

**Radek Horák<sup>1</sup>****SOLUTION TO THE TECHNICAL INFRASTRUCTURE AND ECONOMIC-MATHEMATICAL METHODS****ŘEŠENÍ TECHNICKÉ INFRASTRUKTURY A EKONOMICKO-MATEMATICKÉ METODY****Abstract**

The application of economic-mathematical methods is used to propose a solution to the technical infrastructure because both solving the technical infrastructure and using economic-mathematical methods require economical conducting operations. The proposals can include a lot of solutions but only the most efficient one can be put into practice. That is why the optimal solution to the underground utilities is being looking for.

**Keywords**

Technical infrastructure, economic-mathematical methods.

**Abstrakt**

Při řešení technické infrastruktury lze uvažovat o aplikaci ekonomicko-matematických metod, neboť při řešení technické infrastruktury se rovněž jako u ekonomicko-matematických metod objevuje požadavek na racionální provedení operací často i z hledisek ekonomických. Tyto problémy mohou mít mnoho řešení, ale realizovat je možno jen nejlepší z nich. Proto při navrhování technické infrastruktury se hledá optimální řešení.

**Klíčová slova**

Technická infrastruktura, ekonomicko-matematické metody.

**1. INTRODUCTION**

When designing and building the technical infrastructure not only do current needs in the area have to be taken into account, but also the needs appearing in future have to be predicted. Any refilling the technical infrastructure, especially the underground lines brings big problems, financial ones and also observing a minimal distance between utility services. Therefore, finding an optimal solution for building technical infrastructure involves some effort as early as at the design stage of technical infrastructure.

**2. TECHNICAL INFRASTRUCTURE AND LANDSCAPE PLANNING DOCUMENTATION**

Technical infrastructure can be characterised as pipes and constuction and associated operational technical devices, such as water mains, water tanks, sewerage system, sewage treatment plants, buildings and equipment for waste handling, transformer stations, power lines, lines of public communication network and electronic communication facilities for public communication network,

---

<sup>1</sup> Ing. Radek Horák, Department of Urban Engineering and Civil Engineering, Faculty of Civil Engineering, VŠB-Technical University Ostrava, Ludvíka Poděště 1875/17, 708 33 Ostrava - Poruba, e-mail: radek.horak@mubruntal.cz.

pipelines [1]. Technical infrastructure is an essential component of landscape planning and for this reason it is included into public infrastructure, and it can be defined as publicly useful building in case it is determined to develop or protect a town, region or state area, and if it is specified in published landscape planning documentation [1]. Therefore it is very important to specify the scope of publicly useful building.

The selection of a suitable area as early as during the making landscape planning documentation is the first step in proposing the area, and in future development of the area including subsequent surroundings. The areas have to be charted, then it is necessary to know needs for developing the area and estimate their development, all based on quality prognosis. To obtain fundamental data of the area, especially limits of using it, a territorial analytical basis will be used. The data are acquired by landscape planning office and they are intended for landscape planning activities of buyer/customer and also for a town planner of landscape planning documentation and its basis. Landscape planning bases are guaranteed with respect to up-to-dateness because they are continuously updated by a buyer who gets new information about the area. First-rate prognoses can be obtained, for instance, from landscape planning bases which were an energy master plan in force of Law No 50/1976 Sb., about landscape planning and building rules (building law) as subsequently amended. Since 1. 1. 2007 the Law No 183/2006 Sb., about landscape planning and building rules (building law) as subsequently amended, has been in force, a landscape study can conduct a similar function of the energy master plan. Additional research carried out in the landscape is convenient for getting complete data and familiarity with the area. In the area where technical infrastructure is partially built it is essential to chart its condition and decide wheather the technical infrastructure is going to be completely or partially used or if it is necessary to adjust it. Providing that these fundamental data are known, the design of technical infrastructure can be possibly solved mathematically. The solution has to meet economic requirements and also objectification of the solution. For this purpose economic-mathematical methods can be used.

### **3. TECHNICAL INFRASTRUCTURE AND ECONOMIC-MATHEMATICAL METHODS**

Economic-mathematical methods deal with analysis and subsequent solution to objectively various problems. There is a numerous number of problem solving but only the best of it must be effected [2].

A convenient economic-mathematical method for designing technical infrastructure is the method of transport problem. The transport problem is solved in the place where there is a need for transporting certain "material" available at some place to a requested destination. The restrictions that must be obeyed can be divided into two groups. The former group refers to a capacity warehouse and the latter to meeting requirements of customers.

The transport problem can be applied to the solution to technical infrastructure because it is a similar problem, which means transportation of "material" with some restrictions as a capacity warehouse is (in technical infrastructure it is the capacity in the place of connection) or customers' requirements (in technical infrastructure it is a case of needs in particular zones of purchase).

This must be known to solve transport problem [2]:

- Number of buyers/customers
- Number of suppliers
- Buyers' requirements
- Suppliers' capacity
- Transport expenses
- Amount of transported goods

An objective function which can be determined for transport problem is defined [2]:

$$z_{\min} = \sum_{i=1}^m \sum_{j=1}^n c_{i,j} x_{i,j} \quad (1)$$

Restrictive conditions for possibilities of individual suppliers are defined for this function like this [4]:

$$\sum_{j=1}^n x_{i,j} \leq a_i \quad (i = 1, 2, \dots, m) \quad (2)$$

Restrictive conditions for requirements of individual suppliers are defined for this function like this [4]:

$$\sum_{i=1}^m x_{i,j} = b_j \quad (j = 1, 2, \dots, n) \quad (3)$$

At the same time it counts  $x_{i,j} \geq 0$  [2]:

then

$$z_{\min} = c_{1,1} x_{1,1} + c_{1,2} x_{1,2} + \dots + c_{1,n} x_{1,n} + c_{2,1} x_{2,1} + c_{2,2} x_{2,2} + \dots + c_{2,n} x_{2,n} + c_{m,1} x_{m,1} + c_{m,2} x_{m,2} + \dots + c_{m,n} x_{m,n} \quad (4)$$

An objective function  $z_{\min}$  secures minimisation of transport demands during the problem solving. A system  $m$  of its own restrictive conditions ensures that no suppliers will provide more than their capacity is. A system  $n$  of its own restrictive conditions ensures that all customers' requirements will be fulfilled entirely [2].

The transport problem is defined by equations  $m + n$ . In this system of equations  $m * n$  variables and  $m + n$  conditions of non-negativities are known [2].

In case that a number of buyers is different from a number of suppliers, the task must be adjusted by a fictitious buyer like this [2]

$$b_{n+1} = \sum_{i=1}^m a_i - \sum_{j=1}^n b_j \quad (5)$$

Steps in solving transport problem can be divided into these points [2]:

1. Verification of solvability of the task
2. Verification of balance of the task
3. Finding initial basis solution
4. Verification of non – degenerativeness of basis solution. It is such a solution that has all the basis variables positive. In the system  $m + n$  linear independent equations there are only  $m + n - 1$  linear independent equations and a basis task solution contains  $m + n - 1$  basis variables  $x_{i,j}$ . In case of degeneration of basis solution the degeneration is removed
5. Optimality test. In case the test of optimality is not met, the change of basis and repeated assessment is made according to the point 4

To find the solution itself it is necessary to divide the solved area into individual zones, in which the zones correspond to individual buyers. In the individual zones it is possible to determine the centre of gravity  $T_i$  that corresponds to the place of purchase in the zone. The final centre of gravity of the whole suggested area  $T_v$  is determined on the basis of defining centres  $T_i$  in individual

zones, their sizes and needs. So the importance of needs of individual zones are taken into account to find the final centre of gravity  $T_v$ . Then the site links to the technical infrastructure and a final centre of gravity  $T_v$  correspond to the suppliers.

#### 4. TECHNICAL INFRASTRUCTURE AND NUMERICAL METHODS

The method of bisection interval which is one of numerical methods is used in order to find the most convenient solution. It is the case of equation solution  $f(x) = 0$ .

To solve the problem, the equation  $f(x) = 0$  is considered to be a continuous function in the interval  $\langle a, b \rangle$ , where  $f(a), f(b) < 0$ , and just one root of the equation  $f(x) = 0$  lies in the interval  $\langle a, b \rangle$  [3].

The solution is following [3]:

$$\begin{aligned} a_0 &= a, \\ b_0 &= b, \\ x_1 &= (a_0 + b_0)/2. \end{aligned}$$

If  $f(x_1) = 0$ , then  $x_1$  is the root of the equation  $f(x) = 0$ .

If  $f(x_1) \neq 0$ , then the interval  $\langle a_1, b_1 \rangle$  is defined as  $\text{sign } f(a_0) = \text{sign } f(x_1)$  and then

$$\begin{aligned} a_1 &= x_1, \\ b_1 &= b_0, \\ \text{otherwise} \end{aligned}$$

$$\begin{aligned} a_1 &= a_0 \\ b_1 &= x_1 \end{aligned}$$

and the bisection of interval  $\langle a_1, b_1 \rangle$  is continued.

Intervals  $\langle a_k, b_k \rangle$  with midpoints are got by gradual bisection [2]

$$x_{k+1} = \frac{a_k + b_k}{2} \quad (6)$$

where

$a, b$  are extreme points of interval  $\langle a, b \rangle$  where the root lies, and also of all intervals  $\langle a_k, b_k \rangle$  which were obtained during the calculation

$x$  – midpoint of interval  $\langle a_k, b_k \rangle$

#### 5 PROCEDURE OF SOLUTION - TECHNICAL INFRASTRUCTURE USING ECONOMIC-MATHEMATICAL AND NUMERICAL METHODS

To make the problem easier the application is shown on the area with four zones  $Z1 - Z4$ , there are four centres of gravity  $T1 - T4$  situated in these zones and referring to four buyers. There is determined a final centre of gravity  $T_v$  for the whole area and also site links to the technical infrastructure, both of which correspond to 2 suppliers. The amount of transported medium for individual routes  $x_{m,n}$  is calculated from the transport problem.

technical infrastructure  
+ site links

area divided into zones  $Z1 - Z4$   
determined centres of gravity  $T1 - T4$ ,  $T$  and  $T_v$ ,  
calculated amount of transported medium  $x_{m,n}$

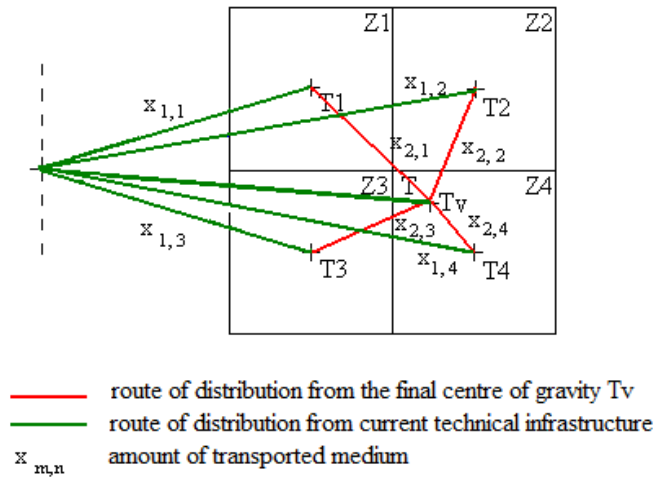


Figure 1: – illustration of routes from suppliers to buyers including the amount of transported medium in the interval between the site links to the technical infrastructure and a final centre of gravity  $T_v$

Two routes from suppliers are known for each buyer, and they transport the amount of medium necessary for buyers, which is

$$x_{1,1} + x_{2,1} = b_1$$

$$x_{1,2} + x_{2,2} = b_2$$

Four routes from each supplier are known for buyers and they transport the amount of medium that equals the supplier capacity, which is

$$x_{1,1} + x_{1,2} + x_{1,3} + x_{1,4} = a_1$$

$$x_{2,1} + x_{2,2} + x_{2,3} + x_{2,4} = a_2$$

$$x_{3,1} + x_{3,2} + x_{3,3} + x_{3,4} = a_3$$

$$x_{4,1} + x_{4,2} + x_{4,3} + x_{4,4} = a_4$$

On the basis of calculation of amount of medium on individual routes only one route from a supplier is determined for every buyer. The fact that the route transports more medium is decisive in determination whether the route is to be left or eliminated. For this purpose the following values are compared

$$x_{1,1} \text{ a } x_{2,1}$$

$$x_{1,2} \text{ a } x_{2,2}$$

$$x_{1,3} \text{ a } x_{2,3}$$

$$x_{1,4} \text{ a } x_{2,4}$$

The method of bisection interval is used in order to find more convenient solution. The interval is halved between the site links to the technical infrastructure and a final centre of gravity  $T_v$ .

This way one more supplier is obtained because the site links to the technical infrastructure, the final centre of gravity  $T_v$ , and a new site arising from a halved route between the site links to the technical infrastructure and the final centre of gravity  $T_v$  become a supplier.

Accuracy of approximation to the root  $\varepsilon$  will be fixed until the condition is fulfilled:

1. during the first bisection interval -  $z_{\min}$  before the application of method of bisection interval is smaller than  $z_{\min}$  using the application  
 $z_{\min}$  (before the application of method of bisection interval) <  $z_{\min}$  (using the application of method of bisection interval)
2. in following bisections –  $z_{\min}$  from a previous application of method of bisection interval is smaller than  $z_{\min}$  from the application of method of bisection interval  
 $z_{\min}$  (from a previous application of method of bisection interval) <  $z_{\min}$  (from the application of method of bisection interval)

Provided that the condition mentioned in point 1 above is not met, bisection of interval follows and also an assessment if the condition in point 2 above is met, it means  $z_{\min}$  (before the application of method of bisection interval) <  $z_{\min}$  (using the application of method of bisection interval). The process of bisection of interval continues up to the meeting the condition under point 2.

After meeting the conditions under point 2 all centres of gravity arising from the method of bisection interval are considered whether there is a better solution for them than  $z_{\min}$  from the last application of method of bisection interval. All the centres of gravity arising from the method of bisection interval are used to evaluate the solution.

At the beginning of the solution to the technical infrastructure using transport problem, parameters of technical infrastructure are calculated for the routes from the site links to the centre of gravity which arose by method of bisection interval and to the final centre of gravity  $T_v$ . The parameters that transport a required amount for individual zones are included in this stage. So dimensions of technical infrastructure have to be recalculated for the sections from the site links to the technical infrastructure to the centre of gravity arising from the method of bisection interval and from the centre of gravity arising from the method of bisection interval to the final centre of gravity  $T_v$  according to the results of solution to the technical infrastructure using transport problem.

At the beginning of the technical infrastructure solution using transport problem, the routes for an adequate amount of transported medium are dimensioned for the route from the site links to the technical infrastructure to the centre of gravity arising from the method of bisection interval and from the centre of gravity arising from the method of bisection interval to the final centre of gravity  $T_v$ .

routes	amount of transported medium
from the centre of gravity arising from the method of bisection interval to the final centre of gravity $T_v$	$\Sigma$ amount of medium for all buyers/customers
from the site links to the technical infrastructure to to centre of gravity arising from the method of bisection	$\Sigma$ amount of medium for all buyers + amount of medium of the route from the site links to the technical infrastructure to the centre of gravity arising from the method of bisection interval = $2\Sigma$ amount of medium for all buyers

To recalculate the results, the routes for the adequate amount of medium are to be dimensioned. It counts for the routes from the site links to the technical infrastructure to the final centre of gravity  $T_v$  and from the centre of gravity arising from the method of bisection interval to the final centre of gravity  $T_v$ .

routes	amount of transported medium
from the centre of gravity arising from the method of bisection interval to the final centre of gravity $T_v$	$\Sigma$ amount of medium for all buyers arising by transport problem method, for whom the routes from the final centre of gravity $T_v$ will be suggested
from the site links to the technical infrastructure to the centre of gravity arising from the method of bisection	$\Sigma$ amount of medium for all buyers arising by transport problem method, for whom the routes from the centre of gravity arising from the method of bisection interval will be suggested + amount of medium for all buyers arising by transport problem method, for whom the routes from the final centre of gravity $T_v$ will be suggested

Then the routes of technical infrastructure from suppliers to buyers will be dimensioned for a requested amount of transported medium.

## 6. CONCLUSION

Technical infrastructure is an essential component of landscape planning and its optimal proposal during the processing landscape planning documentation ensures basic conditions for effective usability of the area. From the earliest stages of a project preparation a lot of problems are necessary to solve to construct technical infrastructure. And the solutions that guarantee the longstanding technical infrastructure and thus ensure the project requirements have to be provided.

Predetermination of distribution of each zone in the area and their needs is required for building technical infrastructure. The needs have to be assessed not only for the current situation in the known area, but also for the needs arising in the future. The solution to the technical infrastructure can be based on economic-mathematical methods, or more precisely on the transport problem.

The solution to the technical infrastructure using transport problem can be applied as the background to processing the landscape planning documentation and also landscape planning materials or as the project documentation for planning permission.

## LITERATURE

- [1] zákon č. 183/2006 Sb., o územním plánování a stavebním řádu (stavební zákon), ve znění pozdějších předpisů
- [2] HOLOUBEK, J.: *Ekonomicko-matematické metody*, Mendlova zemědělská a lesnická univerzita v Brně, ústav statistiky a operačního výzkumu, 2007. ISBN 978-80-7157-970-0
- [3] BOHÁČ, Z., ČASTOVÁ, N.: *Základní numerické metody*, VŠB – Technická univerzita Ostrava, katedra matematiky a deskriptivní geometrie, 2004. ISBN 80-248-0520-0

## Reviewer:

Ing. Alois Novotný, Pionýrská 1, Bruntál.