REHABILITATION OF SEWER NETWORKS : ADDRESSING SOCIO-ECONOMIC IMPACTS IN THE CARE-S PROJECT

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ABSTRACT

Rehabilitation of sewer networks has to serve various objectives, both in terms of present general performance, and in terms of long term sustainability. Part of these stakes are external to the sewerage utility operation, such as social impacts of sewer failures, or social impacts of works. Knowledge and assessment of social and economic external costs have been addressed in a component of project CARE-S, supported by the European Commission. This project has developed a decision support environment and software prototype, including different tools to assist decision-makers in the different tasks necessary to pipes rehabilitation planning and programming.

The aim of the work presented here was to help addressing the socio-economic ("indirect", or "external") costs linked to rehabilitation, i.e impacts of failures and impacts of rehabilitation works to third parties, by providing guidance and methods for assessing criteria representing these social costs:

- decision criteria for comparing a limited set of technologies when considering a given single pipe (impacts of rehabilitation works),
- decision criteria for comparing various pipes candidate to rehabilitation, given the related failures or failures hazards (impacts of failures).

The two sets of criteria are to be used in two respective multi-criteria selection tools, together with other criteria.

KEY WORDS

decision making, rehabilitation, sewer system, socio-economy.

INTRODUCTION

Rehabilitation of sewer networks has to serve various objectives, both in terms of present general performance, and in terms of long term sustainability. Part of these stakes are external to the sewerage utility operation, such as social impacts of sewer failures, or social impacts of works. Apart from possible compensation, the corresponding costs are not bared by the utility. Nevertheless, these external impacts are to some extend considered in real life decisions, and should therefore also be taken into account in decision support systems.

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Knowledge and assessment of social and economic external costs have therefore been addressed in a component of project CARE-S " Computer Aided Rehabilitation of Sewer systems", supported by the European Commission under the 5th Framework Program, joining 17 sanitation utilities and 15 research and development teams (http://care-s.unife.it).

CARE-S project has developed a decision support environment and software prototype, including data management procedures, a set of performance indicators, models describing the condition and evolution of sewers, models describing the risks and consequences of failures, a database describing rehabilitation technologies with their characteristics, an assessment of socio-economic criteria, a long term planning tool, multi-criteria decision tools. The objective is to help utility managers to rehabilitate the right pipe, at the right time, with the right technology.

The aim of the work presented here was to help addressing the socio-economic ("indirect", or "external") costs linked to rehabilitation decision, i.e impacts of failures and impacts of rehabilitation works to third parties, by providing guidance and methods for assessing criteria representing these social costs:

- decision criteria for comparing a limited set of technologies when considering a given single pipe (impacts of rehabilitation works),
- decision criteria for comparing various rehabilitation projects, defined each at pipe level, given the related failures or failures hazards (impacts of failures).

The two sets of criteria are to be used in two respective multi-criteria selection tools, together with other criteria. This work was based on both literature and analysis of real world data (claims, compensations, failure events…). Criteria had also to be adapted to available data and results: pipes defects and failures as described and forecasted by CARE-S models, socio-economic environment as characterized by reasonably accessible data… Two pieces of software have been created and included in the CARE-S software prototype, in order to help decision makers in assigning values to the two sets of socio-economic criteria.

FRAMEWORK AND DEFINITIONS

WHAT ARE SOCIAL COSTS AND WHY CONSIDERING THEM

As mentioned above, sewer networks are open systems. Hence, different failures and works have consequences on persons, belongings, activities… which are external to the wastewater utility, and for which this utility may be liable (in legal, financial or moral grounds), even if these consequences may have no or limited counterparts in the utility budget and expenses. To whatever extend it may be, the utility cannot overlook external consequences of its actions or of the network operations.

A CARE-S survey (results presented in Werey et al 2005) made on the involved countries and utilities showed that either regulation or management concerns address to some extend external consequences of failures or of works.

Inside the CARE-S decision support system, the decision was met to address explicitly at least part of the social costs, which could in a first approach be defined as the value given to external consequences to third parties. The definitions below have been agreed on within the CARE-S project, as parts of the collective glossary.

DEFECT or FAULT : established condition of the pipe which does not comply with the nominal design and has a lower potential for functionality or use (definition inspired by RERAU – French national project on rehabilitation of sewer networks)

PERFORMANCE DEFICIENCY : temporary operation or behaviors of the pipe or of the network which does not comply with the general or basic objective; this deficiency is linked to a *defect* and can be linked to an external trigger event such as rain (definition inspired by RERAU – French national project on rehabilitation of sewer networks)

FAILURE : termination of the ability of a pipe or of a network to perform a required function; a failure is a *defect* or a *performance deficiency* and is defined in reference to a required level of performance (definition inspired by French AFNOR standard on maintenance terminology NF EN 13306)

EXTERNAL EFFECTS (due to *defects/performance deficiencies*) : physical changes, due to the *defect* or *performance deficiency*, which impact the "world outside" the undertaking (example: presence of rainwater on a street because the condition of the pipe has decreased the hydraulic capacity, which would otherwise have been sufficient to avoid flooding for this rain event); the "undertaking" is the public or private company or organization which is in charge of the sewerage service and of the corresponding assets

EXTERNAL EFFECTS (due to rehabilitation works) : physical changes, due to rehabilitation works, which impact the "world outside" the undertaking (example: presence of work areas in the street); the "undertaking" is the public or private company or organization which is in charge of the sewerage service and of the corresponding assets

EXTERNAL IMPACTS (due to *defects/performance deficiencies* or to rehabilitation works) : consequences of *external effects* on persons, on activities, on private and public properties and items or on the environment (example: traffic disturbance due to street flooding or to works)

SOCIAL COSTS (due to *defects/performance deficiencies* or to rehabilitation works) : assessment / valuation of *external impacts* ; social costs represent costs incurred by society (including sewerage service customers) as a result of sewerage works or of failures, and for which utilities or companies have no direct responsibility apart from possible compensation; if there is a compensation, the net social costs are the social costs minus the compensation amount (definition inspired by AWWARF)

IMPACTS OF SEWER PIPES FAILURES: ADDRESSING RISK AND VULNERABILITY

conceptual scheme

The scheme of figure 1 displays the concepts introduced with the above definitions. Vulnerability has not been introduced in the definitions above: we will define it as the quantity of "stakes" which can be exposed to external effects (population, goods, activities, natural patrimony and resources…) and the fragility of it towards the effects.

Let us consider three examples.

1° the pipe is not tight, and there is exfiltration

We will consider this exfiltration as a continuous phenomena, even if during rains the increased water level inside the pipe may increase exfiltration. The defect is non tightness, and the misfunction which exists without an external trigger is exfiltration. The external effect will be wastewater released in the soil and possibly in the groundwater. The pollutant transfer effect will depend on exfiltration discharge, soil type (permeability…) and distance to groundwater. The initial quality of the groundwater, the global volume and dynamics (flow speed, renewal period…) and the present or future water uses (which may be sensitive to this pollution) will be the parameters accounting for vulnerability. The consequences on present and future water uses will be the external impacts, and the valuation of these impacts are the social costs.

2° the pipe has a reduced hydraulic capacity

This means that during any rain, the water level inside (or outside) the pipe will be higher upstream from that pipe, and that there will be overflows, water overtopping in basements or on the surface, more that if the condition of the pipe was good; the differential in hydraulics as soon as it shows outside the network will be the effect of the misfunction. People, goods, activities, traffic… in the area or in the buildings which will be more flooded than "normally", together with their sensitivity to flooding, will constitute the vulnerability. All types of damage or disruption will constitute the external impacts.

3° the pipe has a structural collapse

This defect may have several consequences, for instance in terms of flooding, odours… Let us consider the case where this collapse leads to surface soil depression: the defect "collapse" has a direct external effect, soil depression. The vulnerability of the pipe environment will depend on soil use, traffic if it is a road… And external impacts may, according to the situation, be damage to road structure, traffic disruption or at least (increased) traffic jams…

One crucial point is that we should logically only take into account those defects and misfunctions which are to be considered as failures. Minor blockages in separated wastewater pipes may not be failures, though they are defects. A flooding event due to a rain which exceeds the network design and the regulation or standards, and which is not increased by the hydraulic operation and condition of the network, is not a failure of the network.

definition of failures

If we base on the definition proposed for "failure", a defect or a misfunction would be a failure if they do not comply with either:

- the regulation and compulsory standards ?
- voluntary standards ?
- the initial design and foreseen operation conditions ?
- the will of the utility manager / utility owner ?

The non compliance can be defined, measured, characterised through:

- the existence or occurrence of the defect or misfunction (for instance a structural pipe collapse)
- the frequency of the defect / misfunction (for instance a combined overflow exceeding the permitted frequency); the Middlesex University Flood Hazard Research Centre (Green et al 1993, Tunstall et al 1993) performed a survey for

OFWAT on the perception of water and sewerage customers: the majority of people ask for being exposed to less than 2 network flooding every 10 years. Flooding is generally considered worse than having a car stolen, and as serious as a fire in the kitchen with the fire brigade being obliged to intervene.

- the intensity of the defect / misfunction (for instance non tightness leading to infiltration exceeding a given percentage of dry weather flow)
- the occurrence of the misfunction given the frequency of the trigger event (for instance flooding occurring for a rain of small return period); it would be probably accepted that a network overtops with a 100 years storm if the network is designed for a 10 years storm, and provided the condition of the network does not make this flooding significantly worse
- the consequences of the defect / misfunction (for instance odours due to small blockages).

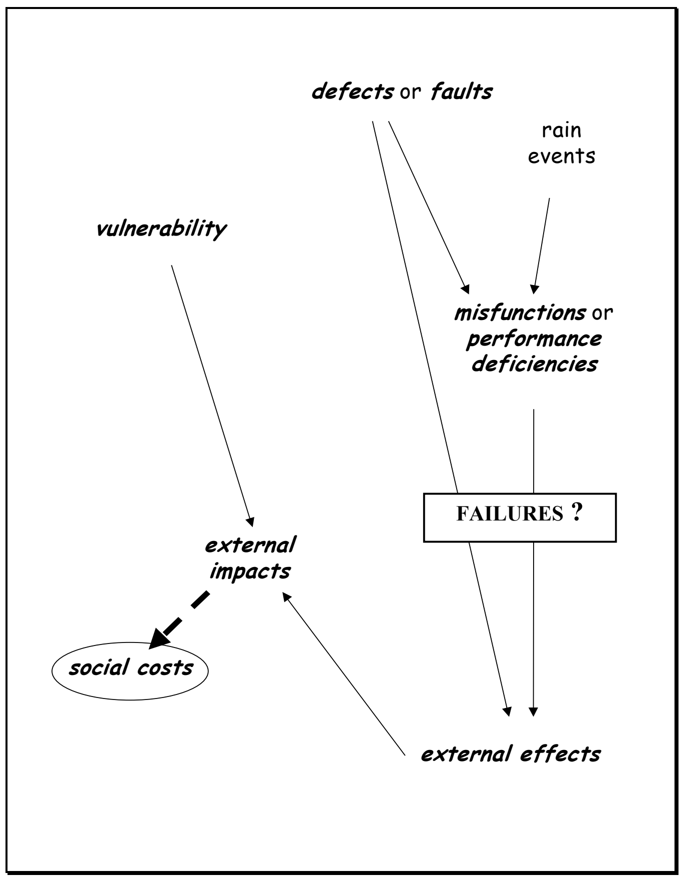

Figure 1: Concepts of failures and related social impacts

The internal CARE-S survey, as mentioned in the introduction, concerned regulations on performance on standards regarding failures, as well as possible compensation systems. This showed a major diversity of situations. Defining the boundaries of failures is a local issue, at undertaking and local government levels. Even if there are national standards, the wastewater service may decide to "do better" and to be more self-demanding towards failures.

External impacts are consequences of failures effects on third parties. But this does not mean that these third parties bare all the impacts. If the wastewater service pays for compensations, this reduces the social cost suffered by these third parties (hence the "net social costs" representing the "remaining part"), and increases the internal cost for the undertaking. If compensations are covered by the undertaking's insurance, it will also reduce the net social costs and increase indirectly the internal costs as the undertaking has to pay for the insurance contract (on a "permanent basis", and not for each failure). The same kind of issues can be met with pollution taxes, due for excessive external impacts, and used by public authorities to enhance or rehabilitate the environment.

The difference between social costs and net social costs depends on each local regulation or policy. We decided to address "whole social costs". But on the basic principle, net social costs excluding direct or indirect compensations should be taken into account. If these compensations where fair and comprehensive, they could be an assessment for social costs.

ASSESSMENT OF CRITERIA

In an ideal world, defining and assessing social cost criteria would be based on a good knowledge and description of failures or works, of the external effects (flooding conditions, soil sinking in due to sewer collapses…), of the pipe environment (street characteristics, traffic, buildings…), and would also consider appropriate economic assessment methods which require also specific data. In practice, various points may be insufficiently known, and uncertainties are sizeable. The literature review done (Werey et al 2005) revealed very fragmented results and information, as well as shortcomings in the few databases identified about real world failures or works and their impacts.

As in CARE-S the criteria were to be used in multi-criteria selection procedures, the objective was to define and assess criteria which are consistent with the social costs, whether calculated in monetary terms or not, and which could deliver a sound and unbiased comparison of either two different rehabilitation projects, or two different rehabilitation technologies, in terms of avoided social impacts of various kinds. Keywords for the approach undertaken were feasibility, consistency and possibility by the utility manager to consider criteria definition which make sense for him. Default calculations were proposed for the two sets of socio-economic criteria, using possible available inputs on one hand delivered by other components of CARE-S, on the other hand describing the network and its environment.

ASSESSMENT OF CRITERIA FOR THE SELECTION OF PRIORITIES AMONG REHABILITATION PROJECTS

The procedure included in the CARE-S decision support system considers a pre-selected set of rehabilitation projects, where each project is a pipe defined with its characteristics (intrinsic ones, local environment…) and data on possible failures.

As mentioned above, criteria are meant to help ranking pipes candidate for rehabilitation, considering their potential failures. These criteria, representing socio-economic costs of external impacts (definitions given in the next section) must hence take into account the potential effects a failure can generate, and the vulnerability of the concerned pipe environment to such effects. If an area shows no vulnerability to a given effect, in other words if there are no impacts, the criteria must show “no cost”.

The occurrences of some failures are of probabilistic nature, such as wet weather flooding or blockages. This probabilistic nature must be taken into account, in a risk assessment approach for the criteria. Some failures may generate “randomly” external effects, such as soil; surface depression due to collapse, which cannot be assessed in probabilistic terms. For such cases, decision was met to consider “threat factors” criteria defined as the probability of the initial failure (e.g. pipe collapse) times a vulnerability indicator.

What are the failures, effects and impacts considered?

Possible defects, misfunctions and external effects are numerous and varied. So are failures. We can only address defects and misfunctions for which there is information available about their possible occurrence, intensity, and/or probability, and which are to be considered as failures. Moreover, the question is then to link the external effects with their occurrence / characteristics / intensity / probability to the failure events, and the impacts to vulnerability and to effects. Failures can only be taken into account as far as they are addressed and described, to whatever extend, in “technical” terms other components of CARE-S decision support system. For the effects which are of probabilistic nature, we have to consider the notion of risk: probability times consequences, the latter being the crossing of effects intensity (water height…) and vulnerability. Effects can also be, to some extend, “random” towards defects or misfunctions:

- blockages may or may not generate dry weather wastewater overtopping in basements or on the soil surface
- blockages and collapses (and more generally structural failures) may or may not induce problems of odours, insects, rodents
- structural pipe collapses may or may not induce soil depression.

In that case, it is not possible to address the chain [defect or misfunction → external effects → impacts], in a deterministic or even full probabilistic way. The choice was met to consider “threat factors”, combining the probability of the “trigger failure” (blockage, collapse, structural failure) with a vulnerability indicator to the possible external effects (overtopping odours and soil depression) : for instance, this would mean combining probability of pipe collapse with road traffic. This must in no way be considered as a “risk”, as we miss the probability of the damaging effects. But such a “threat factor” combines the “best available” information accounting for the potential risk situation.

Table 1 displays the failures, effects and impacts taken into account, and described in more detail in Werey et al 2005. The numbers relate to the types of impacts addressed and for which criteria are considered.

Among the failures not considered for socio-economic impacts, we should mention wastewater treatment plant performance reductions due to clean water infiltration. Two reasons account for not considering it. First, this phenomenon, more than any other considered here, is a cumulative one over the whole network upstream from a wastewater treatment plant; identifying and quantifying the contribution of a single pipe is quite cumbersome. Second, the effect on the receiving water is due to the operation of the whole sanitation and treatment system, which can be assessed, but makes it the more difficult to identify a quantitative or ranking criteria.

Table 1 : Failures, their external effects and socio economic impacts considered in decision making about prioritizing pipes for rehabilitation

		DEFECTS AND MISFUNCTIONS				
		wet weather floodings (with probability)	**blockages (with probability) in dry weather**	**structural pipe collapses (with probability)**	**combined sewer overflows**	**exfiltration**
	are they considered as failures ?	choice of end-user according to probabilities of reaching given levels	all of them	all of them	choice of end-user according to a set of parameters	any
E	presence of water in basements	1, 2	8			
F	presence of water on soil surface	1, 2, 3	9			
F	presence of water on buildings ground floor	1, 2				
E	pollution discharge to surface waters				4	
C	groundwater vulnerability					5
T	no discharge possible to sewer		6			
S	soil depression			7		
	odours, insects, rodents		10	10		

1: flooding damage to buildings and their contents, and business losses
2: flooding intangible damage
3: traffic disruption and trouble due to flooding
4: degradation of surface water quality and consequences on present or future water uses
5: degradation of groundwater quality and consequences on present or future water uses
6: wastewater service interruption
7: traffic disruption and trouble, annoyances to life quality, due to soil depression
8: annoyances and damage from wastewater overtopping in basements
9: annoyances and damage from wastewater overtopping on the street
10: annoyances due to odours, insects, rodents.

ASSESSMENT OF CRITERIA FOR THE SELECTION OF A REHAB TECHNIQUE FOR ONE PIPE

The procedure included in the CARE-S decision support system considers a pre-selected set of "feasible" and "acceptable" rehabilitation technologies (described with various characteristics) for a given pipe, defined with its intrinsic and environment characteristics.

As mentioned above, criteria were meant to help ranking rehabilitation techniques which could be applied to a given pipe. These criteria, representing socio-economic costs of external impacts (definitions given in the next section) must hence take into account the potential effects a technique can generate, and the vulnerability of the concerned pipe environment to such effects. If an area shows no vulnerability to a given effect, for instance noise, in other words if there are no impacts (for instance area with no population and no established labor force), the criteria must show "no cost", and hence no difference to be made between two technologies whatever the noise created. If two technologies generate different levels of effects and consequently of impacts, for instance road surface neutralized, this must make a difference on the "traffic disturbance" criteria.

What are the effects and impacts considered?

These situations are quite simpler than failure ones, as we consider rehabilitation works with different techniques (as described and characterized by another CARE-S tool: a database describing available pipe rehabilitation techniques) which will happen in a given location (a pipe with its socio-economic and physical / biological site environment). The possible effects are those addressed in the rehabilitation techniques database, directly or indirectly:

- noise
- dust
- groundwater pollution hazards
- service interruption
- external surface neutralization (digging, working areas) leading to traffic disturbance and annoyances, and losses of business independently from traffic consequences (smaller attractiveness of shops…).

Werey et al (2005) report addresses each type of impact related to this list (description, existing information and data, proposition for a decision criteria inside the CARE-S framework). The same conceptual description in terms of external effects, vulnerability and external impacts can be done as for failures, but in a more usual and simple way. The works are a certain event, and we can consider that all (or the major part) of the effects are quite deterministic.

The consequences to people (inhabitants, service customers, non residents like labor force and by-passers), to activities and traffic, to groundwater resources and uses are addressed in terms of external impacts.

The duration of works has an obvious influence on the external impacts. Inside the assessment procedure, based on information available on pipe (length) and techniques, the user of CARE-S decision support system is able to assess the duration for each technology, taking into account the information describing the different rehabilitation technologies.

CONCLUSION

Decision making about sewer rehabilitation involves many aspects, among which the socio-economic impacts of both possible failures and rehabilitation works. In order to propose criteria in regard to these aspects, the basic principle of the work presented here was to use and summarize as much existing knowledge and available data as possible. In any case, criteria must be able to take on board decision makers knowledge and experience about either failures or works, and must correspond to the relative importance and sensitivity of real life impacts. Generally, available data are quite limited in representativity, in accuracy, in completeness…

Whatever the decision support system which may be considered, whatever the decision making paradigm, information and data on failures, on works, on their "physical" effects and on socio-economic impacts are very precious. Reporting, monitoring and assessment of such events, and systematic storage of the related data must be strongly promoted. This would allow, locally as well as through synthesis work, to go further in the description and quantification of socio-economic impacts.

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