THE ROLE OF RISK ATTITUDES: DISCREPANCIES BETWEEN HUMAN AND COMPUTER-BASED RISK ANALYSIS IN THE UTILITY SECTOR

Ramon ter Huurne[1]

Construction Management and Engineering, University of Twente, PO Box 217, Enschede, 7500AE, The Netherlands

To prevent excavation damages to utilities, as well as their negative side effects, the utility construction domain is hammering on the importance of localizing utilities in advance of excavation activities. Until now, the predominantly applied way of locating utilities is to dig trial trenches. Trial trenches expose utilities and are, therefore, considered the only method that grants absolute certainty about the utilities' locations. On the contrary, trial trenches only provide a local measure and thus require understanding about where to dig a trench. This study explores the rationale behind the trial trench method in practice to assess how effective risk on excavation damages is managed by the method. To assess the effectiveness, a computer-based risk analysis tool that calculates the level of excavation damage risk on a given construction site was used as a benchmark. After conducting a practice-based study in which the trial trench method of three Dutch construction projects was observed, the outcomes of the risk analysis tool were compared with the locations of the trenches dug in practice. Findings demonstrate differences: The number of trial trenches dug in practice is remarkably fewer than suggested by the risk analysis, whilst the locations themselves often do not align with where the risks are the greatest. The study shows that a root cause for the differences between the tool and practice is the difference in the motivation behind digging trial trenches. Illustrative examples of these differences show that the adopted risk management approaches are typically guided by both the decision-maker's risk attitude, including their intuition, judgement and expertise of the decision-maker, and time and budgetary constraints. All in all, this study demonstrates that the sense of accuracy provided by employing trial trenches cannot always be taken for granted. This study furthermore urges practice to rethink their excavation damage risk management approaches, whilst recommending the institutional setting to steer their initiatives towards establishing a mindset of careful excavation amongst the practice community.

Keywords: computer-based tools; excavation; risk management; utility sector

INTRODUCTION

The construction industry is known for being an industry exposed to high levels of risk, due to the nature of its construction activities, processes, environment and organization (Akintoye and MacLeod 1997). Organizations in the construction industry are continuously confronted with a plethora of situations that may involve many unknown, unexpected, undesirable, or unpredictable factors (Fong 1987).

[1] r.b.a.terhuurne@utwente.nl

ter Huurne, R (2021) The Role of Risk Attitudes: Discrepancies Between Human and Computer-Based Risk Analysis in the Utility Sector *In:* Scott, L and Neilson, C J (Eds) *Proceedings of the 37th Annual ARCOM Conference,* 6-7 September 2021, UK, Association of Researchers in Construction Management, 844-853

Albeit being risk-prone, the construction industry has a poor reputation in coping with risk as many construction projects know time and cost-overruns (Shevchenko *et al.,* 2008). Also, safety in construction still underperforms (Haslam *et al.,* 2005) while more and more environmental and societal factors need to be taken into account during construction works. Due to the complexity and types of risks associated with construction projects and their activities, risk management has become a central topic of discussion in construction management literature.

Risk management is the process of identifying, analysing and assessing the risks the construction project is exposed to so that a conscious decision can be taken on how to handle these risks (Markmann *et al.,* 2013). However, as explained by Simon (1997), decision-makers are typically bounded by rationality, resulting in sub-optimal decision-making. With the rise of computer-based tools and digitization efforts in the construction industry, various authors have, therefore, suggested using computer-based tools to lessen human error during decision-making and improve the effectiveness of risk management activities (Akintoye and MacLeod 1997; Yildiz *et al.,* 2014). Surprisingly, especially given the many uncertainties in construction projects, the added benefit of computer-based risk management is often questioned in practice (Akintoye and MacLeod 1997). One sector in the construction industry dealing with high uncertainties and risks daily, while seemingly marginalizing the use of computer-based risk management tools, is the utility sector.

Utilities concern the cables and pipes that are responsible for transporting water, gas, electricity, telecommunication, sewage, heating and other services (Costello *et al.,* 2007; Jaw and Hashim 2013). Since many of the utilities are buried in the ground, the whereabouts of buried utilities are typically unseen from the surface. Therefore, new construction, maintenance, and remediation projects that work with or nearby buried utilities face a risk of damaging utilities in the process of excavation. The increasing variety and density of the networks of buried utilities due to urban growth, the development of new communication technologies (Jaw and Hashim 2013) and the energy transition (Kern and Smith 2008) further complicates excavation activities.

To prevent excavation damages, and their negative side-effects, accurate and comprehensive information about the utilities' locations and attributes are required (Chapman *et al.,* 2007; Jaw and Hashim 2013). To acquire this information, exposing utilities via trial trenches to visually inspect the buried utilities is the predominantly applied method (Lai *et al.,* 2018). However, trial trenches only provide a local measure at the point where the trench is dug. This means an understanding by the decision-maker is required about the involved risks, to make a cautious decision on where to locate the trial trenches. In combination with the uncertainty about the whereabouts of the utilities, room for human error exists, potentially leading to sub-optimal decision making.

Following this introduction, this study assesses the effectiveness of the trial trench method by comparing trial trench locations chosen by human decision-makers with those locations suggested by a previously developed excavation damage risk analysis tool. This computer-based tool calculates the level of risk to excavation damages on a given construction site, and suggest, given the calculated risk level, where to dig trial trenches. Insights from this comparison may provide valuable lessons for optimization of the utility locating practice in specific and the value of computer-based risk management tools in construction in general.

This study is outlined as follows. First, the related literature on risk management in the construction and the utility sector is described. Then, it is explained how the computer-based risk analysis tool was used to assess the effectiveness of the trial trench method, followed by elaborating on the differences and similarities found. Finally, the findings are compared with the literature before the study is concluded.

BACKGROUND AND RELATED LITERATURE

According to the ISO 31000:2018, a risk is considered the effect of uncertainty on objectives, resulting in a deviation from the expected, leading to economic, environmental or societal consequences, to manage risks in construction, Flanagan and Norman (1997) describe risk management as being a process with four distinct phases (Fig 1). First, risk identification, in which the source and type of the risks are identified. Second, risk classification, in which the type of risks and the effect on the construction project are determined. Third, risk analysis in which the consequences and impact of the risks are evaluated. Fourth, the risk response, in which is decided how the risk should be handled. The entire process is thereby influenced by the risk attitude of the decision-maker.

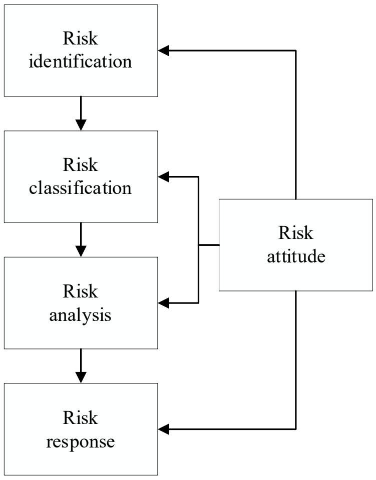

Fig 1: Risk management framework in the construction industry

As part of the risk attitude, decision-makers typically rely on their intuition, judgement and expertise. Due to an often lack of precise information or knowledge of the risks by the decision-maker, also known as bounded rationality (Simon 1997), inconsistencies and vagueness in the risk management process lead to sub-optimal decision-making (Yildiz *et al.,* 2014). Zooming in on the decision-making itself, Rasmussen (1983) explains three types of errors that can be devoted to the risk management process: (1) skill-based, (2) rule-based and (3) knowledge-based. Skill-based errors are the result of misapplying established expertise. This happens when a decision-maker knows how to proceed but accidentally makes an error. Rule-based errors are the result of applying incorrect rules, which are typically created in case a decision-maker lacks the expertise and relies on rules instead. Knowledge-based errors are the result of a decision-maker lacking the knowledge to adapt to new situations.

The uptake of digitization efforts in the construction industry shapes opportunities to use computer-based tools in support of the risk management process to lessen human error (Akintoye and MacLeod 1997; Yildiz *et al.,* 2014). According to Akintoye and MacLeod (1997), computer-based tools are superior to traditional methods. One major reason is that computer-based tools are more capable to deal with dynamic and uncertain environments in comparison with human decision-makers. Despite the theoretical benefits of computer-based risk management tools, the use of these tools is seemingly marginalized in the uncertainty fed utility locating practice.

Generally speaking, four utility locating methods exist: (1) review of utility maps, (2) reconnaissance of the site, (3) use of (geophysical) detection methods, and (4) visual inspection by exposing the utilities through trial trenches. Since exposing utilities is the only method that provides absolute certainty about the utilities location's, trial trenches are still the predominantly applied locating method. However, trial trenches only provide a local measure at the point where the trench is dug and thus require understanding about where to be employed. The effectiveness of trial trenches as a risk management approach, therefore, largely depends on the decisions made by the decision-maker on where to locate the trenches. As part of the decision, the uncertainty about the whereabouts of the utilities leaves much room for human error. Arguably, in combination with the vast number of excavations and associated damage every year, the current effectiveness of the trial trench as a risk management approach seems questionable.

Utility locating is, however, considered a highly challenging task. Utility maps are often inaccurate, incomplete, out of date, or even lacking, whereas the location of utilities is typically only registered in the horizontal plane (Metje *et al.,* 2007). The predominantly applied method to improve the accuracy and comprehensiveness of the utility information is to expose utilities by digging trial trenches. However, trenches are costly, labour-intensive, disturbing, and risk excavation damages while only providing local insights (Costello *et al.,* 2007). Therefore, decisions are made on where and how many trial trenches are dug. Since a root cause of excavation damages is insufficient utility locating before excavation activities (Talmaki and Kamat 2014), the current effectiveness of the trial trench to prevent excavation damages seems questionable. To illustrate, in 2019, over 453.000 damages in the United States (CGA 2019) and over 40.000 in the Netherlands (AT 2020) were reported. These unintentional damages not only interrupt the utility services, but also contribute to project delays, road closures, environmental damages, and fatal and nonfatal accidents (Li *et al.,* 2015; Makana *et al.,* 2018). To illustrate, Li *et al.,* (2015) investigated 10.620 pipeline damages between 1993 and 2013 and found that these excavation damages accounted for 163 fatal injuries, 650 nonfatal injuries and approximately $650 million in property damage.

Following this theoretical notion, this study explores the trial trench rationale to assess how effective the method is currently applied by human decision-makers when compared to a computer-based tool. In specific, this study examines the Dutch utility sector, which primarily uses the combination of utility plans verified by trial trenches in their locating practice. Dutch legislation hammers on the requirement of having an accurate location of utilities at excavation sites, whereas a directive serves as a guideline for safe excavation nearby utilities in practice (ter Huurne *et al.,* 2020). Neither the legislation nor the directive, however, prescribes on which locations to dig trial trenches.

RESEARCH METHOD

The effectiveness of the trial trench method has received limited attention in construction management literature. Therefore, an exploratory research approach was considered most effective. In specific, this study conducts a qualitative comparative case study to gain insights into the topic investigated (Yin 2014). The empirical setting comprises three utility localization cases in the Dutch utility sector. In each case, the utility localization practice was carried out by a contractor, by order of the client, the utility owner. All three cases knew different contractors and utility owners. The trial trenches observed were dug as part of the investigation of the construction site before the actual start of the work. For all three cases, the main purpose of the project was to install new cables and pipes.

Data were collected by observing the trial trench method and conducting interviews with the decision-makers of the trial trench locations. During the observations, the researcher also had unstructured dialogues with the practitioners on-site. The dialogues provided additional clarification of the actions performed. The observations took, depending on the case, one or two full working days. In advance of the observations, the researcher conducted semi-structured interviews with those in charge of the decision-making process regarding the trial trench locations, respectively being project managers, engineers and foremen. Via both the observations and the interviews, insights were acquired into the risk management rationale from both the operational and managerial perspective. All participants were informed about the purpose of the research and the procedures to be undertaken before the data collection, allowing the practitioners to make an informed decision on their willingness to participate in the research. Besides, participation was entirely voluntary and all collected data was anonymized.

After data collection, the risk of excavation damage on the construction site was calculated via a computer-based risk analysis tool. The computer-based tool used in this study is a continuation of the work of Racz (2017a; 2017b). The tool incorporates expert knowledge to calculate risk scores. Multiple parameters obtained from the fieldwork were used for the calculation, including the utility type (e.g. gas or electricity), the utility material, the type of planned construction activities at the site (ranging from low risk to high risk) and the type of area the activities took place (e.g. the type of land use and type of soil). By creating a grid on the utility maps, the tool calculates the corresponding risk level for every single square of the grid. The risk is calculated by multiplying the probability of damaging the utilities with the consequences of the damage. Consequences are from economic, environmental, and health and safety-related nature. This study does not further elaborate on the development of the computer-based tool, but rather focuses on its functioning.

The analysis of the data is twofold. First, the risk management framework (Fig 1) adopted from Flanagan and Norman (1997) was used as a conceptual framework to understand and explicate the risk management rationale behind the trial trench method. Second, this study quantitively and qualitatively compared the outcomes of the computer-based tool with the locations of trial trenches as depicted by the human decision-makers. The tool was used to analyse where human decision-makers depict trial trench locations and how these correspond with the risk score of the tool to highlight differences and similarities.

FINDINGS

The risk management process in none of the three cases was formalized or documented in organizational policies or protocols. The decision-makers decided on where to dig trial trenches based upon their intuition, judgement and expertise. Assessment of the risk management process against the risk management framework (Fig 1) shows the following results.

In terms of risk identification, it was found that the main source of risks is the often incomplete and unreliable utility maps. The observations and interviews show that the main motivation behind digging trenches was to verify the location of cables and pipes, in the x, y and z location. Interestingly, for all cases, practitioners mentioned that the main purpose of having that information is to check the preliminary design of the new cables and pipes against the in-situ situation. In specific, the consequences of concern are potential physical clashes between the design of the to be installed cables and pipes with the layout of the existing network of cables and pipes in-situ. One practitioner explained the need for trenches as following:

"We need to know whether there is enough free space to install the new (electricity) cables. Is the information as shown on the utility maps is correct or not? The only way to be sure is to dig a trial trench."

Regarding the risk classification, practitioners explain that clashes between a preliminary design with the layout of the existing buried utilities needed to be prevented. If the design clashes with the in-situ situation, it was explained that this typically leads to huge project delays and vast additional expenditures.

In terms of risk analysis, both the observations and interviews did not show any type of expressed analytic behaviour. Practitioners used their intuition, judgement and expertise to determine the risk-prone locations. No formalized or quantitative assessments were done to estimate the consequences of damaged utilities. When asked why particular locations were chosen, a practitioner answered:

"We always do it like this (e.g., digging trial trenches). We consult the utility maps and decide where we think the right locations for the trial trenches are".

Yet, a commonality between the cases showed that so-called 'bottlenecks' were typically a reason to dig a trial trench on that spot, showing a sense of rule-based behaviour. Such bottlenecks included amongst other crossings with the utilities, corners in the utility path, or locations where horizontal directional drilling had to be carried out. These were considered spots where the preliminary design faces the highest risk of not fitting in.

As a risk response, trial trenches were dug at the locations of marked bottlenecks. However, besides the bottlenecks, practitioners mentioned that other locations of trenches were typically not selected, being considered less important to the design. And if they were selected, they were based upon their gut feeling. In two of the three cases, this meant besides the trenches at the bottlenecks, no other trenches were deemed necessary to manage the (identified) risks. A remark made by one of the project managers for not digging more trial trench locations was:

"We take a bit of a gamble. We assume that the utilities go in a straight line from trench to trench, but of course you never know for sure. The construction site cannot simply be opened up entirely".

Another notion to be made is that during the observations, in several cases the cables and pipes were not found within the trench. Yet, no additional trenches were dug in those cases, because of constraints in the time and budget. As in one case, these constraints were illustrated by the project manager:

"The new cable or pipe needs to be installed in an as brief as possible time, with the least amount of costs".

When comparing the risk management process as carried out by practice with the computer-based risk analysis tool, the first thing that stands out is the type of risks taken into consideration. Where the computer-based tool is truly focused on the consequences of excavation damages, albeit it being from economic, environmental or health and safety-related nature, the process in practice is seemingly overlooking these types of consequences. The main risk as perceived by practice are physical classes between the design of the new cables and pipes and the in-situ situation.

Looking at the locations of the trial trenches, two differences are observed. First, the number of trial trenches is remarkably fewer than suggested by the computer-based tool as shown in Table 1. This means many risk-prone locations are not investigated in practice. At the same time, the location of trenches occasionally does not align with where the risks are the greatest as suggested by the computer-based tool. Interesting is the often-subtle difference in location, where the tool suggests a trial trench location just a few meters from the spot where the actual trench was dug in practice. In numbers, on average less than twenty per cent of the dug trenches by practice did correspond with those suggested by the computer-based risk analysis tool as high-risk.

Table 1: Comparison of the number of locations of interest for investigation

	Locations investigated in practice	Locations suggested by the computer-based tool
Case 1	10	21
Case 2	12	110
Case 3	123	2850

The findings altogether show that the location of trenches in practice often do not correspond with high-risk locations. The main reason is the risk attitude of practice. Preventing physical clashes between to be installed cables and pipes and the in-situ situation seems to prevail over preventing excavation damages and their consequences. Also, way fewer trenches are dug in practice than would be recommended by the computer-based risk analysis tool. In the next section, the findings are discussed and compared with the literature.

DISCUSSION

Preventing excavation damages is one of the main pillars in the utility sector. Worldwide various initiatives have emerged that focus on the process of careful excavation. Despite these actions, damages to utilities as a result of excavation activities are still commonplace (CGA 2019; AT 2020). This study has shown that to date, prevention of excavation damages, however, does not seem to be the main driver for practice. Instead, economical motives thrive. The risk attitude by practice thereby seems to deviate from the risk perception of the institutional setting hammering on a process of careful excavation. A shift in risk attitude by practice is likely required first before the utility sector could see a real decline in the number of excavation damages.

One possible reason for the current behaviour by practice, are the characteristics of the construction sector. The construction industry is widely regarded as a fragmented and project-based industry (Gann and Salter 2000), in which short term survival prevails over long-term durability. Localization of utilities is typically outsourced to a contractor with a fixed budget and planning in mind. The way the localization process is nowadays arranged seems to leave little room for extensive investigation of the utilities' locations. Besides, contractual arrangements may take away the feeling of responsibility by the practitioners. They are there 'just to do their job', whereas if that same party would feel the negative consequences of improper utility localization, there would likely be a bigger incentive to give more thought to the risk management process. If held accountable, those responsible for damages are only held liable for the direct repair costs, whereas the indirect costs are, by a rule of thumb, a factor twenty-nine times as high as the direct costs (Makana *et al.,* 2016). A shared responsibility to the excavation damages and their costs may stimulate a mindset of careful excavation.

The findings also show a lack of computer-based risk management tools, despite their advantages over human decision-making (Akintoye and MacLeod 1997). This study has shown that not only computer-based tools are much more effective in assigning areas of high-risk, it was also found that practice in many cases missed the high-risk areas. A such, the overall sense of security provided by trial trenches cannot always be taken for granted. Yet, investigating more locations raises another question. Trial trenches are known to be labour intensive and costly, while the method in itself is an extra excavation activity that could potentially lead to damaging utilities. Literature has therefore researched non-destructive alternatives to trial trenches, such as the GPR and vibro-acoustics (Chapman *et al.,* 2007). Incorporating said methods into the established working practices, however, may face difficulty in breaching through established practices and above all requires training and education on their use.

Instead of using computer-based tools, the findings show that risk analysis and management is based mainly upon the intuition, judgement and expertise of practitioners. The latter can be devoted to established (organizational) routines. Organizations tend to develop their activities around their existing products and processes, reinforcing a status quo (Levitt and March 1988). As such, without an incentive to change the current behaviour, literature explains routines most likely are held stable. The process of depicting locations for utility localization is thereby mostly based upon skill-based behaviour as described by Rasmussen (1983). Where such an approach could lead to a rather random approach, findings also showed that localization often occurs at common places. This could be devoted to a set of implicit rules that practitioners incorporate in practice, describing rule-based behaviour as well.

This study also has its limitations. First, the sample size of the study is fairly small. Although the findings show many similarities between the cases, the researcher believes a bigger sample is required to be able to give generalizations about the risk management approach of the utility practice. Yet, the researcher also believes that the findings show enough preliminary evidence that the established way of localizing utilities is not contributing as much to the incentive of the utility sector to decrease the number of excavation damages as desired. Second, the researcher only spent limited time with the organizations studied. Although this study developed an understanding of the ongoing activities in terms of utility localization at these organizations, a more in-depth analysis of the risk management approach for each case could have been beneficial.

In terms of future research, a confrontation between the organizations studied and the outcomes of the computer-based risk analysis tool could enhance the understanding of the perceived usefulness of computer-based risk management tools by practice, whilst at the same time raising awareness about the pitfalls of the current localization practice. At the same time, research on the practical implementation of alternative localization methods seems necessary, so that in the future more risk-prone locations can be investigated compared to what currently is feasible with trail trenches only.

CONCLUSIONS

This study explored the trial trench rationale to assess how effective the method is currently applied by human decision-makers when compared to a computer-based tool. The study showed that locations of trenches are chosen based on intuition, judgement and expertise and do not follow a predefined logic. Where trial trenches are assumed to accurately verify the location of utilities, it was demonstrated that the effectiveness of the method is questionable since (1) in comparison with the computer-based tool, the method leads to a vastly lower number of locations to be investigated, and (2) trial trench locations often do not align with where the risks to excavation damage are the greatest. Arguably, computer-based risk analysis tools may help in assisting practitioners with deciding on where to dig trial trenches.

Findings also demonstrated a risk attitude that is not primarily focused on reducing excavation damages. The main motivation behind digging trial trenches turned out to be the verification of preliminary designs of to be installed utilities against the layout of the buried cables and pipes in-situ. This current risk attitude only partially does contribute to the utility sector's ambition of reducing excavation damages. Economical motives thrive, likely being fed by the construction industry's fragmented and project-based nature. Whereas computer-based tools may help in positioning trial trench locations, a shift in risk attitude by practice is required first. This study urges practice to rethink their risk management approach and recommends the institutional setting to steer their initiatives towards establishing a mindset of careful excavation amongst the practice community.

REFERENCES

Akintoye, A S and MacLeod, M J (1997) Risk analysis and management in construction, *International Journal of Project Management*, **15**(1), 31-38.

AT (Agentschap Telecom) *2020 WIBON En Schade Door Graven*, Available from: https://www.agentschaptelecom.nl/documenten/publicaties/2020/04/21/infographic-wibon-en-schade-door-graven [Accessed 3 April2021].

CGA (Common Ground Alliance) 2019 DIRT analysis and recommendations 2019, Available from: https://commongroundalliance.com/Publications/Media/DIRT-Report/2019-DIRT-Report [Accessed 3 April 2021],

Costello, S, B, Chapman, D N, Rogers, C D F and Metje, N (2007) Underground asset location and condition assessment technologies, *Tunnelling and Underground Space Technology*, **22**(5-6), 524-542.

Chapman, D N, Rogers, C D F, Burd, H J, Norris, P M and Milligan, G W E (2007) Research needs for new construction using trenchless technologies, *Tunnelling and Underground Space Technology*, **22**(5-6), 491-502.

Flanagan, R and Norman, G (1997) *Risk Management and Construction*, Boston, MA: Royal Institution of Chartered Surveyors.

Fong, S W (1987) Risk management, *The Cost Engineer*, **25**, 12-16.

Gann, D M and Salter, A J (2000) Innovation in project-based, service-enhanced firms: The construction of complex products and systems, *Research Policy*,**29**(7), 955-972.

Haslam, R A, Hide, S A, Gibb, A G F, Gyi, D E, Pavitt, T, Atkinson, S and Duff, A R (2005) Contributing factors in construction accidents, *Applied Ergonomics*,**36**, 401-415.

Jaw, S W and Hashim, M (2013) Locational accuracy of underground utility mapping using ground penetrating radar, *Tunnelling and Underground Space Technology*, 35, 20-29.

Lai, W W, Dérobert, X and Annan, P (2018) A review of Ground Penetrating Radar application in civil engineering: A 30-year journey from Locating and Testing to Imaging and Diagnosis, *NDT and E International*, **96**, 58-78.

Levitt, B and March, J G (1988) Organizational learning, *Annual Review of Sociology*, **14**(1), 319-388.

Li, S, Cai, H and Kamat, V R (2015) Uncertainty-aware geospatial system for mapping and visualizing underground utilities, *Automation in Construction*, **53**, 105-119.

Makana, L O, Metje, N, Jefferson, I, Sackey, M and Rogers, C D F (2018) Cost estimation of utility strikes: Towards proactive management of street works, *Infrastructure Asset Management*, 1-34.

Metje, N, Atkins, P R, Brennan, M J, Chapman, D N, Lim, H M, Machell, J and Thomas, A M (2007) Mapping the underworld - State-of-the-art review, *Tunnelling and Underground Space Technology*, **22**(5-6), 568-586.

Racz, P (2017a) Improved strategies, logic and decision support for selecting test trench locations, Netherlands: University of Twente.

Racz, P, Van Buiten, M and Dorée, A (2017b) Naturalistic decision-making perspective on uncertainty reduction by civil engineers about the location of underground utilities, *In*: *Proceedings of the 13th International Conference on Naturalistic Decision Making*, 174-184.

Rasmussen, J (1983) Skills, rules and knowledge; signals, signs and symbols and other distinctions in human performance models, *IEEE Transactions on Systems, Man and Cybernetics*, **13**(3), 257-266.

Simon, H A (1997) *Administrative Behaviour: A Study of Decision-Making Processes in Strategic Decision-Making Processes in Administrative Organizations 4th Edition*, New York: MacMillan.

Shevchenko, G, Ustinovichius, L and Andruškevičius, A (2008) Multi-attribute analysis of investments risk alternatives in construction, *Technological and Economic Development of Economy*, **14**(3), 428-443.

Talmaki, S, Kamat, V R and Cai, H (2013) Geometric modelling of geospatial data for visualization-assisted excavation, *Advanced Engineering Informatics*,**27**(2), 283-298.

ter Huurne, R B A, olde Scholtenhuis, L L and Dorée, A (2020) Mutual learning: A comparison between the Dutch and international surveying practices, *In*: *Proceedings of the UESI Pipelines 2020 Conference*, 372-380.

Yildiz, A E, Dikmen, I, Birgonul, M T, Ercoskun, K and Alten, S (2014) A knowledge-based risk mapping tool for cost estimation of international construction projects, *Automation in Construction*, 43, 144-155.

Yin, R, K (2014) *Case Study Research Design and Methods 5th Edition*, London: Sage