IT AND SYSTEMIC APPROACH FOR MANAGING SUSTAINABLE URBAN INFRASTRUCTURE REHABILITATION

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ABSTRACT

Urban development sustainability calls for new approaches involving economic, social political and environmental dimensions in order to face the institutional complexity of decision-making. That situation imposes increasingly growing constrains and challenges upon administrations in large cities. Therefore the decision to rehabilitate a particular asset in a strongly urbanize area is a complex task witch depends on many parameters. Often lack of relevant information during infrastructures' life cycle results in imprecise definition of what has to be done creating unexpected changes and costly impacts.

This paper presents a general approach develop base on some work implemented for urban's network rehabilitation. In Verdun by the use of total quality management and knowledge management the project team adopted a systemic approach and developed an integrated management system to manage project information flows, mobilized the internal human resources, managed the dynamics of the process, reduced uncertainties to solved problems.

The propose methodology allows manager to control information feedback loops to manage budget, program, conformance, risk and uncertainties. Development of a conceptual framework is described. The model enables managers to use IT and monitoring equipments to handle information, resource, material and people flows in the most efficient manner to generate add value to a rehabilitated asset and to maximize results integrities during planning and execution phases.

KEY WORDS

sustainability, urban infrastructure, rehabilitation, systemic, monitoring, total quality.

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INTRODUCTION

Urban networks maintenance is a major concern for municipal managers. In the course of time or because of human actions networks are aging and worsen in a natural way. Those degradations can be cause by work or traffic or conditions of use that were not envisaged in their vicinities.

The management of those networks is a complex endeavour that mobilize substantial financial and material resources and requires the collaboration of several stakeholders. The coordination of those individuals constitutes within that management process a considerable task. To find optimal solutions to those problems constitutes a major challenge for urban managers. Today that search has become increasingly difficult because of the more and more intricate bureaucratic, political, institutional, legal, economic, administrative, technical, social and cultural environments that prevail in the public management framework, figure 1.

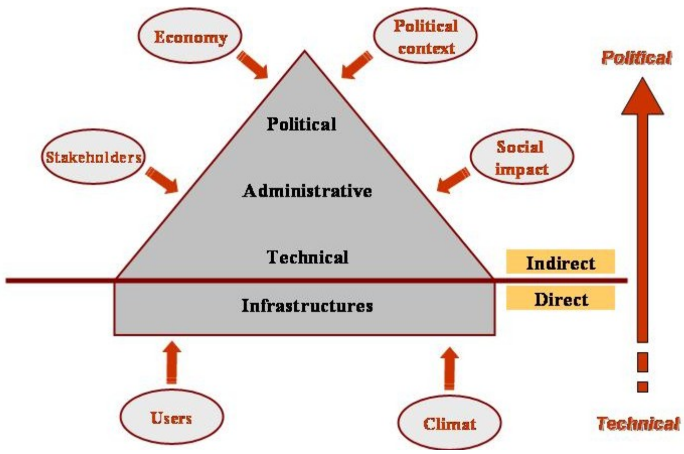

Figure 1: Management framework of an urban asset

In that context management of urban networks is also characterized by increasingly demanding conditions in various fields. It is necessary to respect the natural environment in order to prevent risks and to improve functionalities of networks that are often overburden or lack residual capacity.

As an example in rainy times citizen living in urbanize area are often threatened by floods originating from insufficiencies in waste water networks as from water courses. Increase amplitude of discharge can exceed the waste water treatment plant capacity and can generate spillage in water ways of crude surpluses of pluvial waters mixed with worn waters. When it rains those networks are not able to serve their purpose without being likely to flood populations nor to pour pollutants in the environment.

To recuperate water way usages it is compulsory to reflect on the need for restructuring those networks so that they can better play their roles by taking into account impacts related to interactions which they share with the environment. To face that situation and to optimize the rehabilitation of urban networks a more global methodology is needed which would make it possible to bring better structured and improved decision-making process for restoring those old works.

SYSTEMICS AND REHABILITATION

The systemic approach is a general and interdisciplinary theory which studies systems as sets of elements, materials or not in relation in ones and others and forming a whole. That approach has more and more application in scientific circles in particular in biology, economy and sociology to name only a few. According to a systemic approach an urban infrastructure would be describe as an urban system or urban subsystem that offers basic services to population in cities. Transportation, wastewater evacuation, drinking water and electricity supplies are some explicit examples.

An original concept call urbistic developed in Switzerland considers cities more globally as systems. It is thus a systemic approach applied to solve city problems. It aims by the use of feedback control loops to master information relative to decision-making to manage in a more rational way resources like water, energy, people, capital or waste that flows through a city by the mean of an urban infrastructure (Storelli *et al.* 1999).

That concept proposes to use monitoring through large scale field instrumentation, automation, data processing and telecommunication to acquire, control and organize information in order to facilitate the decision-making process in agreement with sustainable development principles. Sustainable development is a responsible management approach which is base on development models which meet the needs of present generations while preserving the possibilities of satisfying the needs of future generations socially, economically, culturally, politically and ecologically.

Monitoring is then the corner stone of that approach because it is the chosen tool to seek for achieving the level of service which is needed to allow improvement of the processes at stakes. Consequently urbistic can strongly profits from technological developments in the fields of automatism, data processing and telecommunications (TIC) (Revaz *et al.* 2000).

The key management tasks necessary to maintain an infrastructure can be represented conceptually by a disc superimposed on a flow of information like illustrate in figure 2.

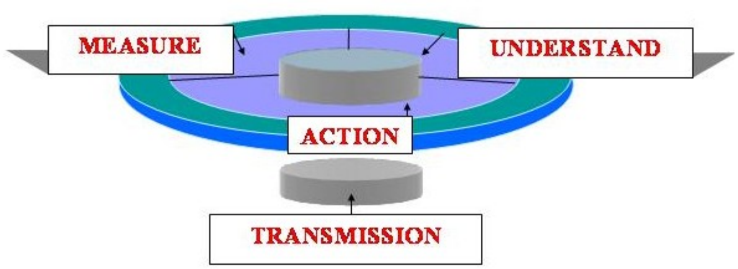

Figure 2: Measure-understand- action- transmission (Dion 2000)

The process can be express then in very simple words. First it is necessary to measure to know (data collection) and analyze to understand (data processing) so it becomes possible to carry out suitable actions (decision-making) and to share relevant information for coordination (transmission). The exploitation of data during the data processing phase rests on the use of one or generally several models which correspond to the behavior of the system studied as a whole or by subsystems which interact the ones with the others (Schmidt-Lainé and Pavée 2002).

In a more concrete form that information is not effectively transmitted but it is rather shared by the various stakeholders who must have the most relevant information to carry out their tasks efficiently. From a conceptual point of view monitoring can offer a mean to articulate the project management process through a quality evaluation procedure with the satisfaction of the need to fulfill in perspective and by taking into account the technological, economic, social, political and environmental constraints of the system under study. Also it is the systematic follow-up in a very flexible way and on a temporal scale of the management process which creates feedback loops. That follow-up is made using performance indexes and project targeting or other means to comply with sustainability indicators during all phases of those infrastructures life cycle that is ;

- strategic planning,
- evaluation and diagnosis,
- decision-making,
- scheduling,
- inventories,
- measurement,
- budgeting,
- allowance of resources.

With such a broad point of view in mind the management of urban infrastructures is well beyond the only prerogative of daily maintenance tasks. Indeed it is a much more complex reality. In general the management of maintenance of urban infrastructures constitutes the whole of the decisions to be taken, interventions to be carried out and resources to be mobilized with an aim of maintaining those works in good operating condition in the most efficient way possible.

The resources being limited that action is constantly subjected to conciliation at technical, administrative and political levels in order to succeed in planning the maintenance or even rehabilitation investments of existing networks that are no longer functional. For that purpose the knowledge of real conditions of networks operation become essential. That knowledge is increasingly crucial to manage risks in an urban environment. It is thus advisable to define which factors determines networks conditions and which are the procedures which allow its operation. That implies the knowledge of its structure, flows, interactions and the impacts of those flows in those networks vicinities. Figure 3 shows the management cycle of an urban infrastructure.

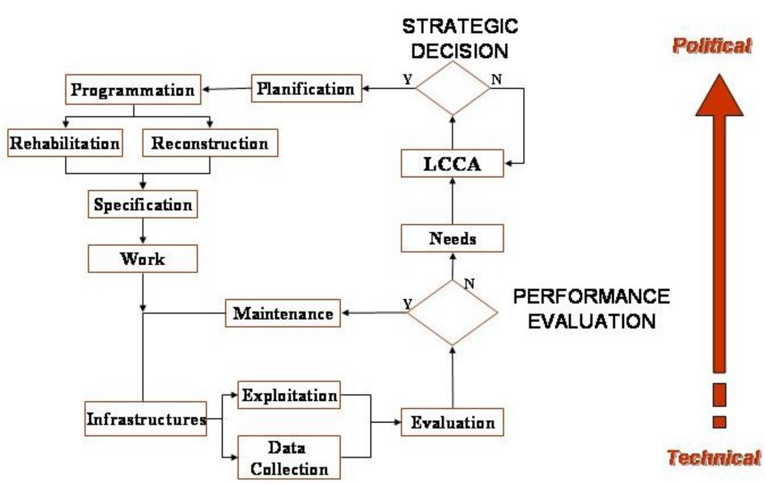

Figure 3: Systemic approach to rehabilitation

That cycle is compose of three elements. Two of those elements are stages, development and operation. Those two stages are link by the third element the decision-making process. Studies, planning, construction are activities which generally belong to the development stage. Exploitation, maintenance and data collection on another side are rather related to the operation stage. Figure 3 shows clearly that it is the decision-making process made up of evaluation, needs and performances analysis and the life cycle cost analysis (LCCA) which conditions the strategic choices to be carry out in regard of structural and functional conditions of networks. Consequently to control all the management process in whole it is necessary to control primarily the decision-making process. That action is thus closely related to the problem of managing information links to the real conditions of operation. That information is essential for the control of performances, costs, resources and schedules. That knowledge allows managers to program investments judiciously toward the renewal of obsolete existing networks and to make sure that they still fulfill user's needs. It helps the manager to monitor conformity or in other words manage the conformance of an asset. It should be specified that the management of conformity is a process which consists in being ensured that a product or a service comply to a customer need. Traditionally that endeavor was perceived as being technical and complex and limited to manufacture process control.

Today the management of conformity falls under a vision much broader of quality management. According to that vision, it is necessary to satisfy customers by offering quality products and services and to carry out that quality conformance by a joint effort of all people working; personnel, suppliers, distributors and those which deals with after-sales services (Kélada 1987). Thus according to Kélada that vision of total quality management cannot be the subject of a project or a program because is a continuous process which relates to everyone any time and everywhere in an organization. Total management of quality is in fact a philosophy a way of thinking on which the strategy of management of performances and all the operational policies are based. That vision exceeds the framework of a group implied directly in the delivery of products or services. It is a cycle as shown in figure 4.

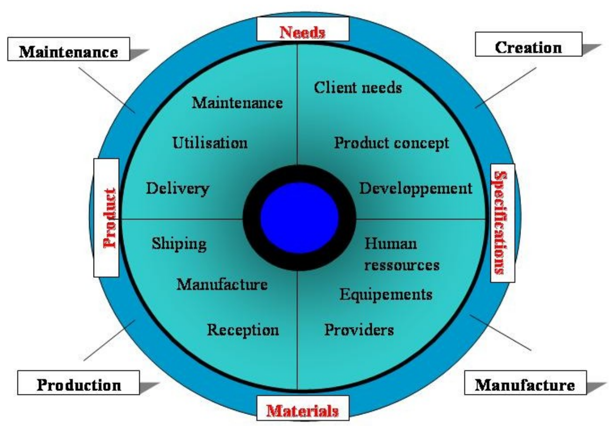

Figure 4: Quality cycle (Kélada 1987)

Thus for products and services providers the cycle of quality starts with the customer requirements. It includes those of shareholders and of the organization in general including also those of partners, suppliers and distributors.

At various level by its overlapping actions; inspections during process, tasks aiming at quality control, guarantees offered by quality assurance and proactive approach targeted by total management of quality, the process of management of conformity presented in figure 5 provides a whole series of follow-up procedures (Winch 2002).

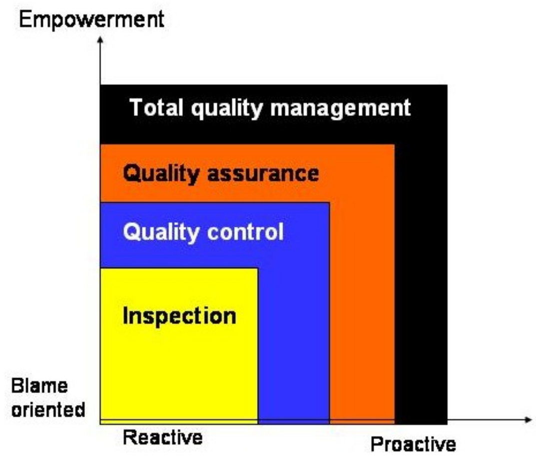

Figure 5: Approaches to conformance quality management (Winch 2002)

Those procedures are centered on the motivation of individuals by proactive approaches and set of values in opposition to reactive approaches that are blame oriented which for a long time showed their inefficiencies. Inspections make it possible to check if work is supplemented with satisfaction. Quality control uses control techniques to reach high levels of quality. Quality assurance rely on an external accreditation process to make sure that the practices of quality management are scrupulously followed and total quality management provides the motivation of continuous improvement.

According to the total quality management model the process of managing conformity is registered in the control of feedback loops which make it possible to improve all dependent process on one hand with the definition of needs and on the other hand with all actions necessary to ensure success of realization. Managing urban infrastructures according to that model consist in articulating feedback loops to achieve budgetary objectives in respect of a maintenance program and in a broad view which embraces all the process in respect of specifications, health and safety while generating less environmental impacts. The process of managing conformity aims in that case at eliminating any problems occurring during the life cycle of a network. It could be for example to eliminate accidents which can occur because of ambiguous drawings or from labors problems or non-observance of specifications. That process determines also up to which degree the requirements of the users will be met.

For an urban network, management of conformity is thus based largely on inspection, bench marking and performances monitoring. It is also based the benefits of proactive approaches targeted by total quality management and on feedback loops which results.

Problems often appear when the integrity of a product is not well defined or when specifications are change in the course of a project.

It can also occur when programming and budgets are badly managed and when defective information generates failures and accidents. This is why project managers must also approach conformity in a perspective which embraces health and safety and to respect environment in order to minimize risks of accidents to people and environmental prejudice throughout a network's life cycle.

Such a model is closely related with the total management concept presented in figure 6 and which aims at making a achieving organization (Flamand 1997).

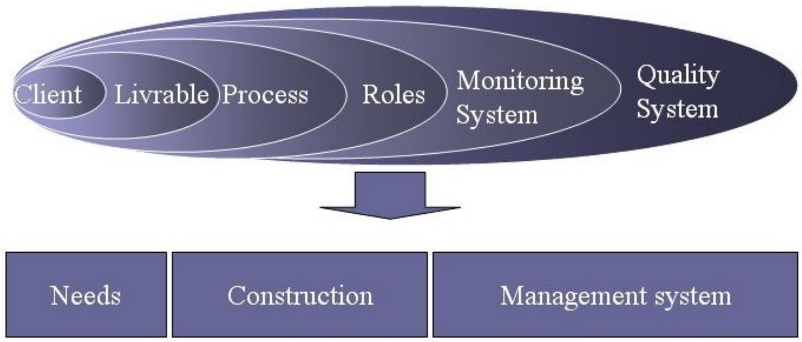

Figure 6: Global management parameters (Flamand 1997)

According to that model an achieving organization answers the needs of its customers by a complete integration of total quality management practices. That integration must be carried out during all phases of production at all level of an organization and for the total duration of the product's or service's life cycle.

That model is also connected with the evaluation and review process use in concurrent engineering which consists in binding by a feedback loop all activities of a system life cycle from design to disposal (B.S.Blanchard 1998).

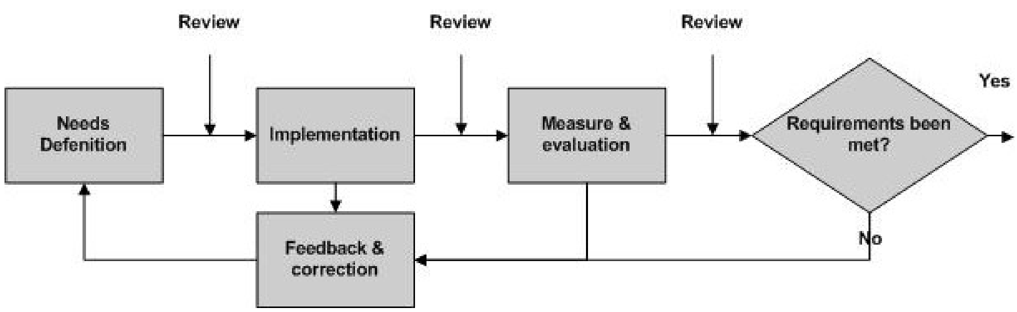

Figure 7: Evaluation and review process (B.S.Blanchard 1998)

That loop ensures at the same time the passage of information from top to bottom to satisfy the activities of definition and decomposition necessary for planning. Then from the bottom to the top of informations produced by the integration and the validation acquired at the time of startup, during operation and disposal.

Figures 8 presents how that loop is integrated into the processes within the generic Vee developmental model when it is adapted for construction.

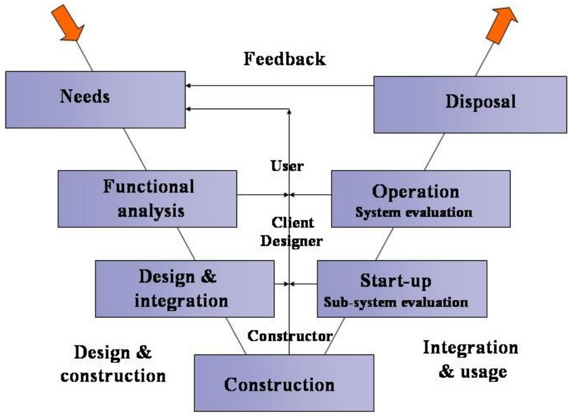

Figure 8: Vee developmental model (adapt from B.S.Blanchard 1998)

The respect of the level of services relative to infrastructures management is easily introduce to respect the users needs and match the project mission as it is schematically applied to network operation in figure 10 (Storelli, Dion, Claivaz 1999).

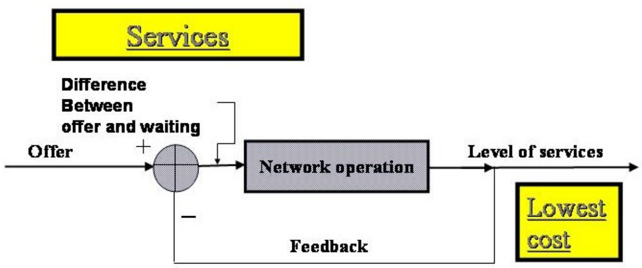

Figure 9: Mission of network operation (Storelli, Dion, Claivaz,1999)

That makes it possible to deliver the mission related to maintenance tasks of urban infrastructures witch is basically to rehabilitate the networks and offer the level of services awaited at the lowest cost. The follow-up is carried out by a systematic monitoring of information flows using a series of feedback loops according to the global management model during all the phases of a network life cycle and trough the key management tasks; data collection, data processing, decision and implementation, figure10.

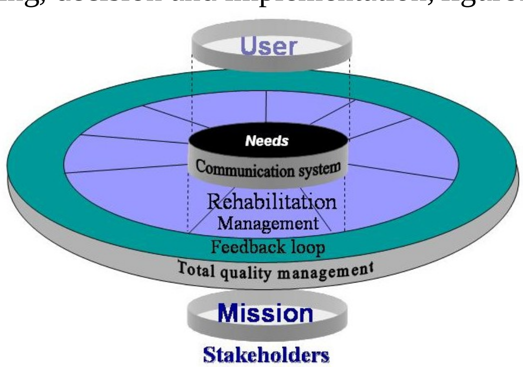

Figure 10: Riding a rehabilitation project (Storelli, Dion, Claivaz, 1999)

To carry out a systematic monitoring offers then a mean to articulate all the processes involved with the respect of the mission while generating added value and introducing mechanisms for continuous improvement by the use of generated data.

Also trough networking the addition of expert systems, artificial intelligence tools, knowledge base aided design software's and integrated data bases can thus be introduce more easily to improve the whole process. Research and development efforts in the field of expert systems resulted in recent developments of integrated management operating systems for urban infrastructures (SIGIU) which are strongly facilitated by technological developments related to the networking of urban systems. That technological brake trough is particularly marked in the fields of artificial intelligence, data processing, telecommunications (TIC), multi agents and mobile agents approaches to communication (Quintero and Al 2005).

However in the light of current knowledge it is difficult to evaluate and quantify the gain or profit obtained by the control of every single feedback loops implied in the delivery of a rehabilitation project. However it is undeniable that the access to new knowledge and reliable, relevant and quality information in order to structure the decision-making process is in oneself a tangible and measurable benefit.

THE VERDUN PROJECT

To show those benefits let us refer to the city of Verdun's waste water network rehabilitation project where that methodological approach has been followed.

Verdun was facing recurring floods in its down town district. The ageing and degree of degradation of its waste water infrastructures were the causes. The state of the network which for a great part was set up during the demographic explosion of the First World War required the implementation of large scale corrective measures to obtain general rehabilitation. To express the extent of the problem let us note that the municipality underwent from 3 to 4 floods per year which were each object of 60 to 80 complaints and whose cost by complaint varied between 1 000 $ and 60 000 $.

Being given the problem amplitude a possibility would have been to rebuild all combine sewer network into a separate sanitary and storm sewers in accordance with Quebec's regulation for new networks. That option was quickly eliminated for economic reasons. Indeed since the majority of current buildings in that district have flat roofs on more than 75 kilometers of streets it would have cost the municipality and its residents more than 175 million to conform to that ministry of the environment's directive.

When one takes account of expenses and costs for financing such a rehabilitation project it is more than 350 million that it would have been necessary to defray for that only district. The task to find other solutions was considerable because an extrapolation of those costs to the whole of the municipality which is in majority serve by a combine network was at that time evaluated to more than 1,6 billion $.

Based on that information a needs analysis to correct hydraulic and environmental dysfunctions of the network was carried out. That study aimed at determining the functional state of those urban infrastructures and up to what point requirements and standards relating to water's quantity and quality were respected. It aimed according to the methodological approach presented above to comply to sustainable goals to determine and reduce economic and social impacts due to floods on residents and to control and decrease environmental impacts of combine sewer overflows CSO on the St. Lawrence river. It also aimed at minimizing the fullness of work in light of physical constraints on the territory and to reduce maintenance activities necessary to maintain profitability.

Also at the same time the strategic decision was made to use monitoring by the mean of large scale field instrumentation in the down town district using automation, data processing and telecommunications to acquire the necessary information for that study and to make the proper decision.

For that purpose an exhaustive inventory was carried out over many years calling upon various methods; visual inspection, sampling, laboratories' analyses and inspections using cameras in closed circuit (CCTV). Also a SCADA system and a real time control system RTC were implemented. History of networks' construction and occurrence of floods were also established.

Further studies were carry out using operational research and management techniques, decision and forecasting models, computerize tools for simulation, quality control instrumentation, LCCA, benchmarking, scheduling of work software and optimization algorithms to achieve project goals more effectively. Information was share between various actors involved.

Also visualization, modeling and virtual reality tools were used with success when it was necessary to share information with decision makers.

Corrective measures proposed; retaining tanks, sub-surface networks, regulation structures assisted by the use of new technologies for management, operation in real time and control of water quality proved to be effective methods for hydraulic and environmental rehabilitation. By reducing flooding, frequency and concentration of pollutants in the waste water discharge in the St. Lawrence river and by maximizing the interception of first flush, the network reorganization implemented can be regard as been a credible alternative to classical approach that consist in reconstruction of an outdated network.

The validated and envisaged quality dataset will make it possible to act remotely on the various control bodies to use in an optimal manner the treatment and storage, transport capacity of rehabilitated sewer in order to minimize the impacts of discharges and floods.

In that case the benefits of generating key data by the mean of information feedback loops are considerable from an improvement of functional and environmental performances point of view and from an economic standpoint.

The use of systemic and global integrated management techniques calling upon RTC techniques allows to foresee the complete network rehabilitation for an amount of about 50 M $ instead of the 350 M $ anticipated. Also like many other projects carried out throughout the world it lets foresee economies of more than 50 % on the costs of water treatment because of volumes reduction. Moreover the environmental profit related to rivers' usages recovery is priceless (Colas *et al.* 2004; Marsalek and Chocat 2002; Pleau *et al.* 2005; Schutze *et al.* 2004).

The qualitative follow-up of networks and prevention of pollution risks provide by the system are an additional demonstration of profits related to the control of feedback loops. Measurement makes it possible to detect any going beyond of threshold and to alarm managers. It makes it possible to prevent risks by detecting rather early a tendency towards a dysfunction and makes it possible to include/understand phenomenon in order to plan then build and operate networks more judiciously.

Finally the approach presented in this article highlights potential synergy between distinct elements of a system and supports identification of actions to be privileged to improve efficiency. Application of that holistic solution to various city networks would consequently facilitate comprehension of interactions between systems and potential domino effects on networks (Robert B. *et al.* 2002). Analysis of data by various system managers and sharing information between various concerned municipal services would not only make it possible to plan joint actions but also to implement preventives measures to minimize consequences of catastrophes (ice storm, flood, earthquake, etc.) and to work out intervention plans.

CONCLUSIONS

The control of the relatively complex process and tasks associated with rehabilitation of urban networks lies in the control of flows of information necessary for the definition of the level of service required by users. It lies also on necessary actions required for sharing that strategic information with various actors for mobilizing and motivate human and financial resources necessary for planning, realization and control of activities.

That process is subjected to many human and budgetary constraints, to tight and unforeseeable schedules and must satisfy multiple performance's quality criteria. To adequately manage those constraints managers needs more global methodology and effectives tools. By adopting systemic approach and using TIC tools inherent to that approach they can achieve their goals more effectively.

The use of those integrated tools and methods and of the qualitative and quantitative data-processing functionalities that they provide can generate a considerable added value. That added value appears by improvement of effectiveness and efficiency not only during construction but also on the whole length of the work life cycle. Planning and control of rehabilitation are carried out in a way much more systematic. Time necessary for quantities' calculation, for estimation of cost and management of the supply chain are decreased considerably.

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