Gas mains in multi utility ducts
Risk management: a decision making tool

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This paper details the results of a study performed by NUON, TNO & KIWA, KIWA Gastec and KEMA. The study was initiated by the network organisation: Centre for Underground Construction (COB).

Modern urban development results in a shortage of available space for cables and mains and in a shortage of time slots to block streets in order to erect, repair or replace these infrastructures. Both effects mean that it is essential to install all infrastructures in special ducts. A multi-utility duct is an underground structure that contains more than two types of public utilities and includes its own drainage, ventilation, lighting, communication, power, monitoring systems, access facilities etc. It is often difficult for the parties involved to agree on building a utility duct. City council officials and utility companies have to agree on items such as technical acceptability, design of the duct, management of the duct, mutual liability, etc.

This paper describes a risk assessment method by which the designers and decision-makers are provided with a powerful tool to assist them in determining which combination of utility mains is feasible given the specific location. The method does this by providing a common language and knowledge base for all stakeholders such as utility companies, city councils, real estate developers, etc. After reviewing the risk involved in the various solutions, the method provides information on the stakes involved for each stakeholder. This transparency is a crucial factor to get the negotiations ongoing and focuses on the real issues at hand.
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1. Introduction

1.1 Motivation

The infrastructure for gas, electricity, water, telecommunication, sewer systems, district heating, etc. is traditionally located underneath roads and footpaths. Modern urban development results in a shortage of available space for cables and mains and in a shortage of time slots to block streets in order to erect, repair or replace these infrastructures. Both effects mean that it is essential to install all infrastructures in special ducts. A multi-utility duct is an underground structure that contains more than two types of public utility and includes its own drainage, ventilation, lighting, communication, power, monitoring systems, access facilities etc.

It is often difficult for the parties involved to agree on building a utility duct. City council officials and utility companies have to agree on items such as technical acceptability, design of the duct, management of the duct, mutual liability, etc. And last but not least who pays the bills. City council officials have little or no knowledge about the utility infrastructures. Utility Companies officials have as little knowledge of city planning. This hampers the discussion. This paper describes a risk assessment method by which the designers and decision-makers are provided with a powerful tool to assist them in determining which combination of utility mains is feasible given the specific location.

Risk assessment is of major importance for utility companies. Utility companies have to cope with risks involving third party liability. Liberalization of utility companies results in stringent regulation on reliability of energy supply. European law on employee safety is tightened. Assetmanagement becomes more and more risk based driven. Design of and final decision on the use of utility ducts should therefore be based on risk assessment.

The method also provides a common language and knowledge base for all stakeholders such as utility companies, city councils, real estate developers, etc. This is of the utmost importance since mutual understanding and the need to solve a common problem are basic requirements for finding the optimal design for utility ducts along with the public and private areas involved.

1.2. Organisation

This paper presents the results of a study that was initiated by the Netherlands Centre for Underground Construction (COB). COB is a network organisation. In COB, over a hundred businesses, government offices and science institutes work together. COB considers it her mission to contribute, through co-operation, in a lasting and sustainable way to a responsible development, construction and management of underground spaces. COB wants to do this through preserving already developed knowledge, creating new knowledge, and in a more broad sense providing a positive development climate for innovative ways of underground use of space. Based on this mission, COB aims at tangible, practical research on current issues with social relevance. Well known Dutch research institutes as TNO, Gastec, KIWA and KEMA performed the study. NUON Assetmanagement and NUON Tecno provided Assetmanagement knowledge and hands on experience.
1.3 Limitation & definition

The study has been done for a random combination of mains and cables. This complex system largely depends on the type and number of cables of mains in the duct and the construction of the duct. Some typical duct systems are shown in figure 1 [2]. The risks created by bundling of cables and mains are always related to the risk applicable to traditional position underneath roads and footpaths.

1.4 Method of research

Literature research was used in order to determine which (inter) national standards apply to bundling of cables and mains. Literature research was also used to determine the risk bearing objects and the risk involved. This was complemented with interviews of experts closely involved in design, building and operation of Utility Ducts. This resulted in a risk identification database that can be used for all types of utility ducts. This model was verified and tested in a workshop. About 40 Dutch experts with a wide range of expertise tested and made worthwhile additions to the model. The NUON Assetmanagement risk management method was used to design a tool that facilitates the decision making process.

<table>
<thead>
<tr>
<th>Schematic Cross section</th>
<th>Description</th>
<th>Schematic Cross section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>🍀🍀🍀🍀🍀🍀🍀🍀</td>
<td>Conventional underneath surfaces</td>
<td>🍀🍀🍀🍀🍀🍀🍀</td>
<td>Combination of small duct and accessible working area’s</td>
</tr>
<tr>
<td>🍀🍀🍀🍀🍀🍀</td>
<td>Structured Conventional underneath surfaces, possible use of small ducts (1 duct contains 1 cable)</td>
<td>🍀🍀🍀🍀🍀</td>
<td>Accessible utility duct</td>
</tr>
<tr>
<td>🍀🍀🍀🍀🍀🍀🍀</td>
<td>Cable and mains drain accessible from surface</td>
<td>🍀🍀🍀🍀🍀</td>
<td>Non accessible utility duct</td>
</tr>
</tbody>
</table>

Figure 1: overview of typical utility duct layouts
2. Process to come to consensus concerning a solution

To support the stakeholders with their decision upon which type of solution should be used, the process given in figure 3 was developed. The goal of this process is to provide stakeholders insight and understanding of each other’s point of view.

Figure 2 Decision support process to obtain consensus on the solution

In this figure the following steps are given:
- Step 1: Stakeholders determine their view on the predetermined values of society.
- Step 2: The risks involved with every solution(s) are identified and described.
- Step 3: Each risk is scored against the values of society.
- Step 4: The risk profile of the solution(s) is provided for each stakeholder.
- Step 5: Stakeholders determine which solutions meet their combined wishes best

The solution(s), which are to be compared, are created during and/or before the start of the process.

Steps 1 to 4 will be described in-depth in the following paragraphs. Step 5 is basically a negotiating process in which consensus must be achieved.

2.1 Step 1: Weighing of values by each stakeholder

The process starts with an information session. All stakeholders must have a shared knowledge of the bundling of cables and mains, the environment, the urban developments involved, etc. In this step, each stakeholder provides the others with insight into his or her interest in the bundling of cables and mains. Specifically, each is given 100 points, which he/she can distribute over the predetermined values of society, e.g.: finance, safety, service quality and reliability. The result of step 1 is given in table 1.

Table 1 Result of step 1: weighing of values by each stakeholder

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Finance</th>
<th>Safety</th>
<th>Servic</th>
<th>...</th>
<th>Value n</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility 1</td>
<td>20</td>
<td>10</td>
<td>50</td>
<td>...</td>
<td>12</td>
<td>100</td>
</tr>
<tr>
<td>Phone company</td>
<td>30</td>
<td>50</td>
<td>5</td>
<td>...</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>City council 1</td>
<td>20</td>
<td>50</td>
<td>10</td>
<td>...</td>
<td>9</td>
<td>100</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
<td>...</td>
<td>100</td>
</tr>
<tr>
<td>Stakeholder</td>
<td>12</td>
<td>60</td>
<td>20</td>
<td>...</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>
2.2 Step 2: Risk identification

Risk is a result of a probability and an effect. In order to get transparent risk identification all possible failure modes must be identified. This must be done considering:
- Normal operation of cables, mains and duct
- Maintenance and repair operations
- Extreme situations (fire, leakage, explosion)
- Construction, installation of cables and mains and removal

Not only the interaction between cable, main and the duct must be identified. Also the influence of the environment, e.g. the effect on traffic, fire safety, possible victims, terrorism, etc. must be identified.

This risk identification process requires a major investment in time. Also, the expertise is not always available within the decision-making group. Therefore the COB study developed databases of failure modes, effects, frequencies and possible preventive actions. The database is applicable to all type of utility ducts. The COB study [1] identified the most important failure modes. A set of 19 cause effect relations was analysed: leakage, lire/explosion, failure of pumps, sparking/EMC, corrosion, inundation, inundation (poisonous), failure of compressors, electrocution, breakage, fire/explosion/suffocation, fire/explosion/suffocation (poisons), illumination, duct alarm system failure, heating, cooling, duct control system failure, melting, sinking. Underneath is example is given of such an analyses.

Table 2: typical example of risk identification

<table>
<thead>
<tr>
<th>Failing medium:</th>
<th>Natural gas, industrial gasses or liquid fuels.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fail mechanism:</td>
<td>Leakage</td>
</tr>
<tr>
<td>Effect on:</td>
<td>All cable and mains, duct and surroundings</td>
</tr>
<tr>
<td>Scenario:</td>
<td>Fire/explosion</td>
</tr>
<tr>
<td>Effect:</td>
<td>Fall out, leakage of one or more cables and mains, damage or destruction of duct, damage to surrounding buildings, multiple victims inside or outside the duct.</td>
</tr>
<tr>
<td>Preventive measures:</td>
<td>Gas detection system, fluid detection system, automatic shutoff valves, and automatic fire suppression.</td>
</tr>
<tr>
<td>Type of bundling</td>
<td>Probability</td>
</tr>
<tr>
<td>Underneath roads</td>
<td>0,02 per km per year</td>
</tr>
<tr>
<td>Duct</td>
<td>0,002 per km per year</td>
</tr>
</tbody>
</table>

For every fail mechanism the probability was determined, using data available or expert opinion (Cooke method). Always the probability of failure in standard location underneath road and footpaths was used as basic reference. Data on these failure rates are more widely available. An example is given in table 2. Technical properties, technical standards, failure modes, probabilities and effects were used in construction of these risk matrices.
Given a specific utility duct, the database can be used to determine quickly the risk applicable to this situation. This tool clearly shows the risks and the ability to reduce the risks. It also provides information about which risk can be neglected, reduced, accepted or are inadmissible. However, it does not provide the answer whether the design of the duct is the optimum solution in relation to the interest of all stakeholders.

2.3. Step 3: Score risks against values of society

In this step, the risks described in step 2 are translated to the values of society. To obtain a quantitative measure for the risk, it is defined by the equation “risk = frequency x impact”. In this equation frequency stands for the number of occurrences of an event per year and impact for the impact it has on society. The impact of an event is predetermined by the guidelines given by the COB database, see paragraph 3.2. The solution and area specific result will be a table listing the possible events and their impact, see Table 3.

Table 3 Predetermined impact of an event

<table>
<thead>
<tr>
<th>Event</th>
<th>Finance</th>
<th>Safety</th>
<th>Service</th>
<th>…</th>
<th>Value n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackout &lt; 8 hours</td>
<td>20</td>
<td>0</td>
<td>50</td>
<td>…</td>
<td>1</td>
</tr>
<tr>
<td>Gas Explosion</td>
<td>50</td>
<td>1000</td>
<td>10</td>
<td>…</td>
<td>30</td>
</tr>
<tr>
<td>Flooding &lt; 1 day</td>
<td>800</td>
<td>20</td>
<td>500</td>
<td>…</td>
<td>9</td>
</tr>
<tr>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>Event n</td>
<td>30</td>
<td>10</td>
<td>500</td>
<td>…</td>
<td>0</td>
</tr>
</tbody>
</table>

In step 2 “Identify and describe risks” the frequency of an event was already determined. Multiplying the numbers given in table 2 with this frequency provides a table containing the risk of an event set against the values of society.

2.4. Step 4: Score solution for each stakeholder

With the results obtained from step 1 and step 3 it is possible to determine the risk of each event for each stakeholder using the equation: risk = frequency x impact x weight. Since these numbers are all weighed, they can be summed to obtain an overall risk and the risk profile (or risk per value) of the solution, see table 6. Since the weight distribution of each stakeholder differs, each will have a different risk profile and overall resulting risk. For the example given in Table 6 this particular stakeholder obtains a resulting risk of 13,214 for this particular solution. The evaluation table also provides the stakeholders with information into why and which event dominates his or her position. In this particular example, event n dominates on the value service. Without taking into account the required investment, the preferred solution is the one with the lowest remaining risk. It is likely that the preferred solution is not the same for each stakeholder.

The process provides the negotiating step with unbiased information about the roles and positions of the stakeholders present at the negotiation table. It does not provide information about the
investment required and how this investment should be divided among the stakeholders. That is something the stakeholders will have to reach consensus about.

Table 4 Result of risk evaluation of the stakeholder’s view of a solution

<table>
<thead>
<tr>
<th>Event</th>
<th>Frequency (per year)</th>
<th>Finance (w=20)</th>
<th>Safety (w=10)</th>
<th>Service (w=50)</th>
<th>…</th>
<th>Value (w=12)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackout &lt; 8 hours</td>
<td>0.05</td>
<td>20</td>
<td>0</td>
<td>125</td>
<td>…</td>
<td>0.6</td>
<td>146+</td>
</tr>
<tr>
<td>Gas Explosion</td>
<td>0.001</td>
<td>1</td>
<td>10</td>
<td>0.5</td>
<td>…</td>
<td>0.36</td>
<td>12+</td>
</tr>
<tr>
<td>Flooding &lt; 1 day</td>
<td>0.005</td>
<td>80</td>
<td>1</td>
<td>125</td>
<td>…</td>
<td>0.54</td>
<td>207+</td>
</tr>
<tr>
<td>Event n</td>
<td>0.5</td>
<td>300</td>
<td>50</td>
<td>12500</td>
<td>…</td>
<td>0</td>
<td>12850+</td>
</tr>
<tr>
<td>Risk of solution</td>
<td></td>
<td>401+</td>
<td>61+</td>
<td>12750.5+</td>
<td></td>
<td>1.5+</td>
<td>13214+</td>
</tr>
</tbody>
</table>

3. Conclusion and future developments

International literature and standards do not give information and regulations on the subject of bundling of cables and mains in utility ducts. The existing regulations are not prohibitive to the use of utility ducts. Using expertise available, ‘all’ risks applicable to utility ducts were identified, described and quantified. Also, possible preventive measures were identified. This provides a common database for all involved in decision making on the design of utility ducts. This way, all involved in the decision-making process share the same knowledge.

Interest of parties involved does normally not coincide. The decision making process is often characterized as a negotiating process. A tool was designed to support this process. Making the individual interest clear to the other participants by defining ‘values’ and ranking of these values does this. Using the risk database, the importance of a specified risk for the participants can be easily identified. This way, the discussion will be focused on the really important risks for every individual participant. The discussion can be focused on methods to reduce the risk to a level that is acceptable.

This study will result in a report that will be published in June 2006 [1]. This is the first result of 3 research efforts on the topic of utility ducts covering the subjects: risk analyses, cost & revenues for the community, efficient and low cost methods for building and operating utility ducts. The risk database and the decision support tool will be used in utility tunnel design by the parties involved in COB. Almost all major stakeholders are involved and a number of utility ducts are planned for. This way, the database as well as the decision support processed will be tested and improved.
References

[1] Risicoanalyse en risicobeoordeling van bundeling van kabels en leidingen in Infrastructuren, COB rapport O13, 2006
[2] Promoting the urban utilities tunnel technique using a decision-making approach, LEGRAND Ludovic; BLANPAIN Olivier; BUYLE-BODIN Francois, University of Lille-LML, Cite Scientifique, Tunnelling and underground space technology, (2004), 19(1), 79-83, 8 refs.
List of Figures and Tables

Photo front cover. J den Hartog, NUON Assetmanagement, 2005

Figure 1. Overview of typical utility ducts layouts
Figure 2. Decision support process

Table 1. Results of step 1
Table 2. Typical example of risk identification & probability analyses
Table 3. Predetermined impact of an event
Table 4. Results of risk evaluation