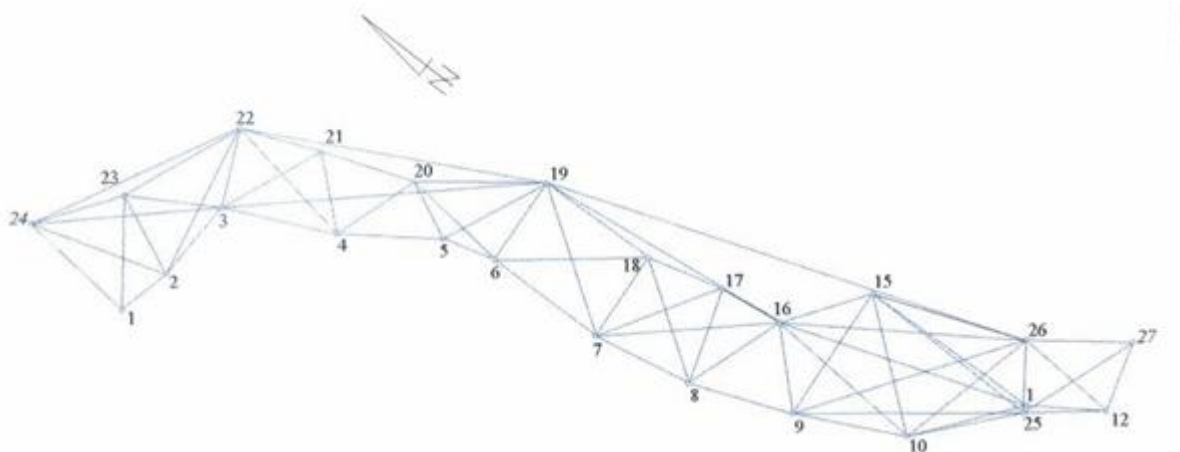


Fig. 8. Schematic diagram of a basic investment network (Polish acronym-PSRM).

## **7. FINAL CONCLUSIONS**

**The construction of an underground requires many different geodetic activities throughout all the stages of the investment. It starts with designing, continues through the building stage until the final stage when the completed objects are operated.**

**During the extension of an underground network one should do the following:**

- **take into consideration the geodetic experience gained during the construction of the first underground line in Warsaw,**
- **conduct all preparatory work according to the newest technologies of digital mapping and documenting,**
- **establish a modern control network making use of precise measuring equipment,**
- **including the newest technologies of control measurements and control network updating methods,**
- **assess the threats posed to the construction affected zones and design the scope of monitoring,**
- **implement new technologies monitoring horizontal and vertical displacements for specific objects,**
- **establish a system of spatial information containing data on the state of geometry, structural traits of monitored buildings as well as geotechnical and other data, maintaining a special geo-reference to the basic map.**