Trenchless Technology – Solution for CO_2 Reduction


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text: **LUCIE KARÁSKOVÁ NENADÁLOVÁ**, Research Centre Řež, Husinec-Řež

Introduction

Utility investors, municipalities, water and sewerage companies, and gas companies, when considering the options for laying, rehabilitating or repairing utilities, often decide on which technology is optimal to use from the wide range of trenchless technologies, or whether it is better to use a conventional technology for installation (Act No. 83/2006 Coll., 2006). There is no comprehensive overview of the technology parameters for the investors that would guide them through the decision process regarding the method of construction. If the decision-making process includes environmental criteria, the advantages of particular technologies when compared to traditional utility installation methods, or their mutual comparison, are not yet known (Volf, F., 1982).

Construction projects implemented in various sectors of civil engineering begin to monitor environmental parameters, both qualitative and quantitative. The constructions are monitored particularly in terms of deciding on the implementation (EIA), but the possibility to compare different alternatives with various environmental stresses is also being introduced (Act No. 100/2001 Coll., 2001).

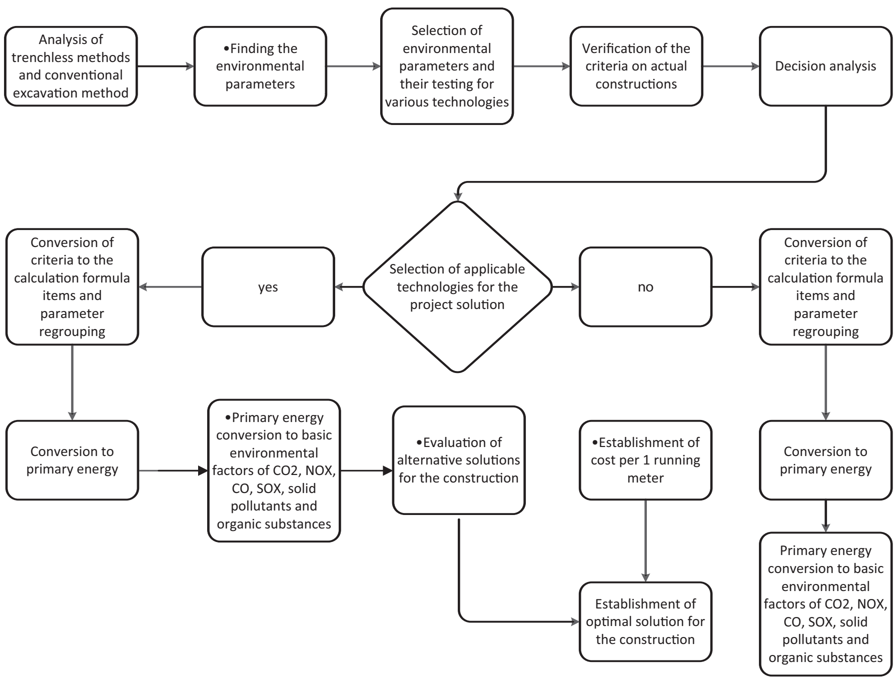

Fig. 1. Methodology Development Process Diagram. Source: Author

There are analogical solutions to the environmental impacts of constructions. For example, environmental impacts of building constructions are now frequently monitored both in absolute and relative terms. Relative comparison allows simplifying the calculation as in relative comparison, only the differential parameters and values are observed, not all parameters. In the standard 73 0540 Thermal Protection of Buildings, or for example in the subsidy program Green Light to Savings, the buildings in a low-energy or passive standards are compared with a so-called reference building which has pre-defined parameters. Similarly, trenchless solutions can be compared with a conventional excavation solution where the compared values for the excavation solution are standardized (e.g. per 1 running meter of sewer DN 200) and the differential parameters and values of both solutions are compared. It is also possible to compare trenchless solutions with each other. By comparing the environmental parameters, the alternative with the lowest environmental impact can be determined.

Development of Methodology

Development of methodology is based on rigorous analysis of both the works carried out employing the excavation method (the traditional way of construction) and trenchless one. A partial step was to identify the environmental criteria that have been tested for various technologies and then tested on real buildings. For the development of methodology, the decision analysis has been used to select the possible technologies for the project. By using the environmental criteria and their transferring to the items of the calculation formula and regrouping into the following parameters: materials, machinery, installation of utilities, transport, and externalities and the primary energy conversion and transfer to the environmental factors of carbon dioxide CO_2, carbon monoxide CO, nitrogen oxides NO_x, sulphur dioxide SO_2, solid pollutants and organic substances, we receive a suboptimal solution for the construction, see Figure 1.

Desicion Making Process for Selecting the Most Appropriate Technology for a Particular Construction

The decision-making process for selecting the most appropriate method of construction and selection of appropriate trenchless technology uses an elimination decision method - K.O. decision system (Heralová et al., 2012). To create the methodology, "data sheets" have been prepared which include the following: basic technical description of the specific trenchless technology, potential materials used, limiting conditions, machinery used, clarifying requirements for cleaning, possibility of implementation without traffic disruption, implementation time schedule, service life of the new works, streamlining the application risks, sensitivity of technology to elements, sensitivity to the quality of the cleaned pipe, geological conditions, environmental criteria, size of the starting and target pits, progress and time schedule, space limitations, restrictions on construction, operation and maintenance conditions, service life, possibility of installing branches, pulling radius.

By comparing the technical and environmental criteria for trenchless technology employing the K.O. decision system, we get a selection of technologies applicable to a particular construction. Table 1 shows an example of the K.O. decision for the construction specified below – Construction of water pipe DN 300, power cables and sleeves.

Tab. 1. Basic decision diagram for the K.O. system for example of construction water pipe DN 300, power cables and sleeves. Source: Author

Type of technology according to data sheets	Limiting condition	K.O.
Relining	Not a rehabilitation	N/A
Jacking	Length of the jacked pipe	N/A
Piercing (Hammerhead Mole)	Top wall height may not be kept, unsuitable distance	N/A
Simple shield tunneling	Top wall height may not be kept, unsuitable distance	N/A
Microtunneling	Minimum diameter of the pipe for constructing DN 250: water pipe could be installed but the diameter for power cable and other sleeves is small; several utilities may not be pulled in	N/A
HDD	The technology enables pulling in several utilities in a special tow and larger distances	Applicable
Destructive pipe replacement	Not a rehabilitation of the existing network	N/A
Application of tight slipining methods (Compact pipe, Swagelining, etc., technologies)	Not a rehabilitation of the existing network	N/A
Shotcrete lining	Not a rehabilitation of the existing pipe	N/A
Plowing	The technology enables laying pipes over large distances, pulling in several utilities simultaneously	Applicable
Excavation technology	No limiting conditions	Applicable

Using the K.O decision-making system, it was found that the applicable trenchless technologies for the construction of water pipe DN 300 and parallel installation of other utilities are the plowing technology and technology of controlled horizontal drilling. When comparing the selected trenchless technologies, the following was found:

- Each of the selected technologies requires different machinery (particular equipment needs to be compared);
- The most massive earth movement will be for the traditional technology;
- For the HDD technology, there will be no parallel laying of the warning foil;
- Only the traditional excavation technology will require bracing;
- The most accurate utility installation will be for the plowing technology;
- The fastest site preparation will be for the plowing technology;
- The fastest laying will be for the plowing technology; the lowest number of employees will be for the plowing technology;

Fig. 2. Traffic jam, fot. Fotolia

- The HDD technology does not require occupying the entire length;
- Both trenchless technologies can be used even in difficult field conditions.

From the environmental point of view, maximum damage to the root system will be done both by the plowing technology and the conventional excavation technology.

Using the bill of quantities, the amount of energy consumed was calculated and by the conversion to the environmental factors, the amounts of consumed CO_2, NO_x, CO, SO_x, solid pollutants and organic matter emissions were found. An alternative using conventional excavation technology was also calculated for comparison.

The Calculation Of Environmental Parametrs

After selecting the appropriate technology for a given construction, the construction is further evaluated according to the bill of quantities. The methodology deals with the comparison of materials used in terms of energy need for the production of the materials used for the utility construction and thus by their indirect effect on the environment. The next evaluation item is the transportation of machines for trenchless technology; for larger pipe diameters, the equipment is transported from considerable distances, which does not have entirely positive impact on the environment in terms of emissions consumed and the production of the machines for trenchless technology also represents a burden. Another construction parameter is the actual implementation of construction works, and namely the speed of the construction implementation, which is directly related to time of the deployment of the machines on site, where there are significant differences in the construction methods used (Baugeräteliste Technisch-wirtschaftliche Baumaschienendaten, 2007). The methodology also quantifies the possible externalities. Within the methodology, traffic restriction on the road, or its complete closure, is considered an externality. Also regarded as externality is traffic interruption on the railway with the necessity of introducing a replacement bus service, see [1].

$$E_e = \sum_{i=1}^{n} q\, H$$

Where:

E_e Primary energy consumed for externalities [MJ],
q Fuel consumption [kg],
H Fuel efficiency [MJ/kg].

The methodology parameters were calculated as the amount of energy consumed for the production of materials and machinery and through their conversion according to the emission parameters used in the Czech Republic, the amounts of consumed emissions - solid pollutants, sulphur dioxide [2], nitrogen oxide, carbon monoxide, and the most monitored greenhouse gas, carbon dioxide, were found.

$$\boldsymbol{e_{SOx}} = \sum_{i=1}^{n} \boldsymbol{k_{eSOx}} \frac{\boldsymbol{E_C}}{\boldsymbol{H}}$$

Where:

e_{SOx} Amounts of consumed emissions SO_x [kg],
k_{eSO} Emission parameter SO_x [-],
E_c Primary energy consumed [MJ],
H Fuel efficiency [MJ/kg].

The Origin and Impact of the Emission Calculated Using the Methodology on the Environment

Nowadays, mainly greenhouse gases are being discussed, carbon dioxide being considered the most important representative of the greenhouse gases group (Bartusek S., 2012). When using the methodology, we obtain the direct difference in the amounts of emissions consumed, especially regarding carbon dioxide. Other selected pollutants to determine the difference in the emissions consumed are sulphur dioxide which forms an important item due to the sulphur content in fuels. The amount of solids generated during combustion processes in the transportation of materials to the site and the use of construction machinery has a negative effect on the human body with respect to inhaling dust particles. As a byproduct of incomplete combustion during the construction of utilities, nitrogen oxides originate which subsequently penetrate into all parts of the environment. The last assessed pollutant is carbon monoxide that is produced during incomplete combustion of fuel, especially during the transportation of materials to the site.

Results

Example 1: Evaluation of the amount of emissions consumed during the construction of the DN 300 water pipe, power cables and sleeves

According to the K.O. decision-making process, it was found that the appropriate technology for the construction of DN 300 pipe, power cables and sleeves is the plowing technology, HDD, and as the alternative, the conventional excavation technology was calculated.

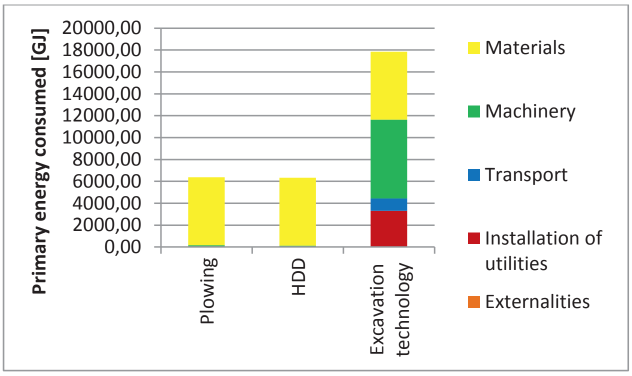

Fig. 3. Construction of water pipe DN 300, power cables and sleeves, primary energy consumed [GJ]

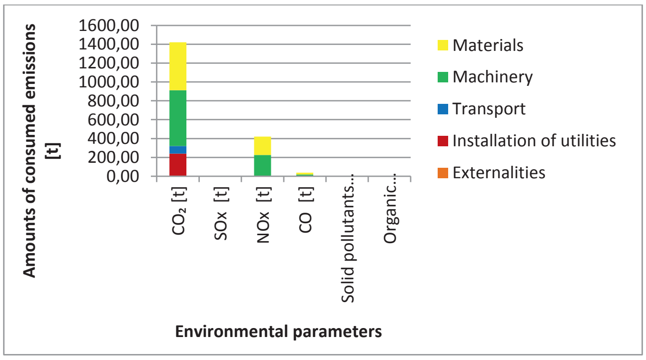

Fig. 4. Construction of water pipe DN 300, power cables and sleeves, the conventional excavation technology

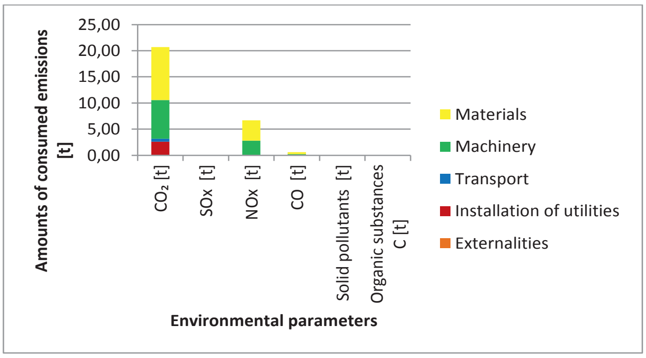

Fig. 5. Construction of a sewer pipe under the railway line in urban areas, Augerboring

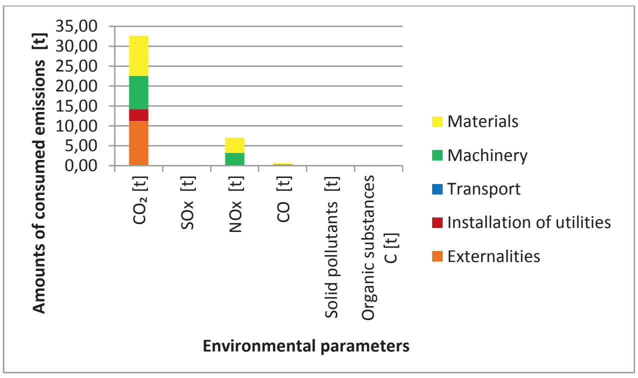

Fig. 6. Construction of a sewer pipe under the railway line in urban areas, the conventional excavation technology

Fig. 7. Carbon dioxide emissions are bad for human health, fot. Fotolia

By evaluating the environmental parameters, see Figure 1, 3 for the construction of water pipe DN 300, we find that in terms of CO_2 and NO_x emissions consumption when implementing the construction employing the plowing and HDD methods, both values are the same. Other environmental parameters are negligible for trenchless technology.

The traditional technology shows much greater consumption of CO_2 and NO_x, the greatest impact being caused by materials; construction machinery used and pipe laying. When compared with conventional excavation, the trenchless methods of plowing and HDD have 65% less impact on the environment.

Example 2: Evaluation of the amount of emissions consumed for jacking the pressure sewer pipe DN 600 in steel sleeve DN 800 under the railway

This example shows the construction of a sewer pipe under the railway line in urban areas. The technology used was Augerboring (uncontrolled horizontal drilling with screw conveyor) and conventional excavation technology as an alternative.

The most significant environmental parameters are CO_2 and NO_x. In relation to the work, again the most important are the production of the pipe material, machinery used and the implementation for both alternatives.

The difference between the environmental parameters is 25%, see Figure 4 and 5, due to the difficulties when implementing the trenchless method and transfer of materials.

The externality of interrupting the rail link on the Oldenburg – Leer route was considered, and its replacement by bus service during the execution of earth work in the case of the conventional excavation technology. The externality has a significant influence on the production of CO_2 and NO_x.

Experience and Conclusion

Trenchless technologies show great diversity, which is ideal for their application for the vast majority of utility constructions. So far, however, no original methodology for evaluation, from the environmental point of view, of construction of utilities using trenchless technology, was developed or published in the Czech Republic or abroad. Within the thesis "The methodology for evaluating the utility construction using trenchless technology

Fig. 8. Trenchless technologies are technologies that allow for the construction and rehabilitation of underground infrastructure, fot. Fotolia

from the environmental point of view", the methodology of environmental assessment of utility construction was elaborated.

The summary of various applications for methods of laying utility lines showed a wide range of classifiable criteria, most of which are fundamental to the environmental parameters. The decision-making process for technology selection has to stem from the comparison of objective parameters of the construction to achieve the best selection of solutions for implementation. When searching for parameters, it was found that not only the environmental parameters should be taken into account, but also the basic technical parameters of the route, in order to compare the individual technologies and to quantify them in terms of the environmental parameters.

Using the K.O. decision-making system, seven already implemented constructions have been evaluated within testing the methodology; the technologies applicable to the tested constructions have been selected from the data sheets. Particular constructions have shown that it can be well recognized for which construction a technology is suitable, usable or unusable. For most assessed constructions, the use of a trenchless solution competes with the use conventional excavation technology.

When deciding on the option of the technology used for laying utilities or their rehabilitation, an environmental assessment is very useful.

Acknowledgement

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Technologie bezwykopowe sposobem na ograniczenie emisji CO_2

Technologie bezwykopowe to technologie pozwalające na budowę i odnowę infrastruktury podziemnej. W niniejszym artykule opisano metodologię oceny bezwykopowej oraz wykopowej budowy infrastruktury podziemnej pod względem oddziaływania na środowisko. U podstaw tej metodologii leży analogia do oceny oddziaływania na środowisko obiektów budowlanych, które są obecnie monitorowane zarówno w kategoriach względnych, jak i bezwzględnych.

Opracowana metodologia opiera się na gruntownej analizie środowiskowej konstrukcji wykonanych metodami bezwykopowymi i wykopowymi. Wpływ budowy infrastruktury podziemnej jest monitorowany przez specyfikacje środowiskowe i techniczne, obejmujące wszystkie działania budowlane wykonywane w trakcie budowy i instalacji. Podczas oceny konkretnych inwestycji znaleziono najważniejsze parametry wpływające na sposób budowy i wybór poszczególnych technologii bezwykopowych.

Wszystkie policzalne parametry budowy zostały podzielone na pięć podstawowych grup: materiały, maszyny, transport, instalacja infrastruktury podziemnej oraz wpływy zewnętrzne, w tym porównanie materiałów powszechnie stosowanych w budowie infrastruktury podziemnej, produkcja i transport maszyn, warianty budowy i instalacja infrastruktury podziemnej. Opracowana metodologia pozwala zmierzyć możliwe wpływy zewnętrzne, takie jak zmniejszenie natężenia ruchu kołowego lub całkowite zamknięcie drogi lub zakłócenia w ruchu kolejowym. Konwertując techniczne i ekonomiczne parametry budowy do pierwotnych źródeł energii, a następnie sprowadzając je do ilości mierzalnych z punktu widzenia ochrony środowiska, zgodnie ze wskaźnikami emisji, otrzymujemy ilości zużywanej emisji. Przy użyciu opisanej metodologii szacowane są ilości takich związków, jak CO_2, CO, NO_x, SO_2 oraz pyły i materie organiczne.

Otrzymuje się w ten sposób szybki przegląd wpływu poszczególnych technologii na środowisko. Przez porównanie inwestycji wykonanych zarówno metodami bezwykopowymi, jak i wykopowymi można dostrzec różnicę w zużyciu emisji CO_2, a tym samym ocenić zasadność doboru technologii pod względem oddziaływania na środowisko.