Develop a safer ground piercing method/process for fiber to the home installation

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Summary
Cable strike is one of the safety challenges that construction industry's utilities sector is facing. Such incidents can cause injury and death for operators, as well as costly repairs and compensations. Fiber4all, a Dutch company which is responsible for Fiber-to-the-Home (FttH) connection is suffering from the same problem. Despite specialized equipment, work preparation and process organization cable strikes still occur. Even though the number of such incidents in comparison to the total number of the connections is very low, stakeholders want to avoid such incidents as much as possible. An exploratory study was carried out based on the incidents' reports from January 2013 till March 2015. Our findings in this study indicate that the majority of cable strikes are associated with human errors and incorrect information in FttH installation. Apart from exploratory study, an investigation was accomplished through six interviews with operators within the FttH work environments. From operators' perspective and their experiences of incident occurrence a taxonomy of the causal factors of cable strikes was constructed. This study suggests to investigate and invest more attention into the human aspect of the system despite the initial understanding, which was more focusing on technology improvements.

Keywords:
Boring process, fiber installation, safety, human aspects

1 Introduction

Developments over recent centuries have created dense utility networks under the ground. Underground buried services represent major threat to construction works all over the world. The U.S. itself has more than 14 million miles of underground utilities and pipelines, many of which are in crowded urban locations where several lines are using the same underground space. Errors in locating excavations for installation of new cables or for repair of current utilities can lead to damage to cables and pipes resulting in costly repair, delays and personal injury (Sterling, 2000).

One current major development in The Netherlands is to provide houses and companies with high-speed data connectivity known as the installation of Fiber-to-the-Home (FTTH) networks. Reconstruction, realignment and installation of such networks in residential and populated areas require careful execution to prevent damage to existing networks.

Drilling mole (known also as a racket, piercing tool, or pneumatic mole) is the most widely used trenchless method for underground infrastructure installation such as cables and pipes. It minimizes the disturbances to the ground, and is the simplest and least expensive technique (Simicevic & Sterling, 2001).

Fiber4all (a part of Schuuring company), the contractor which is responsible for providing houses with fiber connection in The Netherlands, is using drilling mole method because of the tool size and the low disturbances to the customers' gardens. However, uncontrolled use of this boring tool can cause extensive damage to existing underground infrastructure including electricity cables, telecommunications lines, steel and plastic gas piping, potable water and sewer lines made from various materials including clay and concrete. Striking one of these utilities can create a serious threat to the operator and the owner, and consequently the repair will often cause delay and unplanned high costs. In order to minimize the risk of occurrence of such damages the research work is being conducted at the University of Twente in collaboration with Fiber4all company. By analysing the causes of the problem, a holistic solution can be suggested to prevent the reoccurrence of similar damages.

2 Case Study

In order to analyse the problem of moling or ground piercing method for fiber to the home installation, we have decided to analyse the whole system of the boring process. The system of the FttH process can be divided in three main parts; the mole (piercing tool), environment of the boring and operators. Each of these subsystems which comprises of different components, must be analysed in order to find out the main cause of the damage occurrence. The system is presented in Figure 1.

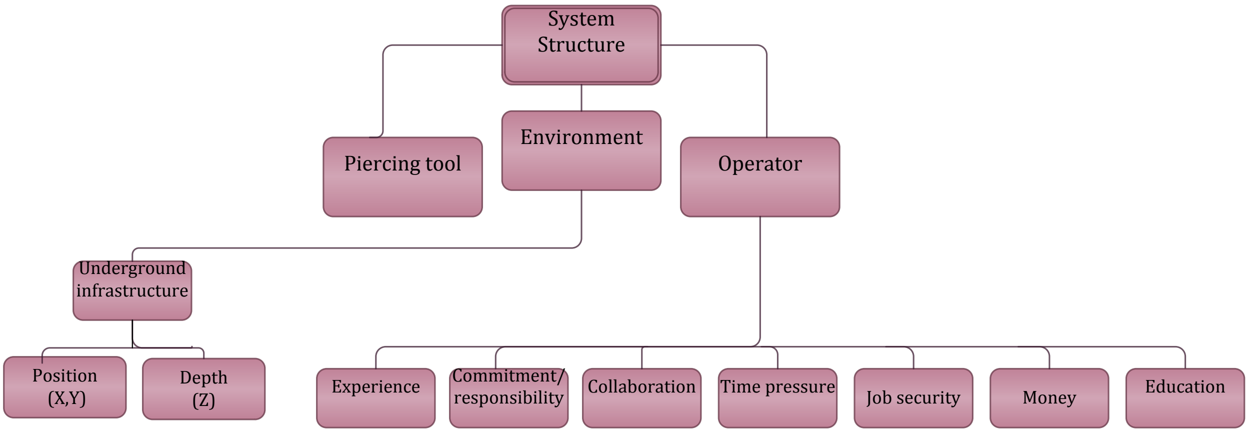

Figure 1, System structure

The boring process of the FttH connection is shown in Figure 2. The flowchart demonstrates the process of the drilling by impact mole, where the decisive moments for the operators can be seen, and used for better understanding of the failure occurrence.

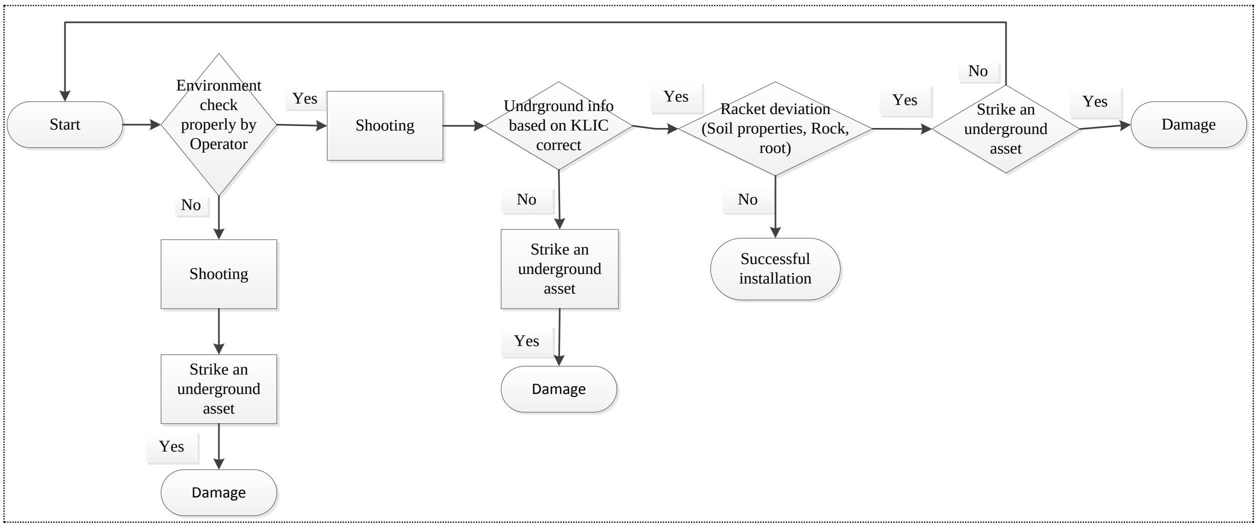

Figure 2, failure demonstration in the boring process

3 Problem analysis

The first and most important part of the solution development to any problem, is a problem investigation. Problem investigation should start with the problem analysis and should address following three questions:

- What is the problem exactly?
- What causes such a problem?
- What is the context in which such a problem is occurring?

Providing answers to these questions will help significantly during the design process for finding solutions and choosing the best solution.

There are several methods available to perform a structured analysis of failure. The main objective of all these methods is a failure prevention. Some of these methods are applied in the design phase and before any failures occur, such as the Failure Mode, Effects and Criticality Analysis (FMECA) and Fault Tree Analysis (FTA) which aim to detect possible future failure modes. Some other methods are applicable after the occurrence of a failure. The main focus of these methods is on providing a solution to prevent additional failures, either by analysing the root cause of the failure (e.g. root cause analysis—RCA) or by concentrating on failures with the highest priority (e.g. Pareto and degrader analysis) (Tinga, 2013). Therefore, for analysing the causes of damages in this project, we use the Pareto analysis which is applied after failures occurrence and is focusing on providing a solution to prevent failure recurrence.

To start with problem analysis an initial statistical analysis was performed based on the report of damages, provided by Reggefiber for 49 cities with the damage information for the period of January 2013 till March 2015 (Reggefiber, 2015). This report consists of information about damages occurred in both, main trenches and garden trenches, caused by one of the digging or drilling methods: impact mole, machine digging, hand digging and horizontal directional drilling (HDD). Since we are dealing with damages occurred in the gardens by use of the impact mole (piercing tool), only these records were extracted for damage analysis. Each damage has been reported with following detail information; date of damage, damaged infrastructure type, type of damage, activity proceeding, depth of damaged infrastructure, is damaged infrastructure laid based on KLIC, cause of damage, place of occurred damage, address, etc. After the thorough analysis of the report, following results were obtained: 575 out of 2200 total accidents were occurred in the gardens and from those, 179 were happened while the mole (piecing tool, racket) was being used.

Figure 3 shows the occurrence of damage through various activities for fiber installations.

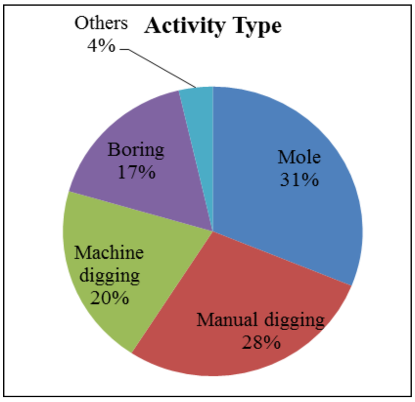

Figure 3, Damage in gardens by different activities

This pie chart reveals that 31% of the damage happened while the impact mole was being used and this surprisingly followed by manual digging with 28% which is quite a high figure. Meanwhile, machine digging caused 20% of the accidents in the gardens. Our main focus is on damage occurring by the impact mole which has the highest amount of damages in comparison to the other techniques.

Further on only the damages occurred during the moling are analysed. Figure 4 shows the causes of accidents in the gardens with the mole according to the damages' report.

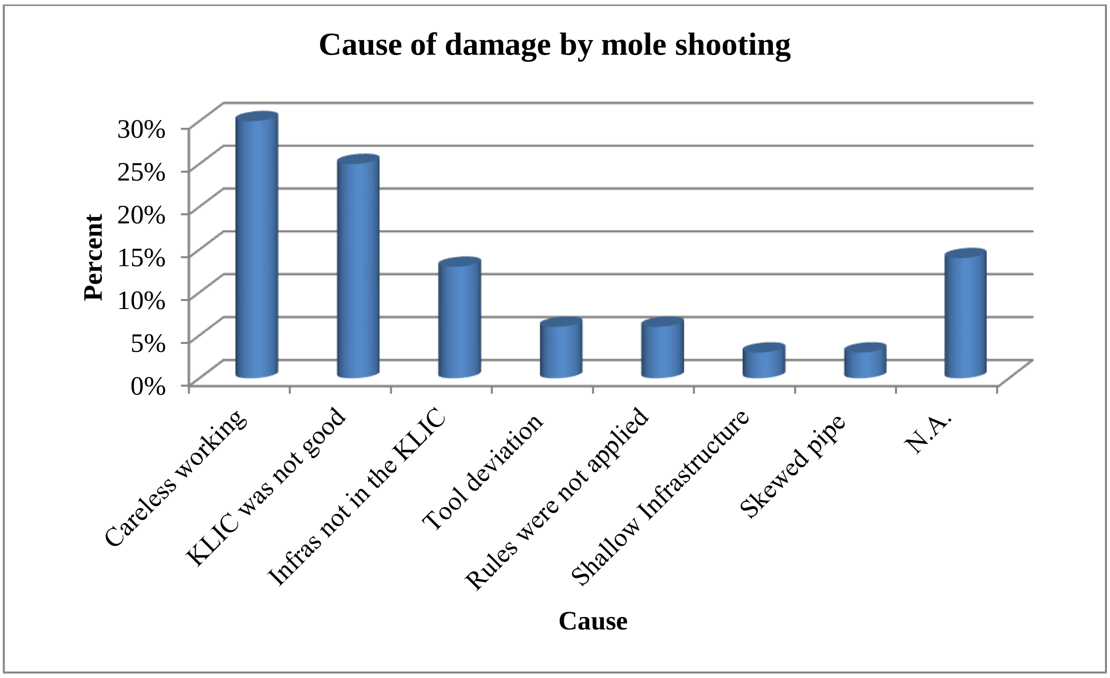

Figure 4, Cause of damage in the gardens by mole shooting

A large portion of the damage, was caused by the operators which was due to their careless working and in some cases not applying the rules. Some damages occurred by trusting on KLIC while during the work, the workers realized that either the underlying assets were not mentioned in KLIC or were not actually located at the position suggested by it.

Through the bar chart presented in Figure 4, we can see that the main cause of damage in gardens is careless working of operators (30%) and the second main cause is unreliability of the KLIC (25%), in other words, infrastructure was not in the same spatial position of KLIC suggestion. The third main cause which is also related to KLIC is that operators face the infrastructure that has not been mentioned in KLIC and trusting this information has caused 18% of the accidents. Other cases which account for small fraction of the damage are; the impact mole has been deviated from its intended path by hitting the hard objects (6%), the operators have not followed the rules of the instruction (6%), the infrastructure were shallow (3%) or the pipelines were skewed (3%).

Figure 5 from the record of damage shows that only 45% of the underground infrastructures were laid in the position recorded in KLIC and 41% of them were not. This means that civil workers increase the probability of the damages by over trusting the information in database, which in 40% of cases is not correct.

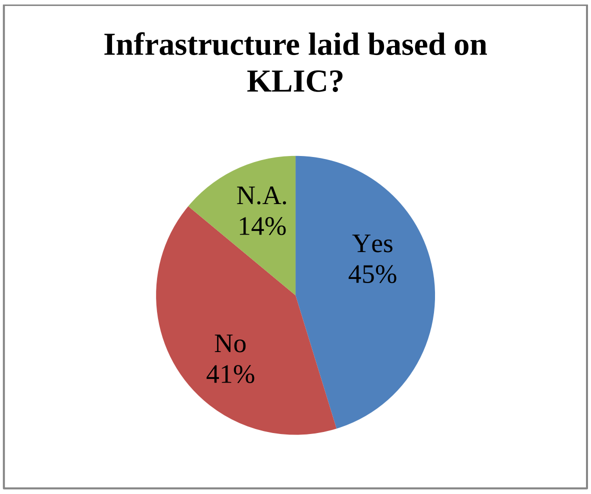

Figure 5, was underground infrastructure based on KLIC?

Following the previous chart, chart in Figure 6 confirms that in 54% of the cases the damage incidence is blameworthy. Through this figure, it can be stated that in over 50% of the cases, the damage occurrence is blamed on operators, because of their careless working and over trusting KILC.

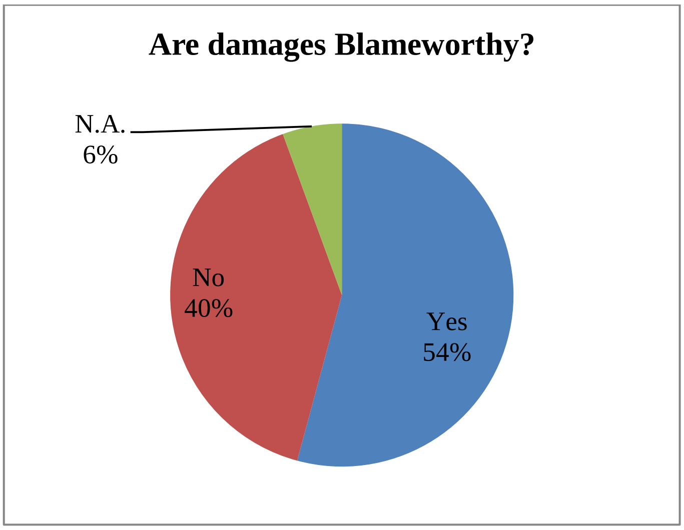

Figure 6, was damage blameworthy?

In Figure 7 accidents which have been caused by the same or similar cause, have been categorized in one group. For instance, *the information from KLIC was not correct* and *infrastructure was not in KLIC at all*, have been put together in the category of *KLIC*. *Careless working* and *rules were not applied* have been put in the category of *operator*.

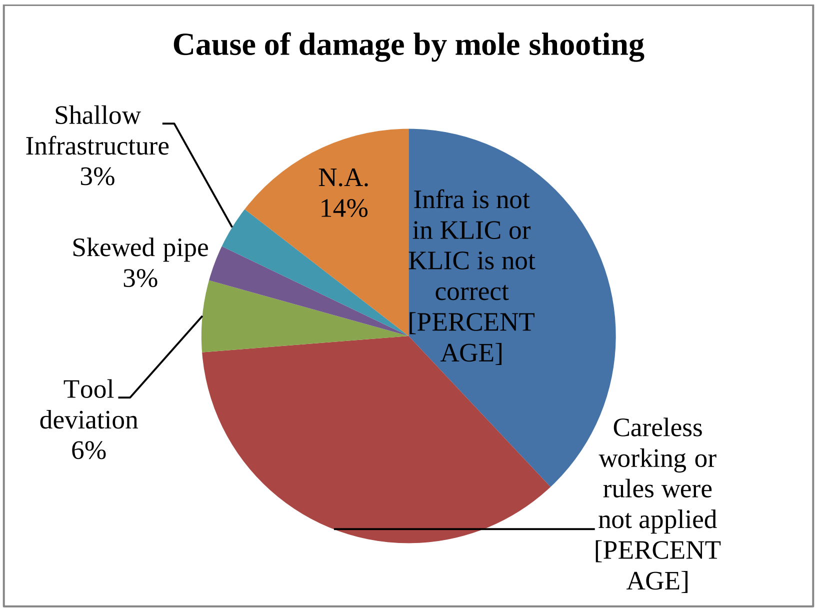

Figure 7, Cause of damage in the gardens by the impact mole

As the pie chart above shows 38% of the accidents is due to unreliability of the KLIC, either by information not being correct or by not mentioning the existing infrastructure at all. This figure is followed by operators which accounts for 36% of the accidents. Only 5% of the damage has been occurred by tool deviation which can be counted as tool caused damage. Only a small portion (3%) of the accidents are caused by skewed underground pipes.

Based on

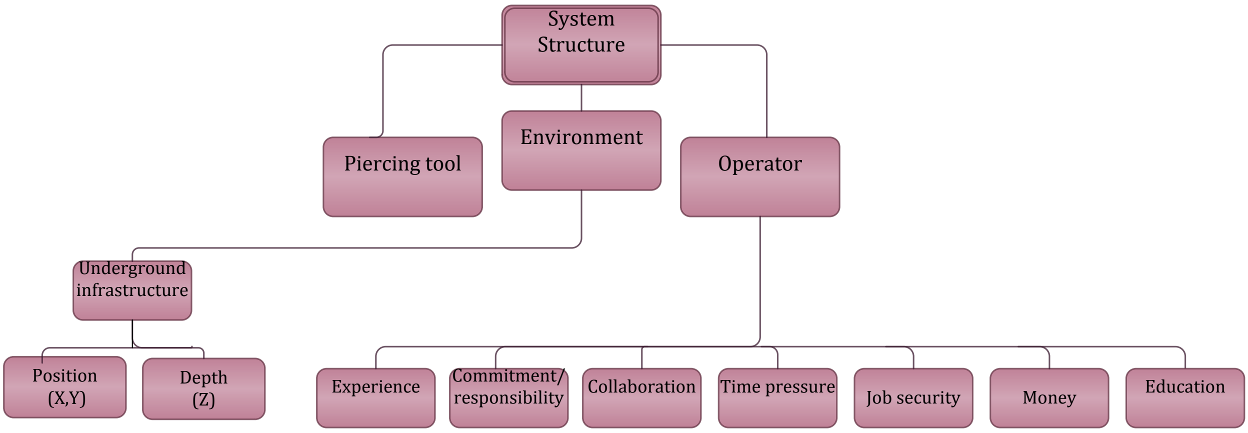

Figure 1 which described the whole system, we can group KLIC (which gives information about the underground assets), skewed pipes and shallow infrastructure as environmental component of the system and these three account for 44% of the accident’s cause. Table 1 shows the three environmental components and their effect on the damage.

Table 1, damage caused by the system components

Component	Reason	Percentage
Impact mole	Tool deviation	6%
Environment	KLIC is not correct,	44%

	Infra is not in KLIC, Shallow infrastructure, Skewed infrastructure.	
Operator	Careless working, Not following the rules.	36%

3.1 Application of Pareto Analysis

Pareto analysis focuses on the problems that propose the greatest potential for improvement, showing their relative frequency in a descending order. The Pareto analysis is applicable to rank such improvement for complex systems. In complex systems, various failures harm the operation of the system in different ways.
Based on the Pareto analysis 20% of the sources are responsible for 80% of the problem. It is to say that there are few vital causes against the many trivial causes. Therefore, this top 20% of the sources must be point at in order to have an improved system and reduction in repair costs. In other words, Pareto avoids shifting the problem where the proposed solution erases some of the causes but deteriorates others (Tinga, 2013).

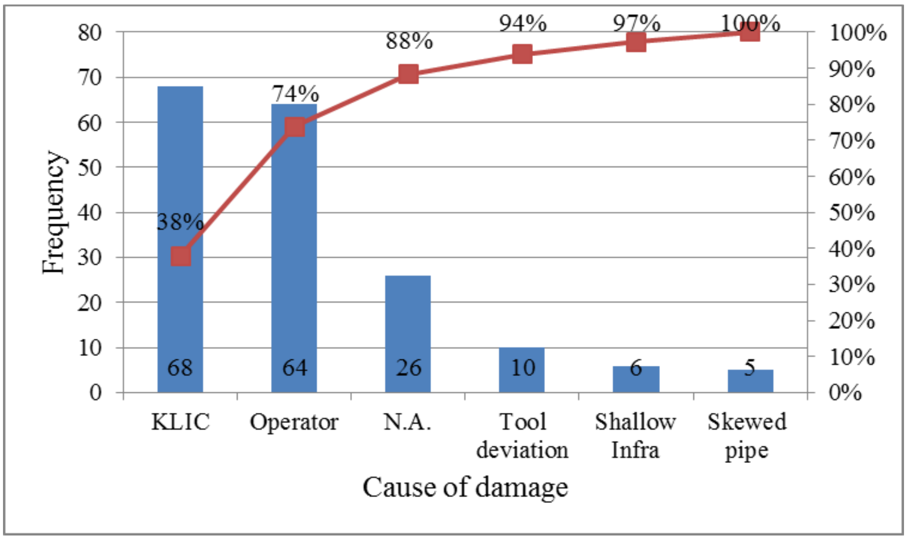

Figure 8, Pareto analysis for causes of damage

The digging (shooting here) should be started when the situation is completely clear. But from the failure analysis we figured out that sometimes (about 36% of the cases) operators start the boring process before making sure about the safety issues. According to Robert McFarlane that says “Reputable studies have concluded that as much as 75% of downtime is the result of some sort of human error” (Bigelow, 2011), our result also is conforming his statement. Moreover, failure analysis is not about identifying the person who caused the failure and punishing him but understanding why he did the wrong thing and correcting it.
According to the statistical calculation of the Pareto analysis which has been displayed in Figure 8, 74% of the failures in the gardens are caused by both unreliability of the KLIC and operators of the impact mole. It means that the operators and KLIC are the main causes of the underground excavation damages.

4 Exploratory study on human errors

To have a better understanding of the human activities during the work process and find out the reasons why cables are stroke mainly and why human errors are made, six interviews with the operators were undertaken. Through these interviews and going to the detail of the process, we figured out few reasons for cable strikes. These finding have been shown in a schematic Figure 9.

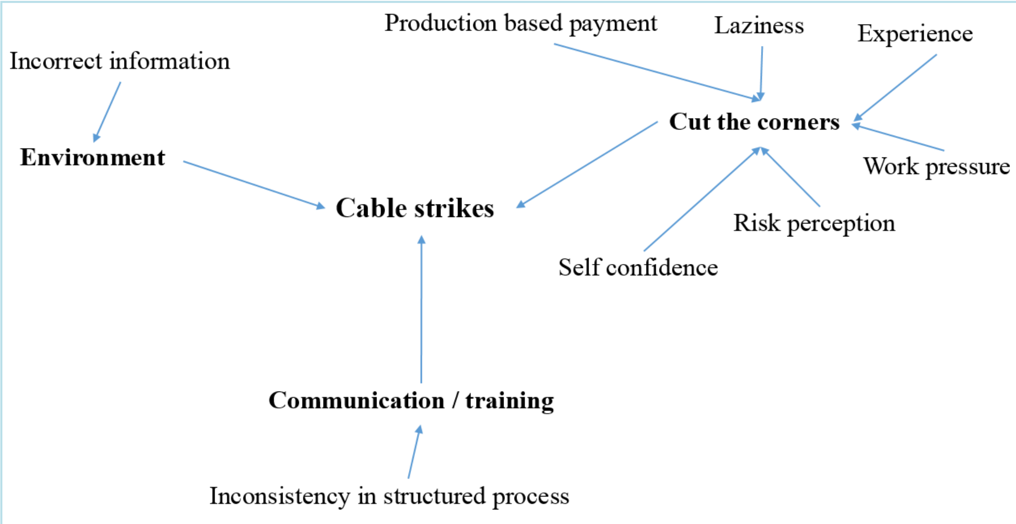

Figure 9, Causal factors of cable strikes

5 Outlook

In order to address the problems, a first proposal for improved practice is developed. This approach requires taking into consideration both human factors and work structure for a safer installation. A standardized procedure with three check points (before the installation, during the installation and after the installation) must be established, as following:

1. Insist on structured instruction/information for operators before they start their work.
2. Insist on standardized work procedure that every qualified operator must follow step by step during the boring process.
3. And a final report should be submitted with detail information of each connection that reports whether everything was according to the procedure or not and if not what went wrong.

Structured instruction and procedure should be certified through a legal organization such as CROW (an independent research organization in the field of infrastructure, public space and traffic and transport) which controls the quality of the proposed procedures.

6 Conclusion

According to the statistical calculation of the Pareto analysis, 74% of the failures in the gardens are caused by both unreliability of the KLIC and operators of the impact mole. It means that the operators and KLIC are the main causes of the underground excavation damages while at the very beginning of this project, it was assumed that the tool is causing the majority of the damages. In other words, if the operators work cautiously, prevent disruptions and control the production pressure alongside, following the instruction based on the accurate and trustworthy KLIC, the failure occurrence will decrease dramatically. Moreover, based on the exploratory studies, we found out the cable strikes associated with human errors occur when they cut the corners which comes from work pressure, production based payment, experience, self-confidence, risk perception and laziness. So in order to have a safer system we need to improve the human aspects of the system rather than developing new and expensive technologies.

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