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RESULTS OF RESEARCH INTO THE INFLUENCE OF AN INFORMATION SYSTEM FOR MANAGING CITY UNDERGROUND INFRASTRUCTURE

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Abstract: *The paper describes an information system for transforming an "old-fashioned" city infrastructure management system into an interactive system for the future. The paper presents first results from ongoing research into cost analyses and other characteristics of comparisons between traditional and trenchless (Cured-In-Place, CIPP [l]) construction methods for the rehabilitation of sewer pipes at 3 locations (projects) in Zagreb, Croatia. The management of city underground pipe infrastructure has in the last decade experienced large changes in construction techniques, authority policies, and public opinion. The consideration of social costs in reconstruction and installation of underground public utilities is becoming commonplace in most cities. There remain, however, some public utility companies in some countries, including in central Europe, where decision makers have not made significant steps away from traditional methods of construction and continue to work according to old maintenance programs and without proper information systems. The results of this are ailing city infrastructure systems and nowhere near the amount of necessary money available in order to reconstruct all that needs to be improved. The authors are proposing an information system that combines modern trenchless construction technologies with a restructured maintenance, construction and repair program as an optimal means for improving underground infrastructure conditions in cities at a minimum cost. The presented research results are strong indicators of the potential gains a city can achieve by implementing such an information system.*

Keywords: *research results, comparative analysis, information system, asset management, trenchless technology influence diagram, environmental construction.*

1. THE SIGNIFICANCE OF TRENCHLESS TECHNOLOGIES

Ever increasing numbers of city utility pipes and cables (such as storm and sanitary sewer, gas, water, tel., electric, etc.) and more stringent regulations and quality requirements have greatly increased the complexity of planning, installation and reconstruction of this very valuable infrastructure. As the system of underground pipes grows, little room remains for new installations under the ground surface. Additional problems arise from costly delays of vehicle traffic on the road surfaces above the installations. Surface structures such as buildings, roads, rail tracks, walkways, etc., are often an expensive obstruction that needs to be removed in order to reach the necessary underground location. This is especially the case if social costs due to the construction are taken into account.

Social costs of traditional construction (traffic delays, noise, pollution, etc.) can be very large. Trenchless technologies often offer better solutions for installation and reconstruction of utility pipes than traditional trenching methods. The last decade has seen great improvements and innovations in materials and equipment used in the various trenchless technologies, including: directional drilling, microtunneling, pipe renovation, pipe replacement, lateral connections, local repairs, etc.). In many large cities where social costs of construction projects are considered important, trenchless technologies are already accepted as quality solutions for city engineering projects [3].

2. INFORMATION SYSTEM FOR CITY UNDERGROUND PIPES

In order to take advantage of the benefits of the various trenchless technologies (especially repair and rehabilitation) in city pipe system management, it is necessary to detect critical points in the city pipe network before complete failure of a pipe occurs. The authors present, in Figure 1, an information system [4] that enables the early detection of problems in a city pipe system and in doing so allows the most rational construction technology to be used to correct the problem. The key to the model is the database and collection and storage system. With the proper information and at the right time, costly emergency repairs in a city underground pipe system are prevented [2].

2.1. PHASE ONE: DATA INPUT

In order to enable rationalisation and optimisation of management in later phases, the first phase is for data collection. In this phase all data that is relevant for decision making for construction, maintenance and rehabilitation of pipes is entered into the central database (computer files). The most significant kind of information is:

- Results from regular video inspections in underground pipes. The condition in the pipes is ranked according to a predetermined system of evaluation where the characteristics in the pipes are described according to the following:
  - good condition
  - rehabilitation in 3 to 5 years
  - rehabilitation in 1 to 2 years
  - rehabilitation within 6 months
  - emergency replacement.
- Results from video inspections of newly installed pipes for as-built records (for future maintenance).
- Information about areas in the city with common flooding or other events that require emergency intervention.
- Equipment that is available for performing inspections, cleaning,\ehabilitation, and software and computer support.
- Number of personnel available and their placement.

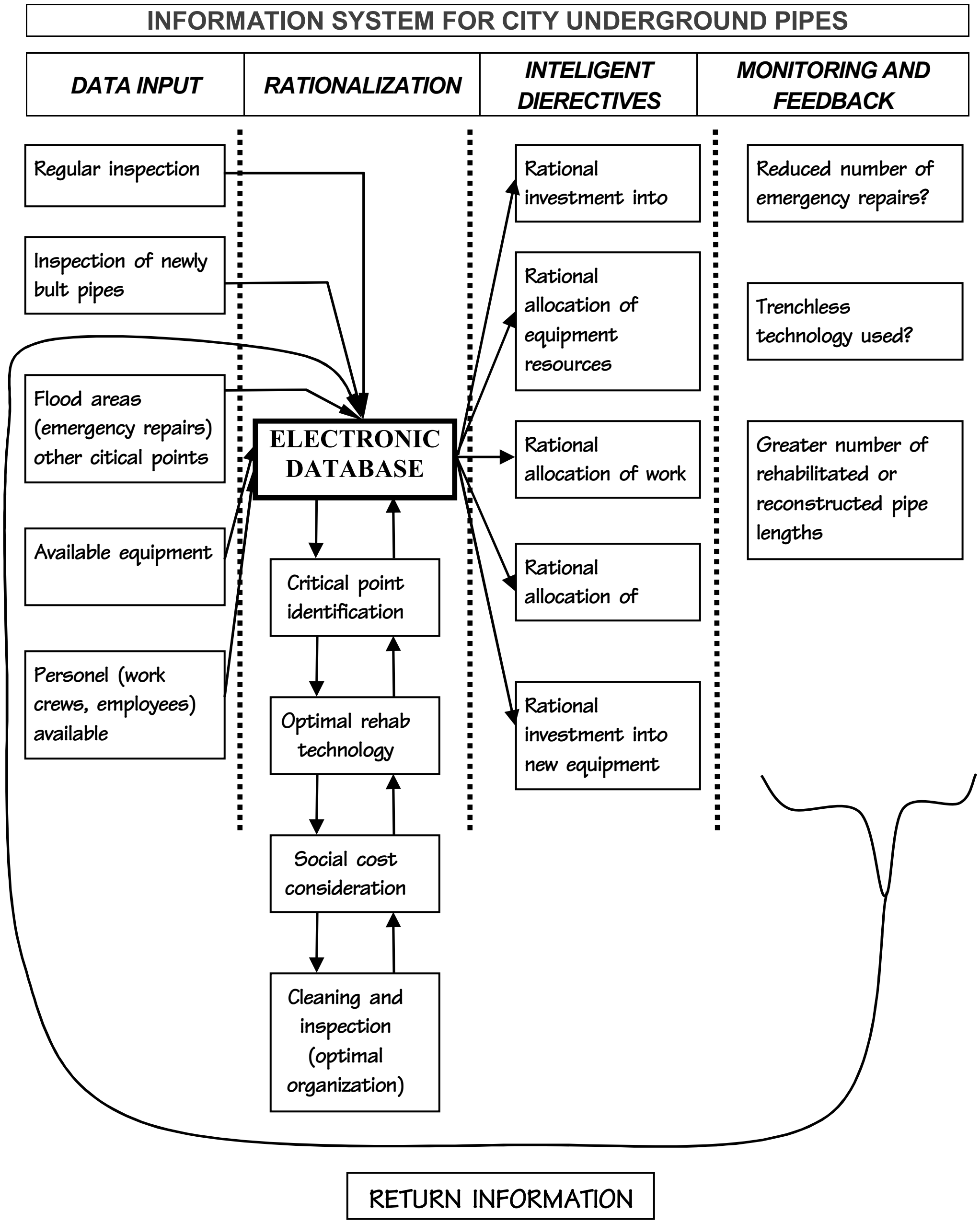

Figure 1: Modern management model for city underground pipes

2.2. *PHASE TWO: RATIONALISATION*

In this phase rationalisation of management of available resources of the utility company is performed.

The key to achieving rational and optimal resource allocation is to have a modern database. This electronic database can be one of several computer programs (i.e. "sewer maintenance management" software) in existence for this kind of data storage and regulation.

Critical points in a system of pipes with a developed database can be recognised and identified. Flood interventions or other failures and video recordings in which damage to pipes is evident, can be labelled as critical points in the system. This kind of information allows engineers to decide whether to rehabilitate the pipe by trenchless methods or replace it by traditional means. In making this decision social costs can be taken into consideration (i.e. traffic disruption, dirt and dust pollution, noise pollution, loss of business to local shops and offices, etc.). Other important aspects related to each technique can also be considered, such as, risk of damage to other existing pipes in traditional excavation, risk of time overruns, and other aspects.

Based on constant monitoring and collection of new information, it is possible to determine an optimal plan for cleaning, video inspection, rehabilitation, reconstruction and new construction. Personnel, equipment and money can be allocated in the most effective way. With an electronic database the amount of necessary administrative data and procedures in the utility company service is reduced and all operational information is kept at one location.

2.3. *PHASE THREE: INTELLIGENT DIRECTIVES*

After the rationalisation phase, it is necessary to make intelligent directives. Results from the rationalisation phase are used in this third phase as goals. Optimal resource allocation, critical points, and optimal technology (trenchless or traditional) can in this phase be used as directives. These directives enable the creation of an optimal plan with exact measures that need to be taken in particular areas of operation of the utility company. These measures have an influence on the quality and efficiency of the complete system of maintenance and development of the utility pipe network. The most significant measures are:

- money invested in reconstruction and rehabilitation of existing pipes
- money invested in new construction and development
- machines resource allocation
- workers resource allocation
- investment into new equipment for cleaning and inspecting underground pipes
- investment into training and hiring of personnel as needed

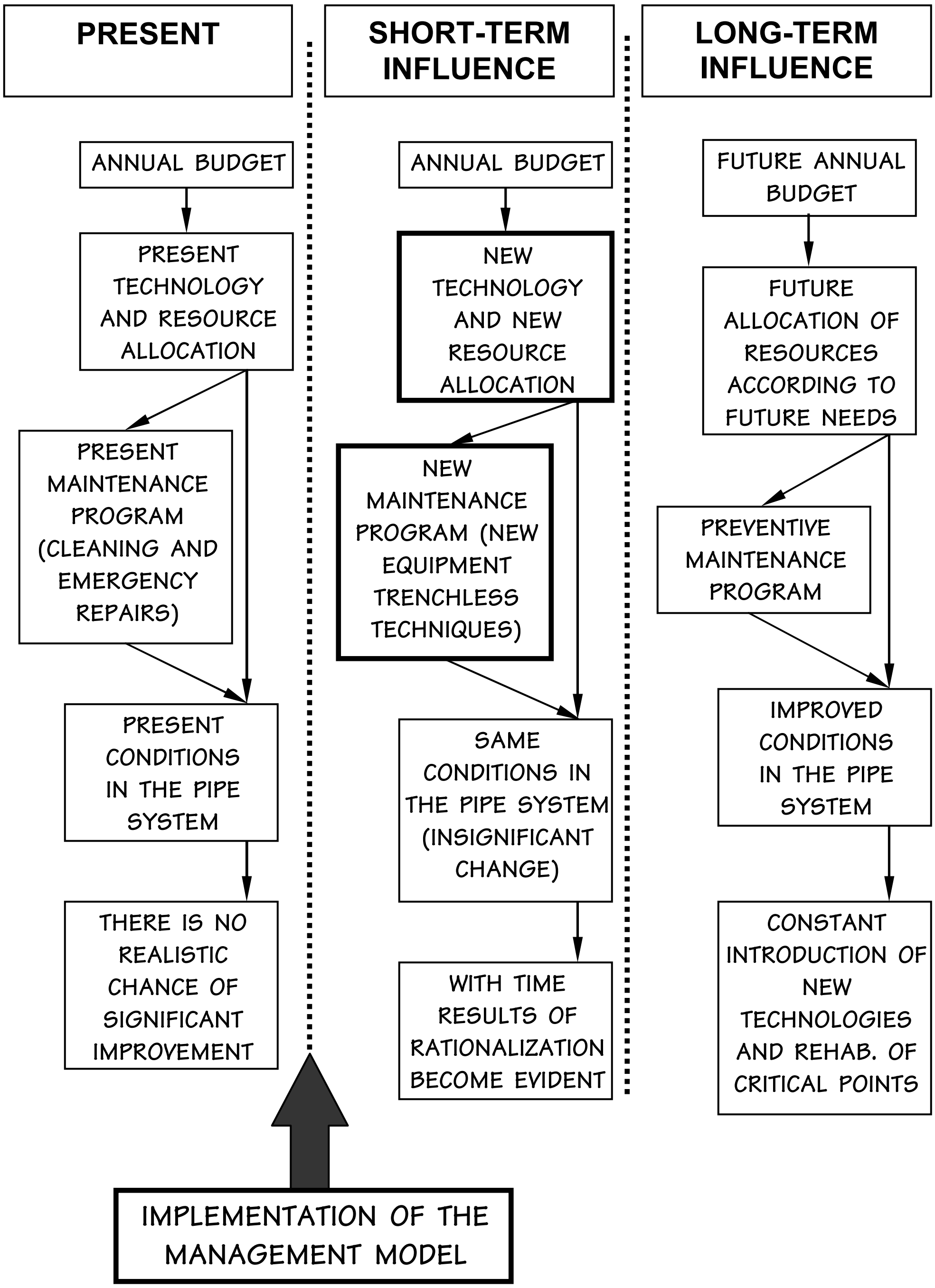

Figure 2: Influence of the management model

2.4 PHASE FOUR: MONITORING AND FEEDBACK

After carrying out planned directives for rational management of a pipe system, a utility company needs to monitor the effects of implementation. It is necessary to observe new occurrences in the pipe system and to use new information as input into the database for future rationalisation and decision making. To analyse the effects of implementation of planned directives various questions need to be posed:

- has the number of emergency repairs (interventions) declined after rationalisation of management?
- can trenchless technologies be used for improved problem solving?
- has the amount of rehabilitated and repaired pipe length per year increased due to new and cheaper technologies?
- in which situations were trenchless techniques the better option?
- are there any evident faults in the planned directives?
- is the overall quality of the pipe system improving?
- where should future investments be made (workers, equipment, technology, ...)?

3. INFLUENCE OF THE INFORMATION SYSTEM ON THE OPERATION OF A CITY UTILITY COMPANY

Figure 2 shows a diagram of the influence of the information system on the operation of a city utility company and on the quality of the underground pipes. The diagram is divided into three sections: present, short-term, long-term. Every section represents the operational condition within a city utility pipe system and company from the time of implementation of the information system to the distant future.

3.1. PRESENT

The first section represents the "present" (or initial) conditions in the system. The present yearly budget of the utility company is the result of the present (traditional) technologies which have not changed in years. The present method of construction, maintenance and rehabilitation of underground infrastructure pipes can be, in many cities, summarised as cleaning, emergency repairs and some reconstruction prior to complete failure and collapse of the underground pipe.

In many cities (especially old ones) it is a common occurrence that city infrastructure pipes are very old and in poor condition. Since sudden increases in yearly budgets of utility companies are not likely, improvements in the underground conditions cannot be expected either. With the "present" information system, therefore, there is no realistic possibility of improving the condition of infrastructure pipes.

3.2 SHORT-TERM

After implementing the proposed information system for city underground pipes, key factors are changed in the utility company management method. The condition in the pipes is not improved yet, but organisational steps have been made. An electronic database and information system is used, new technologies for inspecting pipes are used, trenchless technologies can be used where appropriate, and new construction, maintenance and rehabilitation can be generally better rationalised. The most important short-term effect of implementing the model is that an electronic database is created and this opens the way to improvements in the pipe system and more efficient investment.

3.3 LONG-TERM

Long-term effects of the proposed information system for city sewer pipes are theoretical. No city utility company can operate their network of pipes without occasional unexpected emergency repairs (interventions). However, the realistic goal of this management model is to achieve a preventive maintenance program for underground pipes and in that way to eliminate most of the required emergency repairs which are very expensive and generally have widespread negative influence on the city population. Critical points in the system can be improved using trenchless technologies before failure occurs. A preventive maintenance program, in all respects, is a more rational and better quality solution.

The future brings new construction and other technologies with it, and the proposed information system allows for new training and hiring of personnel and, therefore, stays open to future improvement and technological developments.

With an improved information system that uses an electronic database and takes advantage of the newest construction technologies (trenchless), an "old fashion" city utility company can be transformed into an effective manager of public property.

4. TRENCHLESS TECHNOLOGY ENABLED THROUGH THE INFORMATION SYSTEM (RESULTS OF RESEARCH INTO THE INFLUENCE OF THE INFORMATION SYSTEM)

The proposed information system has a vital characteristic in that it enables early detection of problems in underground pipes (through a preventive maintenance program), This aspect makes trenchless rehabilitation of pipes possible. The authors have analysed three projects in the City of Zagreb, where sewer pipes were replaced due to deterioration. All three pipelines were situated under city road surfaces. Table 1 shows summarised results of the comparative analysis for trenchless and traditional rehabilitation of the sewer pipe at the intersection of Brestovacka and Miroslava Kraljevica roads. Table 2 shows summarised results for all three analysed projects *[5]*.

Table 2 shows that the average percentage of specific traditional jobs (on-site work activities) that are eliminated (not necessary) in the CIPP trenchless method is 80.7 %. The average percentage of total costs that these activities account for is 87,1 %. Approximately 1,66 m^3 of poured concrete, 4,79 m^3 of gravel and 0,66 m^3 of asphalt is used per linear meter of rehabilitated pipe length.

Other data such as time overruns for the traditional (digging) method, and social costs such as disturbances in vehicle traffic, local city and landscape damage, dirt and noise pollution, are all factors that vary from project to project. However, if it is possible to use CIPP trenchless technology then the benefits are considerable in every case.

It is important to note the large difference in prices for installed pipe lengths for different projects. <u>Costs of purchase, transport to site, and placement near installed position in the performed work for the three analysed projects:</u>

- "Brestovacka road": 550.00 Kn/m^1 for 040cm and 935,00 Kn/m^1 for 080cm (reinforced concrete pipe).
- "Dubravkin put road": 290,00 Kn/m^1 for 080cm (non-reinforced concrete pipe)
- "Jurjevska road": 270,00 Kn/m^1 for 060cm (non-reinforced concrete pipe)

Cost of project per linear meter of rehabilitated (reconstructed) pipe length by traditional method:

- "Brestovacka road": 254,872.22 Kn, 20m = 12,743.61 Kn/m1
- "Dubravkin put road": 39.895.50 Kn, 15m = 2.659 JO Kn/m1
- "Jurjevska road": 3,190.508.00 Kn, 1,635.00m = 1,95138 Kn/m1

From the cost data noted above, it is evident that traditional pipe reconstruction technology has specific characteristics from project to project which depend very much on the contractor and local site conditions. CIPP trenchless technology has much less variation in price per unit length of rehabilitated pipe. This predictability of costs is a very significant characteristic of CIPP technology. Public utility companies can with this technology and a modern information system, make much more precise plans for rehabilitation and maintenance programs of underground pipes. Hence, through better planning public authorities can make better decisions for priority determination in renovation and improvement programs of city pipe infrastructure.

Table 1: Characteristic comparison between traditional and trenchless rehab methods

Rehabilitation of sewer pipe at the intersection of Brestovacka and Miroslava Kraljevic roads in Zagreb, Croatia. Rehab of 040 (8m) and 080 (12m).			
CHARACTERISTIC COMPARISON BETWEEN TRADITIONAL AND TRENCHLESS REHAB METHODS			
	Number of specific jobs required for trad, method	*Number of trad, jobs required for CIPP trenchless method*	*% of specific trad. Jobs that are excluded in CIPP method*
number of specific jobs	32	4	**87,5% excl.**
costs	254.872,00 Kn	29.950,00 Kn	**88,25% excl.**
Volume of natural material used in rehab construction	*Traditional method*	*CIPP trenchless method*	*DIFFERENCE*
concrete	72, 56 m^3	0, 00	**100 %**
gravel	130, 00 m^3	0, 00	**100 %**
asphalt	6, 73 m^3	0, 00	**100 %**
DURATION OF REHAB CONSTRUCTION WORK			
Planned for traditional rehab method		6 days	
Achieved in real conditions		54 days	
Time overrun		48 days (800%) Work was stopped due to very cold weather (unpredictable).	

Planned duration of CIPP trenchless method	*2 days*
Possible time overrun in CIPP trenchless method	1 day (measured in hrs.) Work is carried out in one technological cycle.
SOCIAL COSTS OF CONSTRUCTION AT BRESTOVAC/MIROSLAV KRALJEVIC	
Social costs for traditional (carried out) rehabilitation method	Social costs of the performed construction: • stoppage of city bus transport through Brestovacka road (1^1/2 months) • stoppage of local vehicle traffic • very significant influence on daily travel for local residents • mud, dust and dirt • presence of construction machines on local road
Social costs for CIPP trenchless rehabilitation method	• short stoppage of vehicle and bus traffic in one driving lane (one side of road), (insignificant).

Table 2: Summarised results for all three analysed pipe rehabilitation projects in Zagreb

CRITERIA		Brestovacka Road	Dubravkin put Road	Jurjevska Road	Average
% of specific trad. jobs that are excluded in CIPP method		87,5 %	91,3 %	63,3 %	80,7 %
% of specific trad, costs that are excluded in CIPP method		88,25 %	84,6 %	88,5 %	87,1 %
Volume of natural material used in traditional rehab consconstruction per linear meter	poured concrete / m^1	3,63 m^3/m^1	0,52 m^3/m^1	0,83 m^3/m^1	1,66 m^3/m^1
	gravel / m^1	6,5 m^3/m^1	2, 19 m^3/m^1	5,68 nrVm^1	4,79 m^3/m^1
	asphalt / m^1	0,34 m^3/m^1	0, 15 m^3/m^1	0, 17 m^3/m^1	0,66 m^3/m^1

5. CONCLUSION

In order to take advantage of the potential in new technologies for rehabilitation and maintenance of city underground infrastructure pipes, an appropriate management information system has to be implemented in public asset management. From projects analysed in this research, it can be concluded that Cured In Place Pipe (CIPP) trenchless methods could have provided better solutions for pipe rehabilitation had the proper information system provided the necessary information on time.

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