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Techniques for reducing planned Customer Minutes Lost

KWR Watercycle Research Institute

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1 Introduction

1.1 Motivation

Most drinking water companies have large-scale replacement projects as do other network operators, such as gas and sewer owners. Even though the companies strive to work together to minimize some nuisance for the customers and the public, these projects inevitably involve nuisance such as disruptions to supply. As the number of replacement projects is expected to increase over the next decades due to the ageing networks this type of nuisance as well as the total replacement costs are expected to increase.

The drinking water companies look for innovations that keep the nuisance for customers within acceptable limits while keeping the costs at the same level or lower. Preferably, new techniques are sought that reduce both nuisance and costs.

An important nuisance is the interruption of supply, expressed as customer minutes lost (CML). CML is influenced by the number of disruption events, duration of disruption events and number of affected customers. This report focuses on the reduction of planned CML (due to planned maintenance and rehabilitation) by shortening the duration of events or the number of affected customers.

1.2 Goal

The goal is to make an inventory of techniques and their effects on the reduction of planned CML and costs and assess the results of a pilot study with one or more suitable techniques.

1.3 Approach

In Chapter 2 CML is defined and CML data from the different companies are analysed to establish the type of activities that are dominating the total planned CML. This provides insight into the type of techniques that have the highest potential in reducing planned CML.

In Chapter 3 an inventory of techniques is provided based on a literature and internet study and interviews with manufacturers and drinking water companies. These techniques are described in terms of type of technique, applicability, costs and effect.

In Chapter 4 an evaluation framework and the results of the pilot evaluation are described. The resulting CML reduction is calculated. The evaluation also gives an overall description on performance and hence, does not focus solely on CML.

In Chapter 5 the results of Chapters 2, 3 and 4 are combined:

1. The different techniques of Chapter 3 are described in terms of effect on CML, i.e. effect on duration of disruption events, number of disruption events and number of customers affected.
2. Then the main contributors of planned CML in the companies are combined with the CML reduction as calculated from the pilot study to estimate the potential of different (combinations) of techniques.
3. Finally, aspects of weighing the different scenarios and techniques are discussed.

In Chapter 6 conclusions and recommendations are provided.

2 Background of CML

2.1 Definition of CML

The Dutch water companies defined substandard supply minutes as the annual average number of minutes per customer that (Blokker and Geudens, 2014; Blokker et al., 2005):

- Supply is interrupted: this occurs when the customer receives no water from the tap. No distinction is made between different times of the day or if the interruption is at the request of the customer. This aspect has been incorporated in the Dutch benchmark. This is the part that is the actual customer minutes lost (CML).
- Water has insufficient pressure: there is no precise definition when pressure is insufficient. In The Netherlands we use the norm that CML due to insufficient pressure occurs when the pressure is between 50 and 200 kPa for any customer. The norm in the UK is slightly different, as long as water comes from the tap, no CML is counted. This aspect is not in the Dutch benchmark, but several Dutch water companies use this as a performance indicator.
- Water has insufficient quality: this occurs when the supplied water does not meet the standards demanded for chemical, microbiological, operational and aesthetic parameters. This includes time during boil notices. However, it is a principal choice to include these or not. If included, boil notice can be included using the actual consumed volume, resulting in a 3% count (based on research that less than 3% of all supplied drinking water is used for food preparation, coffee, tea and drinking water). When boil notices occur during periods of interruption of supply, these periods should be counted as one. This aspect is not used today by the Dutch water companies as a performance indicator.

CML is then defined as:

$$\text{CML} = \frac{\sum_{i=1}^{n} T_i * K_i}{\sum K}$$

Where i represents any specific occurrence of CML, n is the total occurrences of CML in a year, T_i represents the duration of CML of occurrence i, K_i is the number of customers affected by occurrence i and ΣK is the total number of customers of the water company.

A difference between The Netherlands and the United Kingdom is that in the UK CML is only counted for events with a duration longer than 3 hours, whereas in NL each minute counts.

This means that CML is influenced by:

A. Number of CML events;
B. Number of customers affected by any single CML event;
C. Duration of any single CML event.

This means that techniques for reducing CML can focus on reducing any of the above.

2.2 CML at the companies

In 2012 the Dutch companies had on average 5:57 minutes of unscheduled interruptions to supply, compared to 7:35 minutes in the benchmark of 2009. In 2012 the average duration of scheduled interruptions was 9:30 minutes compared to 9:24 in 2009. In total this means a CML of 15:27 minutes for the year 2012 on average for all Dutch water companies. There is a tendency for the companies to increase replacement investments due to the aging network (VEWIN, 2013).

Dunea reported in 2012 20:18 minutes of CML of which 87% was planned. This consisted for the largest part on activities in the distribution network, but which type of work is not specified. During replacements of distribution pipes Dunea usually locates the new pipe in the same trench as the old pipe.

PWN has not provided data with which a more in depth analysis can be performed. The data in Table 2-1 are from the benchmark of 2012 (VEWIN, 2013).

Waternet reports for the year 2014 14:01 minutes of CML (Table 2-1). The top 3 causes of planned CML account for 86% of all planned CML in 2014 (9 minutes). The remaining 14% is caused by malfunctioning of main taps, changing of water meters and replacement or repairs of service connections. Of these principal causes of planned CML the average number of customers affected by a CML event was:

1. Valve replacements: 118
2. Hydrant replacements: 100
3. Replacement of distribution pipes: 77

For Waternet techniques for reducing CML will most likely need to focus on reducing the CML when replacing valves, hydrants or distribution pipes. From these numbers it is unclear if the focus should lie on reducing aspects A, B or C (the number of events, the number of customers affected, the duration of interruption). As the number of events is assumed to increase over time, the focus would be more on aspects B and C.

Evides reported 17:07 minutes of CML in 2012 (Table 2-1). For the main cause of planned CML (the replacement of distribution pipes) the average number of customers affected by a CML event was 61.

Anglian Water reports a CML of 19:48 minutes in 2014 (counted for all events with a duration of at least 3 hours), which consisted of planned, unplanned CML and CML caused by third parties. The company aims to reduce this to 12 minutes in 2017-2018. Most of the CML is caused by unplanned events. The company aims to have more planned activities, but one of the reasons for low planned CML is also the approach to replacements. Where in the Netherlands replacements are generally carried out by opening a trench, removing the old pipe and replacing it with a new pipe (either in the same trench or in a new trench and either using a bypass or not), the approach in the UK is to use HDD (horizontal drilling) and leaving the old pipe where it is. Also, in the UK it is very common to install alternative water supplies such as tanks or overland hoses to minimize interruptions.

The Dutch companies usually install a bypass when having to use the same trench for both old and new pipe. Depending on circumstances, such as traffic or weather conditions this bypass may be overland or buried. Dunea always buries the bypass.

The interesting techniques for reducing CML are similar for Evides and Waternet, because the principal causes of CML are the same. There are some differences however:

- The number of affected customers for planned CML events is for Waternet on average larger than for Evides.
- The planned CML of Evides is very much determined by replacement of distribution pipes, whereas for Waternet the replacement of valves and hydrants is very important. This is partly due to a difference in approach, driven by the external

environment. Evides locates the new pipe in the same trench as the old, whereas Waternet mostly locates the new pipe in a new trench. When comparing the replacement of distribution pipes of Waternet and Evides, it can be noted that the CML for Evides is ca. 2.5 times larger, but aspect B (number of customers affected) is slightly smaller (25%) for Evides. The difference is therefore most likely due to aspect C (duration of interruption). Also, there is a difference in focus between different types of work due to different problems in the networks in both areas; which may mean that aspect A (number of events with supply interruption) is also a reason for the difference in CML.

Table 2-1. Overview of CML per water company (D: Dunea, P: PWN, W: Waternet, E: Evides, A: Anglian Water). The blank spots were not provided.

		D (2012)	P (2012)	W (2014)	E (2012)	A (2014)*
CML_{total}		20:18	16:30	14:01	17:07	19:48
$CML_{planned}$		17:39	11:52	10:24	9:48	
Top 3	Replacement of distribution pipes			3:26 (1st)	8:55 (1st)	
	Hydrant replacements			2:54 (2nd)	0:12 (3rd)	
	Valve replacements			2:36 (3rd)	0:23 (2nd)	

*only events that last at least 3 or more hours

2.3 Trends

All companies have redefined their policy on section size over time. For example Dunea currently reduces its design criterion for section size from on average 200 customers to 100 customers per section, or 1000 meters. In practice sections vary in size when performing replacements, with older sections often being smaller (<80) with many valves.

Anglian Water does not have a policy for how many customers a section can contain, but has a policy of a valve every 500-1000 meters.

Most companies shift to more planned CML. This is a result of a better insight into the condition of the network and a transition towards risk-based asset management. Also, there is a tendency for more pipe replacements due to the aging network. This is actually one of the main reasons for the interest in keeping CML low, while balancing unplanned and planned CML and costs.

3 Techniques for reducing planned CML

3.1 Overview

Reducing planned CML can be done in three ways or combinations of them:

A. reducing number of events,
B. reducing number of affected customers,
C. reduce the duration of interruption.

Techniques are most effective in case of a proper network design, including optimal valve locations and adequate information about the location and the condition of the network and appurtenances like hydrants and valves. Reducing the number of customers per isolated section by means of a cost effective network design and keeping well-functioning valves is one approach which takes some time before the effect is noticeable.

Water companies, contractors and suppliers have been searching for and have done experiments with additional methods and techniques which are potentially efficient and cost saving. Smart equipment, working methods and techniques can temporarily reduce pressure locally for online installment.

3.2 Balloon valves

Balloon valves are a technique in which a balloon is inserted in a pipe under pressure, after which it is inflated to close off the pipe. This allows for small sections of pipe to be closed instead of having to close valves (which would lead to isolation of e.g. sections of a 1000 m or ca. 80 customers) . This reduces the number of customers affected. The technique is common practice in the gas world and emerging in the Dutch and UK drinking water networks. In The Netherlands Brabant Water, Oasen and Dunea have experience using this technique (Table 3-1).

The technique can be used in combination with a lock-joint (see also Chapter 5), overland hoses or bypasses to further reduce customer nuisance.

Table 3-1 Overview of balloon valves.

Technique	**Balloon valves**
Short description	Closing off pipes by installing balloons inside pipe under pressure
Maturity	Emerging in UK and NL
Experiences	Field experiment (Oasen, 2012) with balloon valves on a test site. Replacement works (Oasen, 2013) and removal of asbestos-cement pipes with a minimum of CML. Replacement project (Brabant Water, 2014) Replacement works (Dunea, 2015) Placement of fire and washout hydrants (Anglian Water, a few hundred hydrants) Line stop 80 and 100 mm pipes (Anglian Water, several occasions)
Applicability	PVC, AC and PE in range 80 to 200 mm and 250-400 mm The use on CI pipes is not recommended by Kleiss and co., because of risk of damage to the balloon, but provided no problems in a pilot by Dunea.

	For the use on AC pipes, the supplier has developed longer saddles to prevent bursting of pipes. Supplier is intending to develop a timesaving construction to put on and remove the longer saddles more quickly on the AC-pipes.
Method	The method consists of the placement of a saddle, after which the pipe is drilled under pressure. The equipment is fixated and the balloon is positioned in the pipe. Then the balloon is filled until the pipe is completely sealed. This can be monitored with pressure gauges monitoring both the pressure inside the balloon and in the pipe (on one end of the balloon). After use the balloon is removed from the pipe and the saddle is closed. The saddle remains on the pipe and can be reused. The balloon placing tool is made from stainless steel without the use of oil or grease. After use the tool and balloon are disinfected.
Costs	± € 10.000,- for a complete set including balloons
Pro's	Reduces the number of customer affected by a disruption compared to closure with valves, can easily be used in combination with other techniques, such as lock-joints, or overland hoses to further reduce CML. Technique can be easily incorporated in drinking water protocols, such as the hygiene code and is feasible for fitters with standard training.
Cons	Preparation and use takes about one hour, which makes it less suitable for use during unplanned events. Equipment is quite large and can be hard to position in cases where pipe is located near obstacles, such as cables or trees.
References	Kleiss and co. (https://www.kleiss.nl/) Sarco Stopper (http://www.sarcostopper.com/) https://www.oasen.nl/nieuws/Paginas/Fotoverslag-Oasen-voert-proef-met-gasblazen-uit-Artikel.aspx http://www.vanvulpen.eu/nl/nl/5/gasblaastechniek-succesvol-ingezet.aspx

Figure 3.1 Overview of equipment to install balloon valves (www.kleiss.nl)

3.3 Freezing

This technique closes a pipes by freezing the water inside. The technique is common practice in the Netherlands and used primarily for service connections, i.e. small diameter pipes. Anglian Water used this method for several years to isolate fire and washout hydrants.

Table 3-2. Overview of cryogenic freezing.

Technique	**Cryogenic freezing**
Short description	Freezing water inside the pipe with cryogenic equipment
Maturity	Common practice
Experiences	Isolating fire and washout hydrants (Anglian Water, several years)
	Copper service connections 5-28 mm (Waternet, Evides, Dunea)
Applicability	Up to 300 mm (copper, nitrogen)
	Up to 90 mm (CI and copper, electrically)
Method	Electrically: position equipment on section to be frozen
	Nitrogen: wrap pipe with jacket and inject nitrogen
Costs	Relatively high to isolate hydrants and washouts
Pro's	Quick and relative low costs at small diameters.
	Useful to isolate part of a building with copper pipes (especially top floors)
Cons	isolating hydrants by freezing requires a service provider or trained personnel. This makes the method costly.
	the use of nitrogen requires specific knowledge and safety precautions
References	a.o http://www.newmantools.com/cob/accufreeze.htm
	http://www.pompen-service.nl/dichtvriezen.html

3.4 Spade valves

Spade valves are temporary steel valves that are used in many circumstances.

- Under pressure installation of hydrants;
- Under pressure connection of small diameter (up to 75 mm) pipes;
- Under pressure connection of bypass or overland hose;
- Installed in a saddle for in-line closure of PE pipes;
- In a plastic lockable connection at renewal projects;
- As an access point into the main for insertion of inspection equipment, sensors etc.

Examples are described in the tables below.

Table 3-3. Overview of under pressure installation of hydrants, pipes, bypasses, overland hoses.

Technique	
Short description	Under pressure installation of hydrants, pipes, bypasses, overland hoses
Maturity	Common practice (Dunea), emerging for the sector as a whole
Experiences	Dunea has used this technique for several years, primarily for installation of 50 and 63 mm PVC branched pipes and installation of hydrants.
Applicability	Saddles are available for CI, steel, PVC, AC, PE. Flanges with knives are available for diameters up to 75 mm.
Method	Placement of saddle; drilling access to main; installation of flange; installation of pipe, hydrant, bypass; opening of installed item by removing spade.
Costs	??
Pro's	Drilling under pressure without need to close off sections, easily incorporated into working protocols, such as the code for hygienic working. Fitters with standard training can use the equipment.

Cons	Only applicable for diameters 50, 63 and 75 mm PVC/PE.
References	http://www.hawle.com/ http://www.imbemadenso.nl

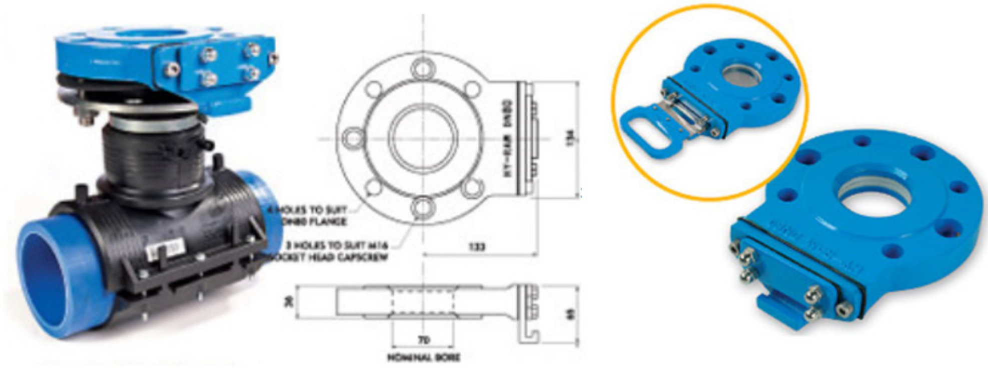

Figure 3.2 Flange closure mounted on saddle (http://www.imbemadenso.nl/).

Table 3-4. Overview of knife shutters with saddle on PE pipes.

Technique	**knife shutters with saddle on PE pipes**
Short description	Reducing customer disruption by temporarily and locally closing off PE pipe
Maturity	Innovative, earlier experiences in gas industry
Experiences	Pilot (Oasen, 2012)
Applicability	PE up to 200 mm
Method	Install saddle; position spade placement equipment; insert round spade; perform activities; remove spade
Costs	??
Pro’s	Reducing number of customers affected by disruption by being able to close off section very close to repairs, the supplier claims as benefits that it is a quick, safe method with minimal digging. The saddle remains in the network and is re-usable.
Cons	Experiences thus far are for unplanned CML, not planned. So far only tested in pilot conditions.
References	https://www.kleiss.nl

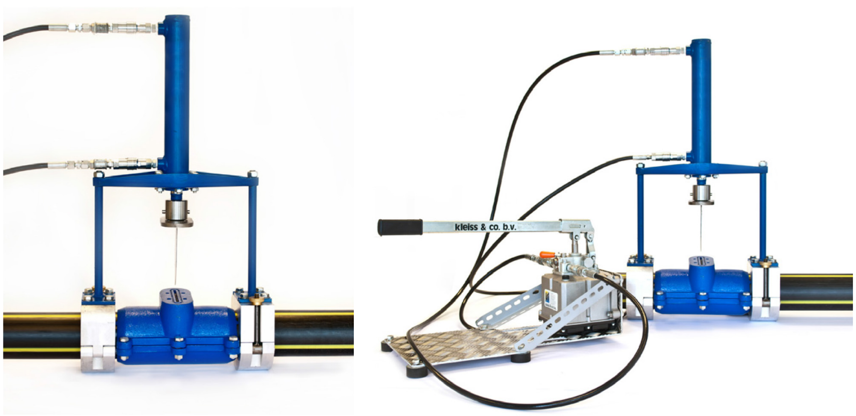

Figure 3.3 Knife shutter on PE pipe with additional equipment (https://www.kleiss.nl/assets/files/WatertoolR-Mesafsluiter.pdf)

Figure 3.4 Resulting cut (https://www.oasen.nl/nieuws/Paginas/Fotoverslag-Oasen-doet-test-met-mes-afsluiter-voor-waterleidingen-Artikel.aspx)

Table 3-5. Overview of Lockable connection with spade valve (Lock joint).

Technique	**Lock joint**
Short description	Connection for PVC, consisting of 2 restraint joints and a spade valve
Maturity	Innovative
Experiences	Pilot with renewal project (Dunea, 2015) Pilot with renewal project (WMD, ???)
Applicability	Can be used as temporary valve
Method	The Lock joint is a connection between pipes used in renewal projects. The device is installed at the end of one pipe (the spade positioning equipment is placed; the spade is inserted), where the steel spade shuts of the pipe completely. This pipe can then be fully operational under pressure. When the next section of pipe is installed, the spade is removed and the new section of pipe also becomes operational. The Lock joint is placed permanently, the spade can be reused. This allows for day-to-day production lengths with customers only experiencing a disruption during the time their section of pipe is renewed. In case this method is combined with the use of a balloon valve, bypass or overland hose, the disruption can be reduced even further. The lock-joint consists of 2 restraint joints that are certified according to KIWA specifications. All remaining parts are made from materials approved by KIWA certification standards. The application for the lock-joint to be certified as a complete product is pending.
Costs	€280,- for a diameter of 100mm; may become cheaper in future
Pro’s	Reduces number of customers experiencing disruptions, Easily combined with other CML reducing techniques, Easily incorporated in working protocols, such as the code for hygienic working, Fitters with standard training can use the device, device is reusable.
Cons	Boil notice required if service connections are installed when pipe becomes operational; The device currently has no KIWA-ATA; the device is still at the innovative stage, which means some improvements are still being made.

References	http://www.prince.nl/innovatie

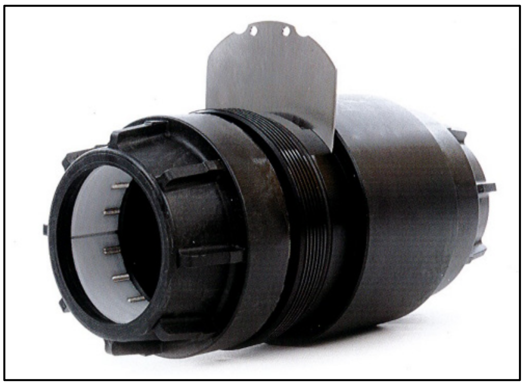

Figure 3.5 Lock joint with open cap and spade (http://www.prince.nl/innovatie)

Figure 3.6 Lock joint with open cap (Photograph taken during pilot Dunea, 2015).

Figure 3.7 Inserting spade into Lock joint (Photograph taken during pilot Dunea, 2015).

3.5 Squeezing pipes

Squeezing of pipes is only relevant for PE as this material returns to the original shape when the pressure is released. In The Netherlands PE experiences with the squeezing technique are limited to small diameters (e.g. connections), but in the UK the technique is more widespread and used for diameters up to 280 mm. Technically this is possible, but there are no experiences with the long-term remaining strength of the material. It is advisable to register these locations so that they can be monitored for leakage and bursts. Also, it is advisable to not subject a location (within a meter) to this kind of stresses more than once.

Table 3-6. Overview of squeezing technique.

Technique	**Squeezing PE pipes**
Short description	Temporary shutting PE pipes by squeezing them
Maturity	Common practice
Experiences	Often used at service pipes when broken or leaking till a new service connection is ready
Applicability	Small diameters in the Netherlands, up to 280 mm in the UK; PB connections are exceptions
Method	Bending and squeezing
Costs	None
Pro's	Quick
Cons	Temporary and in The Netherlands only experiences with small diameters
References	

3.6 Alternative water supply

In certain situations it is required or desired to provide a water supply to properties, for example during renewal or repairs. There are several options:

- Rezoning: adjusting the network configuration by opening or shutting valves, such that the customers receive water from a different direction. This is a technique common for the United Kingdom where the use of DMA's is widespread. In the Netherlands this works well in looped systems (primary and secondary network, and part of the tertiary network), whereas in branched networks (part of the tertiary network) an alternative water supply may be desired;
- Supply water from a temporary tank;
- Supply bottled water;
- Bypasses can be installed during the activities. In the Netherlands these bypasses are usually buried to make sure temperatures remain within the acceptable range, but not always. The bypasses are installed at the beginning of the project and removed when the activities are finished, which means that customers may receive water from a bypass during several weeks. The advantage of this method is customers hardly notice interruptions in supply, disadvantages are the amount of waste (material), the fact that trenches need to be opened several times for one section of pipe and the costs.
- Overland hoses: overland hoses are used to bridge sections without service. They are especially useful in locations where the customers "behind" the closed section cannot be supplied by rezoning. Especially in combination with other techniques, such as balloon valves or lock-joints, these overland hoses are useful to minimize disruptions. Overland hoses can be used to replace a main, but also a single service connection. This does not work with hydrants with back-flow prevention.

Table 3-7. Overview of alternative supply.

Technique	Alternative supply
Short description	Temporary water supply
Maturity	Common practice
Experiences	Most companies use this technique in several ways
Applicability	Useful for renewals (overcome stretches of renewed pipe or dead ends), repairs
Method	Connection with saddle and drilling under pressure use of hoses or pipes
Costs	Appendix I
Pro's	Reduce CML in case of isolated customers
Cons	Expensive, only usable for activities of short duration (or, in the case of bypasses multiple opening of trenches causing additional disruption to customers), costs, possible waste (bypass)
References	

3.7 Valve maintenance

In the case of unplanned or planned CML, when relying on valves to close off a section of the network, it is important that the valves operate as they should. This is not always the case, some valves are difficult to reach or move, others do not close off the pipe completely. If this is the case, the next valves need to be closed, which enlarges the section affected by disruptions.

Water companies apply valve maintenance to avoid this problem, but this is expensive. It is important to know which valves are critical for the operation of the network. Suppose each valve has a reliability of 90%. If a section on average is closed with 2 valves, there is a 19% chance that one of the valves is malfunctioning. If a section is closed by on average 4 valves, there is a 41% chance that one or more of the valves is malfunctioning. Increasing the reliability of 20% of the valves to 95% leads to a CML reduction of 5% if you choose those 20% at random. If you optimize those 20% of the valves according to network performance, age of the valve, number of customers in a section and so on, CML can be reduced by 8,5% (Blokker et al., 2011). OptiValves (https://www.watershare.eu/tool/optivalves/start/) is an optimal valve maintenance tool that allows for better understanding of how valves affect the performance of the distribution system and helps to target maintenance towards the most important valves.

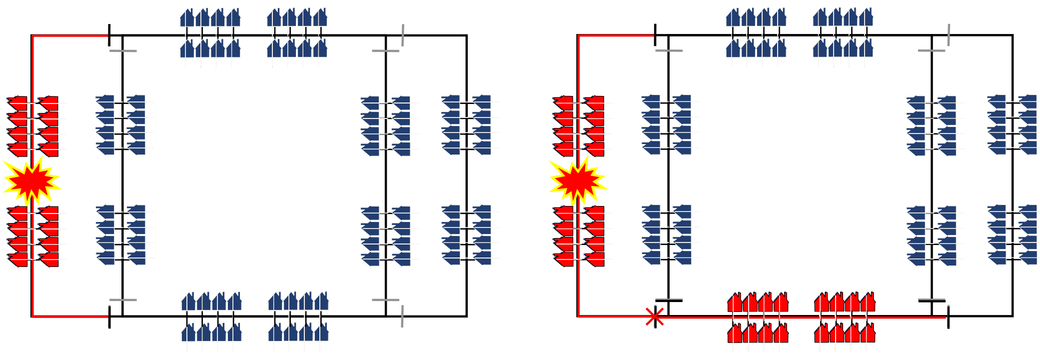

Figure 3.8 Importance of valves. Left figure shows a section close off by valves, the right figure shows the effect of a failure at one of the valves. Another 3 valves need to be closed and an additional section is disrupted affecting many more customers and leading to higher CML.

4 Results of the pilot with balloon valves and lock-joints

4.1 Pilot description

4.1.1 Goals

Besides reducing planned CML, the pilot was used to test a method to:

- Improve customer satisfaction
- Reducing costs

4.1.2 Location

The pilot was located in the residential area Meerburg in the city Leiden. Details of the pilot are found in Table 4.1. The area represents a typical renewal project for the water company Dunea with regards to pipe diameters, materials, service connections, pipe layout, nuisance of surroundings and required network adjustments (removal and placement of hydrants, valves, changes in network geometry).

Table 4-1 Details of pilot location.

	Spaarnestraat	Maasstraat	Zaanstraat	IJsselkade
Material	AC and CI	AC	AC	AC and CI
Diameter	100 mm	100 mm	100 mm	100 mm
Int. pressure	0.28 MPa	0.28 MPa	0.28 MPa	0.28 MPa
Depth	1-1.10 m	1-1.10 m	1-1.10 m	1-1.10 m
Number of residential buildings	22 terraced, 3 flats (12 apartments in total)	14 terraced	22 terraced, 1 flat (4 apartments)	5 terraced, 8 flats (32 apartments in total)
Surface coverage	Pavement	Pavement	Pavement and road	Pavement
Geometry	Removal of 2 hydrants and 1 valve	Removal of 2 valves, addition of hydrant, 1 additional connection	Removal of 2 hydrants, 1 new hydrant, 1 secondary pipe to tertiary	2 new hydrants, removal of 4 hydrants
Specifics		8 trees with roots in the way	New location under pavement, 2 road crossings	Many cables (up to 15) in the way

4.1.3 Approach

The traditional approach for this area would be to first install a bypass at approximately 0,3 meter depth before replacing the pipe in the same location as the existing pipe. This would mean that in each location trenches would need to be dug 3 times. Once to install the bypass, once to replace the pipe and once to remove the bypass. In addition, holes would need to be dug twice to change the service connections, once from the existing pipe to the bypass and once from the bypass to the new pipe. Once the new pipe is installed, the new pipe is pressure tested and checked for bacterial reliability. Advantages of this method are:

- Besides the transitions of the service connections (2 times 15 minutes as a minimum) no additional CML is required for a standard pipe renewal. For other activities, such as renewal of a valve or changes in connectivity additional CML may occur.
- The daily activities do not have to be strictly planned as the consumers are never without water during the activities.

The disadvantages of this method are:
- Nuisance for the public as the trenches have to be dug several times in any one location;
- The costs of digging several trenches and the bypass itself;
- Waste from the bypass, which is used once, Figure 4.1.

Figure 4.1 Waste from using a bypass.

The alternative method used in this pilot is called the HelKo method by Dunea (https://www.youtube.com/watch?v=4zcV5MuAWts) and combines the use of balloon valves and lock-joints. A detailed list of working steps is given in § 4.2.2. The advantages of this method are:
- No costs for a bypass;
- Less nuisance of the public by only using one trench for any one location;
- CML is limited because of the use of balloon valves instead of valves limiting the number of customers affected.
- No waste products from the bypass.

The disadvantages are:
- Boil notice during 4 days;
- No pressure testing possible;
- Strict daily planning required: where you place the balloon valves, you need to replace the pipe the same day. No room for delays.
- The CML may increase because of not using the bypass.

Because no bypass is used this means that customers will be affected by a considerably longer interruption of water supply, in general around 4 hours. But, as the segment is closed with the balloon valve instead of a regular valve, the number of people affected by an interruption is much smaller. Also, customers will experience only one interruption, instead of each time a district is closed off. Another advantage is that people have no water only when the work is done in their street, and are not shut off due to remote (and out-of-sight) work. The total effect on CML is evaluated in this pilot.

The pilot including all the activities was performed by employees of Dunea, no contractors were used.

During the pilot the location of the new pipe was measured digitally each day, hence the revisions were added to the pipe information system on a daily basis. This saved the work of checking data from a contractor in a traditional approach, and generated more reliable results. However, measuring in this way took more effort from the water company as the people doing the measurements had to drive up to the pilot site every day.

4.1.4 First findings of Dunea

The pilot was considered a success by the water company. The activities were finished one month ahead of schedule and the fitters experienced no problems during the activities. The costs were comparable to the costs of the traditional approach in spite of extra costs resulting from this project being a pilot. The expectation is that in the future this technique has the potential to become cheaper and take less time and/or less people on site.

The results from the customer satisfaction survey were very positive. Customers did not consider the interruption of supply a problem and there is the benefit of a trench having to be dug only once. Most customers also did not consider the boil notice of 4 days a problem.

The total resulting CML in this project was about 10% lower than the expected CML in the traditional approach. However, as this depends very much on the site specific activities it is not anticipated that this is the case in each project.

4.1.5 Pilot evaluation aspects

The pilot was then evaluated on the following aspects:

1) Technical aspects (§ 4.2):
   a) Situation assessment
   b) Assessment provisioning:
      - Water quality control (hygiene, flushing, sampling etc.)
      - Correct application and usability of techniques
      - Unforeseen elements
      - Registration in the information system
      - Duration of works
      - Combination with other work
   c) Complexity of the techniques
2) Process (§ 4.3), both in the design and the delivery stage
3) Surroundings (§ 4.4):
   a) Environment
   b) Nuisance for customers and the public
   c) Safety
4) Costs (§ 4.5)

4.2 Technical aspects

4.2.1 Situation assessment

The pipes in the area were assigned for renewal based on age, estimated condition and pipe material. According to the specifications of the suppliers, both balloon valve and lock-joint were suited for the project.

Specific issues for the renewal consisted of:

- Presence of tree roots;
- Location of the pipes underneath the road or pavement;
- Nuisance of cables;
- Possible contamination of the soil.

In preparation for the project 17 trenches were dug to check if the local situation matched data from the pipe information system as used by the water company. In a number of locations this turned out not be the case. However, the planning could be easily adapted. Since the location of the balloon valve determines the production for that day, it is important to know beforehand what to expect. For example, the occurrence of roots or a different location of a pipe (for example, underneath a paved road instead of pavement) may have influence on the achievable renewal length and hence, should be known.

4.2.2 Provisioning

Each working day consisted of the following working steps:

- Preparations:
  - Decide on the next day's production;
  - Give boil notice to the customers;
  - Manholes are dug at the beginning and end of the section;
  - Instruments and materials are prepared;
- At the start of each working day a bacteriological sample is taken from the end of the previous day's production;
- The trench is opened for the length of pipe to be replaced that day;
- Balloon valve is installed:
  - At the end of the scheduled length of pipe to be replaced that day a balloon valve is placed and inflated;
  - Once the pressure is off the pipe, the pipe is cut behind the balloon valve, the remaining pipe is closed off with an end-cap and secured with thrust blocks;
- The pipe is replaced and coupled to the previous day's production using the Lock-joint;
- The trench is closed;
- The new pipe is flushed 4 times;
- The sampling device is moved to the end of the new pipe;
- The next day is being prepared.

The activities were performed according to the standards of the code for hygienic working. In addition, both the new pipes and the lock-joints were sealed upon delivery. The balloon valve was chlorinated before use. After use the balloon valve was rinsed and dried before storing. The balloon was visually checked before use. During the replacement the pipe seal was broken and replaced by a cap, which was consequently chlorinated. After installing the new section of pipe, the pipe was flushed 4 times (standard is 2 to 3 times) with a velocity of 1.5 m/s. Samples to ensure bacteriological reliability were taken both from the new pipe and behind the balloon valve from the existing pipe. All samples were biologically tested (and approved). In addition to the checks on bacteriological quality a quality controller of the water company was present during the activities.

Before application of the balloon valve the pipe was cleaned externally and disinfected. The inside needs to be clean as well. This was no problem for the AC pipes, the CI pipes were corroded with up to 40% closure, see for example Figure 4.2. Nevertheless, all balloon valves closed the pipes off 100%, no leaks were reported. In some locations with CI the placement of the balloon needed to be adjusted, but the gear provided enough flexibility and also in these locations the close-off was 100%. This is noteworthy because the supplier does not guarantee a 100% close-off in CI pipes.

Figure 4.2 Example of corrosion in CI-pipe.

On average installing the balloon took about half an hour and the balloon needed to be kept under pressure on average for about half an hour depending on the pipe material. Cutting a CI pipe is generally faster than finding and breaking the connections for AC. As soon as the end cap was positioned on the existing pipe and the cap was secured, the balloon could be deflated and removed. During the time the balloon was under pressure, the pressure can be monitored with the pressure gauges. Two are available, one for the pressure in the balloon, one for the pressure in the pipe (which side depends on the direction of placement of the balloon). During pressurized conditions it is important to place the pressure stopper to ensure the breather valve was not accidentally opened. During pressurized conditions the balloon remained connected to the pressure pump, so that any loss in pressure could immediately be resolved.

The balloon was used 19 times (15 times on AC, 4 times on CI) and is still usable. The supplier suggests a period of use of one year.

The lock-joints were measured and added to the pipe information system, so that their position remains known.

The technique worked above expectations. No problems were reported. All fitters of the water company could use the equipment without problems. The activities were performed both under good weather conditions and in rainy conditions (no down-pours). There are a few elements that require attention:

- The seal of the new pipes was not adequate for instalment, sand and other contaminations of the site could enter the pipe, so before installing the new pipe in the trench, a new cap was placed and disinfected.
- During the use of the balloon on AC pipes some asbestos fibres were released during the procedure to drill a hole in the pipe for the balloon to enter. The fibres on the inside of the pipes were caught during the flushing procedure. The fibres on the outside of the pipe were not caught and remained in the environment. This also happens in the traditional approach when a pipe is cut or drilled.
- For the use on AC pipes, the supplier has developed longer saddles to ensure the AC pipes cannot burst. These saddles were not used during the pilot, because the AC looked strong enough. It should become more clear what the safety limits of the product are with regards to bursting of the pipe or when to use an additional (back-up) balloon, see also § 4.4.3. Experiences with the equipment from the gas industry could be used.
- The lock-joint is big and heavy to some extent. In some cases (for example with cables) there is not much room to work and this could be an issue.
- In some locations with cables the equipment for placing the balloon valve could not be installed with sufficient room to work.
- The new pipe could not be pressure tested.
- As the lock-joint consists of multiple parts and the center consists of 2 rubber rings, it is possible that these connections have a higher risk of leakage in the future than standard connections.

Figure 4.3 Example of a situation in which cables were causing problems with the use of the balloon valve.

4.2.3 Complexity

All fitters of the water company could use the equipment without problems after being showed once or twice by the supplier. The expectation is that a contractor will need to be trained in the technique and additional quality control will be necessary in case of activities performed by contractors.

4.3 Process

The preparations do not differ from a traditional approach with closing off sections by using valves and using bypasses. The method requires careful planning of the daily sections as the segment that is closed needs to be replaced the same day. In a traditional approach this is less critical. Therefore, it is important to know the situations on-site, such as nuisance factors, lay-out, materials, diameters etc.

The average daily production length was between 30 and 40 meters. Even in the areas with nuisance from tree roots and cables, daily production lengths of 30 meters were maintained. As the estimated renewal time was based on the average daily production lengths of a traditional approach, the project was finished one month ahead of schedule.

During the works the activities are markedly different than in the traditional approach using a bypass. This requires more careful planning of the achievable length of pipe renewal in a day. The new activities are no problem for the fitters of the water company and the activities can be performed according to hygienic standards without problems.

After the initial learning phase of the fitters, no problems were reported.

4.4 Surroundings

4.4.1 Environment

Some relevant aspects are:

- At any one location a trench is opened only once, instead of three times when using a bypass. This saves digging and the use of digging equipment.
- Since no bypass was used, this saved waste and transportation costs, see also Figure 4.1.
- The equipment for the balloon valve and the balloon itself can be used multiple times.
- The lock-joint is a permanent connection which may also function as valve. This suggests that less valves could be required which also means less maintenance. However, not much is known yet about the reliability of the use as valve over time, the practical aspects of using a buried valve and the optimal placement of lock-joints and valves. Therefore, it is difficult to tell if the use of the lock-joint as valve will be workable in practice.
- The asbestos fibres that are released into the environment are a cause for concern, especially when this technique becomes widespread. This should be compared to the impact of conventional techniques.

There was no calculation for CO_2 emissions or an explicit research into the sustainability of the approach.

4.4.2 Nuisance

Potential nuisance for the customers consisted of:

- Interruption of water supply during approximately 4 hours on only one day;
- Boil notice during 4 days;
- Accessibility of residences during the time the trench is open and the pavement tiling removed;
- Noise of digging equipment;
- Less parking spaces available due to equipment and cars and vans from the water company;

- Reinstalling road pavement arranged by the city Leiden after the closure of the trench (including music);
- Dirt on pavement after installment of pavement;
- Visual bother from the location where the materials are stored.

These were further investigated with the calculation of the CML and a customer satisfaction survey.

CML

The CML was calculated for this project and compared to the CML which would have occurred during a traditional approach using a bypass. The work has been splitted in replacement of pipes and the removal of a T-joint as the effects on CML are very different for these different types of work.

Table 4.2 shows the affected number of connections and interruption time for each connection during the activities for each approach. It can be seen that for a pipe replacement in general the HelKo method affects the same number of connections, but for a much longer time period. This is because traditionally a bypass is used, which limits the interruption duration. This is not done for the HelKo method. If an alternative water supply would be used such as connecting to an overland hose the CML for both approaches would be similar. However, this would reduce other advantages of the method, such as the total time of the activities, additional water quality sampling and increased costs and waste.

For the removal of the T-joint it is instantly clear that the HelKo approach has far less affected connections than for the traditional approach. In the traditional approach an entire section would have to be closed during the activities, whereas in the HelKo method this is not the case. During the pilot the nearest lock-joint was dug up and used to close off the pipe. In addition, an overland hose was used for water supply on the other side of the T-joint. Because there were some connections between the lock-joint and the T-joint, this resulted in a limited number of affected connections. An alternative would have been to use the balloon valve. This would have required similar digging activities, but costs a little more time to install than the use of the lock-joint. When using the balloon valve the number of affected connections could have reduced even further, potentially to zero.

Table 4-2 Affected number of connections and interruption time for each connection during the works for both the traditional open trench approach and the HelKo approach.

Type of work	**Traditional open trench**		**HelKo**		
	Connections	Time interrupted (minutes)	Connections		Time interrupted (minutes)
Pipe replacement	111	30		111	240
Removal T-joint	135	240	24*	0*	240

*Use of lock-joint (left), use of balloon valve (right)

Table 4.3 shows the effect on CML of the traditional open trench approach and the HelKo approach. For pipe replacement activities the difference in interruption time for each connection results in an increase of CML of 700%. For the removal of the T-joint the reduced number of affected connections in the HelKo approach results in a 82-100% reduction of CML (depending on whether the nearest lock-joint is used to close off the pipe or a balloon valve). The reduction in CML in the removal of the T-joint is so large that it even compensates for the increase in CML for the pipe replacements with a total decrease in CML of almost 10%.

Table 4-3 Effect on CML with the traditional open trench approach and the HelKo method.

Type of work	Traditional open trench (minutes)	HelKo (minutes)		Difference CML	
Pipe replacement	0.005		0.044		+700%
Removal T-joint	0.053	0.009*	0*	-82.2%*	-100%*
Total	0.059		0.053		-9.3%

*Use of lock-joint (left), use of balloon valve (right)

Results of customer satisfaction survey
During the pilot a customer satisfaction survey was held among the affected connections. This survey consisted of a question form which was filled in by the residents. 80% of the residents returned the form; the high response is probably at least partly due to the fact that the fitters actually waited for the filled in form, rather than having the customers return the form by mail. As only 111 connections were affected the results are statistically difficult to interpret. A few things emerge though:

- Most customers reported “no” to “hardly any hindrance” due to the activities (92%).
- 87% of the customers reported that a boil notice of 4 days was “acceptable”, 5% found it “not acceptable” and 8% was “neutral”.
- Most customers appreciated the alternative water supply (5 liter water bottle), some indicated that because of the hot weather during the pilot more water would have been appreciated.
- Most nuisance was reported over the street works (sand and dirt on pavement) and parking options (limited because of the activities and parking by the fitter crews of the various companies at work in the street). Some people complained about the noise of radios used during the activities. Noteworthy is that these types of hindrance were not caused by the drinking water company, but by the city who carried out the street works.

It would be very interesting to repeat the customer satisfaction survey in different projects to see if these observations hold, but it seems that customers are willing to put up with some nuisance if the works are carried out with consideration for the residents. Therefore, measures like handing out plenty of bottled water, giving notice of interruptions to supply in time so that people can for example shower beforehand and consideration with where to park the vehicles etc. may be as or more important than limiting the CML.

4.4.3 Safety
In general the HelKo approach consists of safe processes:

- The pressure in the close-off part of the pipe can be monitored and additional air can be supplied to the balloon to maintain sufficient pressure during the activities.
- The supplier provides longer saddles to install the balloon valve for the use in AC, in order to avoid the pipe to burst under the pressure of the balloon.
- There is an option to install a second balloon behind the first balloon for additional safety.
- Considering the use of the lock-joint: the water pressure is only reinstated once the shutter has been placed and the trench is clear.
- In the case of an unexpected burst, there is always the option to close the regular valves.

There are a few issues which should be addressed in the working procedures of the drinking water company:

- In practice the longer saddle for use of the balloon valve in AC pipes was not used by the fitters, the AC was deemed strong enough by the fitters. This seems an unsatisfactory procedure as it is difficult to judge the quality of AC by sight alone, the quality may vary strongly and it is not known what the limiting strengths of AC are for not using the longer saddle. It is advisable to introduce clear procedures on when to use which saddle. The experience of the fitters may be of use here.

- There are no guidelines for when to use an additional balloon valve.
- During the pilot the pressure could be monitored constantly, but this may not be needed when the balloon valve becomes a regularly used tool. It is advisable to insert clear procedures who is responsible for monitoring the air and water pressure.
- The lock-joint could lead to leakage problems in the future. It is made of different parts and consists of two rubber rings in the centre.

4.5 Costs

Differences in costs between the HelKo approach and the traditional open trench approach are summarized in Table 4.4. Because of the pilot Dunea has had an extra fitters crew on location. Also, the equipment had to be purchased and the lock-joint is still relatively expensive but may be reused. This resulted in about € 41.000,- more costs than the traditional approach. However, we should keep in mind that this was a pilot. For future projects it is expected that the additional crew is no longer required while maintaining reasonable daily production lengths, the equipment has already been purchased and the lock-joint is expected to become cheaper as the product evolves into a more current instead of an innovative product. This would mean that the dominant cost difference comes from the material costs for either the bypass or the lock-joints. This means that this techniques has the potential to reach the same cost level as the traditional approach.

Table 4-4 Overview of difference in costs between the traditional open trench approach and the HelKo approach for the pilot.

Item	**Costs**	**Traditional approach**	**HelKo**
Extra fitters crew (27 days)	± € 20.000,-	-	Yes
Lock-joints	± 6.000,-	-	Yes
Daily samples	± 1.600,-	642,- (6 samples)	2247,- (21 samples)
Materials bypass	± € 6.000,-	Yes	-
Purchasing equipment balloon valves (2)	± € 21.000,-	-	Yes
Total difference pilot			€ + 42.600,-
Difference without one-time purchase			€ + 20.000,-
Difference without extra crew			€ 0,-

5 Selection of technique

5.1 Effect on CML

5.1.1 Effects on CML of different techniques

The effects on CML are estimated using 3 standard planned activities normally resulting in a principal part of the companies' CML. Between brackets is the anticipated contribution to CML.

1. Pipe replacement: There are 2 common (and some special) approaches in the Dutch drinking water network with activities that cause CML:
   a) In case the new trajectory is in the same location as the old pipe:
      - Installment of a (usually buried) bypass (0)
      - Moving of connections to the bypass (+)
      - Replacement of the pipe and one-sided connection to network (++)
      - Flushing and testing for microbiological safety (0)
      - Move connections to new pipe (+)
   b) In case the new trajectory is in a new location:
      - Installment of the new pipe (0)
      - One-sided connection to network (++)
      - Flushing and testing for microbiological safety (0)
      - Move connections to new pipe (+)
   c) Special case where the new trajectory is in the same location as the old pipe, but no bypass is used:
      - Replace daily section and one-sided connection to network (++)
      - Flushing and testing for microbiological safety (0)
      - Install connections and return to operational use with boil notice (+)

   The largest contribution to CML is connecting the new pipe to the existing network. During this activity 1 section needs to be closed. Case 1c will in general have much larger CML than case 1a and 1b: in 1a and 1b the only times customers are without water is when the connections are moved to a different pipe and when the pipe is coupled to the existing network. In case 1c people are without water during the time that their section of pipe is replaced and during the time the new pipe is connected to the existing network. Case 1c does save costs by not using a bypass and only having to dig one trench for each pipe replacement (instead of 3, 1 for the bypass, 1 for the replacement and 1 for the removal of the bypass).
2. Valve replacement: this activity involves the closing of at least 2 sections surrounding the valve, making this an activity that causes CML. (+++)
3. Hydrant replacement: for this activity only the section in which the hydrant is located needs to be closed, i.e. 1 section causing CML. (++)

There are 3 approaches to reduce planned CML, viz. reducing the number of interruptions (A, § 5.1.2), reducing the number of customers affected by the interruption (B, § 5.1.4) and reducing the duration of interruptions (C, § 5.1.3). In the following sections the potential CML reduction of the various techniques is assessed for the standard planned activities (pipe, valve and hydrant replacement).

5.1.2 Number of interruptions

Many applications of spade valves are specifically designed to perform activities while keeping the system under pressure. For example, installing hydrants, pipes and bypasses with the use of spade valves to an operational network implies that this existing network does not need to be closed off. Without the spade valves a section of the operational network would need to be closed off. Therefore, using these spade valves reduces the number of interruptions.

Lock-joints also reduce the number of interruptions, but specifically for case 1c: pipe replacement without bypass. In this case the daily replaced section of pipe is connected to the existing network. Without the lock-joint each day a section would need to be closed off, whereas with the use of the lock-joint the daily anticipated production can be connected while keeping the existing network operational.

Table 5-1 summarizes the potential effect for all techniques.

Table 5-1 Potential CML reduction for each of the techniques and standard activities for the number of interruptions.

Technique		Pipe	Valve	Hydrant
Balloon valves		0	0	0
Freezing		0	0	0
Spade valves	Hydrants, pipes, bypasses	+	+	+
	Lock joints	+	0	0
	Knife shutters	+	+	+
Squeezing		0	0	0
Valve maintenance		0	0	0
Alternative water supplies		0	0	0

5.1.3 Number of affected customers

Most of the considered techniques influence the number of affected customers:

- Balloon valves, freezing and squeezing of pipes are specifically designed to limit the number of affected customers to the minimum. Instead of having to close an entire section, only that part of the section where the actual activities are taking place is closed. Knife shutters are also used in this way.
- Alternative water supplies are especially useful in areas with for example branched systems. If customers behind a closed off section cannot be supplied with water from a different source, the closed off section may be bridged with overland hoses or with a water supply from tanks. This will be easier for small closed off sections, so these alternative water supplies are especially useful in combination with other techniques, such as balloon valves. The use of a bypass will of course reduce the number of affected customers to nearly zero (only the instatement of the bypass itself will cause a contribution to CML).
- Valve maintenance also aims to reduce the number of affected customers: if all valves work as they should, than the number of sections to be closed is reduced, automatically reducing the number of affected customers.
- Spade valves are designed to limit the number of interruptions and are therefore treated in the next section. Lock-joints work specifically well for case 1b: pipe replacement without using a bypass: in this way, on the first day only 1 section and the customers connected to the replaced pipe are without water for a limited amount of time and the rest of the days no interruptions occur.

Table 5-2 summarizes the potential effect for all techniques.

Table 5-2 Potential CML reduction for each of the techniques and standard activities for the number of affected customers. If the techniques is widely applicable this is also reflected in the score (e.g. freezing is effective in isolating a section, but is only applicable for small diameters. In practice not many valves and hydrants will be located in sections with diameters that small.)

Technique		Pipe	Valve	Hydrant
Balloon valves		+	++	++
Freezing		+	+	+
Spade valves	Hydrants, pipes, bypasses	0	0	0
	Lock joints	+	0	0
	Knife shutters	0	+	+
Squeezing		+	+	+
Valve maintenance		++	++	++
Alternative water supplies		+	+	+

5.1.4 Duration of interruptions
None of the considered techniques specifically aims to reduce the duration of interruption due to activities.

5.1.5 Total effect on CML
Table 5-3 shows the total effect on CML from the different techniques.
- Balloon valves, freezing, squeezing and knife shutters work in a similar way and are very effective to reduce the number of affected people. They do however have different materials and diameters of application. The balloon valve is the most widely applicable technique of these 4 techniques.
- Spade valves work very well for specific situations. Hydrants, pipes and bypasses can be easily installed under pressure, but are only usable on smaller diameters. Lock-joints are designed very specifically for pipe replacements where daily replaced pipe sections are reinstalled the same day. Knife shutters can only be used for PE up to 200mm.
- OptiValves is a very powerful tool to optimize the valve maintenance programme which leads to less CML for almost any activity with interruption of supply.
- Alternative water supplies are effective in reducing the number of customers affected.

In principle it is possible to reduce all planned CML to zero by combining the different techniques. For example, customers without access to water can be directly supplied from a tank. This comes at a cost. Which combination of techniques works best depends on the specific situation. Examples are:
- Balloon valves in combination with an overland hose reduces the CML to zero for valve and hydrant replacements and to a limited number of customers for pipe replacements in branched systems.
- Balloon valves in combination with an overland bypass reduces the need for digging trenches for the bypass and further reduces the CML to only the moving of connections to and from the bypass.
- Balloon valves in combination with lock-joints strongly reduce the CML for case 1c. This is also the combination used in the pilot, Chapter 4. Extending this combination further to the use of overland bypasses further reduces CML to only the moving of connections to and from the bypass, while maintaining the advantage of only having to dig one trench for each section of pipe replacement.

Table 5-3 Overview of effect of the different techniques on CML. The effects are split into duration of interruptions (I), number of affected customers (II) and number of interruptions (III). Effects are noted as +, CML reducing, - CML increasing and 0, no effect on CML.

Technique		Effect I	Effect II	Effect III
Balloon valves		0	++	0
Freezing		0	+	0
Spade valves	Hydrants, pipes, bypasses	0	0	+
	Lock joints	0	+	+
	Knife shutters	0	+	+
Squeezing		0	+	0
Valve maintenance		0	++	0
Alternative water supplies		0	+	0

5.2 Potential reduction of planned CML

Based on the CML contributors of the different companies and the pilot results a few scenarios are examined for their effects on planned CML, Table 5.4:

I. Using a technique for reduction of sections (e.g. balloon valves possibly in combination with other techniques such as the lock-joint as in the pilot). The assumption is that the technique is only used in situations where CML reduction is achieved. Hence pipe replacement is set to zero percent potential reduction as the pilot indicated a CML increase for this part of the activities. Note that in case the technique is used in all situations, the CML could substantially increase.

II. Same as I, but now with the assumption that in every pipe replacement project there will very likely be some part (such as the removal of a T-joint as was the case in the pilot). If for these situations the section reduction techniques is applied an additional CML reduction may be achieved. The 10% as is stated in Table 5.4 is an educated guess based on the pilot results as the data on CML from the different companies do not allow such distinction within specific projects.

III. Using spade valves whenever this results in CML reduction and not anywhere else. Again, for pipe replacements it is completely unknown how much CML reduction is achievable as the CML registration of the different companies do not allow such distinction within individual project. For valves there is no application and for hydrants CML reduction only applies in case of a new hydrant.

IV. Application of a section reduction techniques in combination with alternative water supply. In general (exceptions will obviously occur) it should always be possible to supply water to consumers in the case of planned activities, therefore 100% reduction in planned CML is achievable.

The above is summarized in Table 5-4. The large variation (or uncertainties) are due to the fact that the difference between the contribution of the different types of works for Waternet and Evides are very large (Table 2-1, pg. 6) and the effect per activity can vary for different scenarios.

Table 5-4 Potential CML reduction for different scenarios.

Activity	Factor in total planned CML	I	II	III	IV
Pipe replacement	33-90%	0%	10%	?%	100%
Valve replacement	4-25%	100%	100%	0%	100%
Hydrant replacement	2-28%	100%	100%	0-100%	100%
	Total reduction potential	6-53%	16-65%	0-?%	100%

5.3 Weighing scenarios

In § 5.2 it was demonstrated that the potential for the reduction of planned CML varied between 0 and 100% depending on the type of activities and the combination of techniques. The techniques vary in costs and of course, the more techniques are combined the more expensive the CML reduction is.

CML is not the only relevant factor when deciding which technique to use. A detailed overview of other aspects can be found in van Vossen et al. (2015), where examples are costs, customer satisfaction and ease of use within the company procedures. CML is a part of customer satisfaction, but as the customer satisfaction survey in the pilot showed, not the only part. Accessibility of properties, parking space, duration of activities, noise are part of customer satisfaction as well. The drinking water companies decide in their policies what they consider the most important aspects in a specific situation.

There are several options of weighing alternatives for techniques to use for a project, such as (van Vossen et al., 2015):

- Cost-benefit analysis
- Multi-criteria analysis
- Cost-effectiveness analysis

All of these analyses have in common that the different aspects for weighing need to be quantified. How important is CML compared to costs, accessibility of houses, reliability of the results, safety risks? One option is to value every element with a monetary standard, for example one CML minute represents x euros. Another option is to value elements or categories with a non-monetary weight. In all cases it is important to be aware of the value which is placed on different elements. Otherwise there is a risk that important elements are left out of a weighing of alternatives or only costs are considered, because that element has the most clear quantitative background.

Table 5.5 shows a qualitative assessment of the performance of the different techniques as described in this report on the following elements:

- Application potential: the technique is applicable on a wide range of materials and diameters (- very limited in use up to ++ widely applicable)
- Costs: the techniques is cheap (- very expensive up to ++ relatively cheap)
- CML reduction: the techniques has a lot of potential in reducing planned CML (- no CML reduction up to ++ large potential in reducing CML)

Balloon valves are widely applicable, relatively cheap (only the costs of purchase) and have substantial potential in planned CML reduction. Freezing and squeezing have potential and is relatively cheap, but is only applicable to a limited number of materials and diameters. Spade valves (hydrants, pipes, bypasses) have potential, but are useful in very specific situations. Lock joints are currently only usable for specific materials and diameters, but have the potential to become more widely applicable. They are still relatively expensive, but the expectance is that as they become more widely spread the costs will go down. The lock-joint in itself is not very effective in bringing down planned CML, but there are other reasons why the lock-joint may be an interesting technique, see also the pilot evaluation (Chapter 4). Alternative water supply has a large potential in reducing planned CML, are applicable in a wide range of situations, but can be expensive. An overland hose spanning a few meters of closed pipe is less expensive than a large tank having to be operational for a prolonged period of time.

Table 5-5 Performance of techniques on different elements of weighing alternatives.

Technique		Application potential	Costs	CML reduction
Balloon valves		++	++	++
Freezing		+	++	+
Spade valves	Hydrants, pipes, bypasses	+	+	+
	Lock joints	++	+	-
	Knife shutters	+	++	+
Squeezing		+	++	+
Valve maintenance		++	+	++
Alternative water supplies		++	- to ++	++

6 Conclusions and recommendations

6.1 Conclusions

There are various techniques available for reducing planned CML, which can now be applied in the drinking water distribution network. Most of these techniques focus on the reduction of affected customers during interruption events, but some also focus on reducing the number of interruptions (such as alternative water supply). The techniques vary in applicability, costs and effectiveness. Most constraining are:

- Materials: techniques that are only applicable in for example PE have a smaller potential than techniques that can be used in AC, PVC, PE and cast iron as these materials are more commonly used in the distribution network;
- Diameters: techniques that are only usable on small diameters and can only be used for connections have a smaller potential in reducing overall planned CML than techniques that can be applied to larger diameters;
- Costs: techniques that require large investment costs in general need to be more effective in more situations than techniques that require little investment.

Based on these criteria balloon valves, valve maintenance and alternative water supplies seem to be the most promising techniques. Other techniques such as spade valves, freezing and squeezing may be very useful, but are limited to more specific situations.

Based on the CML data of the DPWE+A companies balloon valves are estimated to give a potential reduction in planned CML of between 6 and 65%. This is a very wide range, which is caused by the limited data on CML the companies could provide. Most companies were not able to provide detailed CML data from which we could make a distinction in the specific type of planned activities in combination with duration and number of affected customers. For an activity as pipe replacement it was not possible to analyse what these activities comprise of (for example, plain pipe replacement, removal of T-joints etc.). As the techniques are efficient for specific situations, this makes the calculation of potential planned CML reduction imprecise.

In most cases a combination of different techniques should be able to reduce planned CML to nearly zero. However, these techniques have costs and in addition, situations may exist in which a technique does not result in a reduction of CML, but is the most efficient technique for customer satisfaction nonetheless when other aspects of nuisance are being considered.

The pilot study performed by Dunea using balloon valves and lock-joints in a pipe replacement project showed that both techniques worked very well with acceptable costs and satisfied customers. The customer satisfaction survey suggested that the customers valued accessibility of properties, parking space, receiving bottled water and working with a customer friendly mentality (e.g. no music) more than having a limited interruption of supply.

This illustrates the importance of placing value on all the different elements of an evaluation of techniques that are important for the water companies (e.g. costs, elements of nuisance, applicability etc.) and having the information from type of activities that occur and what they are comprised of. In this way companies can make a substantiated decision on which technique to use when and where.

6.2 Recommendations

Based on the experiences with the techniques and analyses in this report we present the following recommendations:

- Expand the CML registration: for a substantiated decision on what to focus on for CML reduction, the performance killers need to be identified. It then is important to have information on:
  - What type of activities is causing CML? This means pipe replacement, valve replacement etc. but also information on what pipe replacements usually comprise. Average CML, minimum and maximum, what is causing differences between CML, is CML mainly caused by number of affected customers or duration of events?
  - How much is planned?

  Table 6-1 shows an example for an extended CML registration where per project multiple activities could lead to an interruption, and there is room for remarks on how this project is different from other projects, which leads to an aberration in CML. Reasons could be e.g. that valves were malfunctioning and an extra amount of customers was affected, the interruption was much longer because of malfunctioning equipment, less customers were affected due to new techniques being used, etc.
- Most data in this report were based on one year of CML data, it would be worthwhile to compare different years and look for trends and compare between companies.
- Generate trends based on extrapolation of CML data which give insight into the type of activities expected and their effect on CML.
- Based on these data it is possible to calculate the effects of different techniques and combination of techniques.
- Value the different elements that are important in company policies, next to CML and costs.

Table 6-1. Example of extended CML registration form.

project	Planned / Unplanned	Type of activity	A – # of events	B – # of customers affected	C – duration of interruption (min)	Reason for aberration in CML	CML (s) =A*B*C / (Σ B)
Pilot Dunea conventional	planned	Pipe replacement	1	111	30	n.a.	0.33
		T-joint replacement		135	240		3.19
		total					3.51
Pilot Dunea lock joint + balloon	planned	Pipe replacement	1	111	240	New technique used	2.62
		T-joint replacement		24	240		0.57
		total					3.19
Water meter replacement	planned	standard	5000	1	15	n.a.	7.38
Water meter failure	unplanned	standard	500	1	15	n.a.	0.74
…							

7 References

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Appendix I Costs for alternative water supply

	Asset	Item Cost (£)	Item cost (Euro)
1	20,000 ltr tanker	£135.870,50	€ 184.933,34
2	9,000 ltr tanker	£92.727,58	€ 126.211,51
3	Trailer with chevrons	£3.000,00	€ 4.083,30
4	Racking for trailer	£1.000,00	€ 1.361,10
5	CCB filling Hose	£202,69	€ 275,88
	25m hose ** 253.22 x 3	£759,66	€ 1.033,97
	10m hose** 136.52 x 2	£273,04	€ 371,63
	5m hose** x 1	£97,62	€ 132,87
	End caps	£15,20	€ 20,69
	Hose restraining clips	£10,00	€ 13,61
6	Hose Colour Code Tags (5 colours)	£1,39	€ 1,89
7	Tap for CC Hose	£30,69	€ 41,77
8	CL2 Suitcase	£4.639,40	€ 6.314,69
9	Road ramps 1.5 mtr	£24,00	€ 32,67
10	Road Cones (750)	£45,00	€ 61,25
11	Sample Tap Pressure Gauge Combi	£114,39	€ 155,70
12	Hose Y Branch	£124,50	€ 169,46
13	Restraining Cable (Large)	£12,00	€ 16,33
14	Restraining Cable (Small)	£10,00	€ 13,61
15	Magnetic Whiteboard		€ 0,00
	Noticeboard***		
16	Combination padlocks	£18,00	€ 24,50
17	Male iron connector	£21,50	€ 29,26
18	Female iron connector	£51,00	€ 69,42
19	Male to Female 90o bend connector	£32,00	€ 43,56
20	Hose locking security clips	£10,00	€ 13,61
21	De-Chlorination Units	£462,00	€ 628,83
22	Storage Unit	£4.400,00	€ 5.988,84
23	Double Headed Standpipe	£285,00	€ 387,91
24	Double Headed Standpipe (NRV)	£351,00	€ 477,75
25	Chapter 8 (Signs)	£450,00	€ 612,50
	Men at work signs		
	Road narrows board		
	Arrow board Right		
	Arrow board Left		
	Telecom barrier		
	Permit / Apology board		
26	Wheeled Toolbox	£39,00	€ 53,08
27	Padlocks (Combination)	£102,60	€ 139,65
28	POWER STOP EQUIPMENT	£21.938,00	€ 29.859,81
29	1/ 3” Power Stop Rubber (POWER STOP EQUIPMENT)	£18,00	€ 24,50
30	2/ 4” Power Stop Rubber	£20,00	€ 27,22
31	3/ 6” Power Stop Rubber	£35,00	€ 47,64
32	Fire Hydrant Wizard	£5.206,00	€ 7.085,89
33	Aqua-Stop Line Stop Equipment	£21.833,00	€ 29.716,90
34	Tanker NRSWA chapter 8 signage	£450,00	€ 612,50
35	SAT NAVS	£252,99	€ 344,34
36	Hands Free Kits	£200,00	€ 272,22

Appendix II Other innovative related techniques

Easy access to mains is important for inspection techniques, such as CCTV or leakage detection. Correct assessment of the condition of pipes is important in determining when a pipe should be replaced. If a pipe meant for replacement turns out to be in good condition, this saves CML.

Repairs: if balloons or temporary shutters can be inserted easily, this saves CML and reduces the number of customers affected by disruptions. A disadvantage of the balloon technology is that the pipe needs to be excavated to apply it. A though-bore hydrant may offer opportunities that allows the insertion of a balloon without excavation

Figure II.1 Through-bore hdyrant.

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