

Urban water distribution systems: Preventive maintenance

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Abstract: Preventive Maintenance for Water Utility Networks (PM4WAT) is a European Project which develops an innovative web-based platform and courseware for Vocational Education and Training (VET) on state of the art practice on preventive maintenance of urban water utility networks. The project aims at improved maintenance, increased reliability and decreased disruption of service. The proposed training programme involves: (a) a theoretical part, which includes web-based courseware that covers the principles of preventive maintenance for water utilities including the benefits, the limitations and the organisational aspects, and (b) a practical part, which involves a system that integrates a Geographical Information System, Reliability Analysis and Database Queries to compute how ageing and natural hazards affect the reliability of a network under different environmental conditions. The system offers the trainee suggestions on the best way to rehabilitate the network under study. Among the objectives of the above VET Multilateral Project are: (a) to transfer state of the art preventive maintenance methodologies to personnel of urban water utility networks from domain experts from the participating countries, (b) to develop a simulation platform that advises the trainee on the reliability of the overall network and examines various 'what-if' scenarios, and (c) to develop courseware for web-based as well as off-line training on preventive maintenance of urban utility networks which can be tailored to urban networks from all participating countries (Greece, Italy, Cyprus, Turkey). PM4WAT is a project for the Development of Innovation, convened in the framework of Lifelong Learning Programme Leonardo da Vinci of the Education, Audiovisual and Culture Executive Agency of the European Commission.

Key words: water networks, preventive maintenance, urban water, systems reliability, distance learning training

1. INTRODUCTION

The project develops an innovative web-based platform and courseware for Vocational Education and Training (VET) on state of the art practice on preventive maintenance of urban water utility networks. With the use of the platform improved maintenance, increased reliability and decreased disruption of service are envisaged. The proposed training program involves:

- a theoretical part which includes web-based courseware developed. This part covers the basic principles of preventive maintenance (PM), benefits, limitations, organisational aspects, etc. The platform will provide flexible and friendly authoring mechanisms, self-teaching and assessment capabilities, course and trainee management. Courses are also available as stand-alone multi-lingual multimedia applications on a CD.
- a practical part for off-line use which involves software that integrates Geographical Information Systems (GIS), Reliability Analysis (RA) and Database Query (DQ) to determine how ageing and natural hazards affect the reliability of the network under different environmental conditions. The new system is adapted from a prototype that was developed in an earlier FP5 project and will use real data from a medium sized urban water distribution utility. The system offers the trainee suggestions on how best to rehabilitate the network and

compute the associated cost. The trainee will also be able to examine the effects of different scenarios and learn the most appropriate rehabilitation procedures in case of a natural hazard.

The critical objectives of this proposal are to i) provide state of the art training on PM practices, ii) provide training on pro-active rehabilitation and iii) the effects of natural hazards. This is especially relevant for personnel in earthquake-prone regions. The partners have fused their national experiences and practices to produce a unified curriculum definition, a library of learning content and specifications of the web-based training course. The subject of the course also includes conditions, criteria and guidelines for PM.

2. OBJECTIVES

Most urban water utility networks involve pipe sections that have been subjected to fatigue, corrosion and damage due to settlement, soil erosion, leakage, earthquakes and ageing. As a consequence, the structural resistance, reliability, robustness and resilience of the network vary throughout the network. Preventive maintenance is the only way in which these hazards can be adequately anticipated.

The project is especially pertinent to water utility maintenance personnel in earthquake-prone regions. National experiences and practices have been fused to generate a unified curriculum and a library of learning content. The VET programme aims to:

- transfer state of the art preventive maintenance methodologies to personnel of urban water utility networks from domain experts from the participating countries
- develop a simulation platform that will advise the trainee on the reliability of the overall network and examine various ‘what-if’ scenarios
- develop courseware for web-based as well as off-line training on preventive maintenance of urban utility networks which will be tailored to the different participating countries.

The trend in VET is web-based e-learning in conjunction with advanced ICT tools where course content quality is of paramount importance. These activities, involve training of maintenance personnel, the search for critical factors and clarification of the mission and objectives which, in themselves, bring quality to VET.

VET in preventive maintenance of water distribution networks is rare. Most often, personnel learn on the job. The project aims at providing the courseware on state of the art PM and must be viewed as a positive step in improving the quality of training. With water losses accounting for almost 40% of the water in the network, improved maintenance tools can only be viewed positively.

VET traditionally prepares trainees for jobs with a high practical content. Here, procedural knowledge is preferred instead of declarative. Our objective is to improve the quality and attractiveness of VET for PM by familiarising the trainee with ICT techniques. The transfer of knowledge from co-operating countries can only lead to improved knowledge.

The impressive results on instruction by the use of ICT content and web-based learning has been documented at length. Vocational training is no exception and clearly the amount and range of ICT resources available to both trainers and trainees.

Emphasis is given to develop the quality and attractiveness of VET systems through improved comprehension through ICT media, state of the art ideas of knowledge transfer, curriculum preparation, ways that the new skills can be adapted and be accessible to the target group’s experience and requirements.

2. TARGET GROUPS

It becomes imperative today to train maintenance personnel in the state-of-the-art preventive maintenance and take advantage of new methodology for assessing the condition health and

reliability of a municipal water utility network. Accordingly, the target groups of this project are engineers and maintenance personnel responsible for the maintenance of these networks. The course level will differ for each group.

3. PARTNERS & CONTRIBUTING PARTNERS

The partners of the project are:

Research Academic Computer Technology Institute: RACTI is a financially and administratively independent research institution, supervised by the Greek Ministry of Education and operating under the Private Sector legislation. Today RACTI, employing over 250 persons, is an integrated research environment for the design and development of products and solutions in the area of IT and Telematics. Closely linked to the academic community, the international scientific community, the National and European IT industry and the public sector, RACTI has evolved into a research centre in Computer Science and Technology with an international reputation in basic and applied research. RACTI has undertaken more than 100 R&D projects including LLP, either as a partner or as a project coordinator and has also been serving as the official consultant of the Greek State in IT and in this context, has undertaken several large-scale projects.

RACTI has significant expertise in educational technology, GIS, DSS and water management information systems, intelligent systems and e-learning applications including vocational training. The principal roles of RACTI in the project are: a) responsibility for project management, b) ICT expertise with experience in educational technology and curriculum development c) development of the e-learning platform leading the relevant WP4 d) development of the training simulator leading the relevant WP5 e) active participation in all workpackages.

Centre for Assessment of Nature Hazards & Proactive Planning: The Centre for the Assessment of Natural Hazards and Proactive Planning has been established at the National Technical University of Athens, as a transdisciplinary initiative of the School of Rural and Surveying Engineering. It comprises twelve University Laboratories among which are: Geo-Informatics, Photo-interpretation and Remote Sensing, Reclamation Works and Water Resources Management, Natural Geography and Environmental Impact Assessment, Geodesy and Photogrammetry. More than forty academic personnel belonging to the above laboratories, participate in the research activities of the Centre. There is a long-standing experience on issues related to the assessment of natural hazards and management of natural and man-made systems. The Centre specialises in promoting research and technological development for management of water systems and organises related courses, seminars and symposia. CANaH has a long experience in promoting research, technological development and innovation through a number of systematic activities such as scientific papers publication, electronic dissemination of scientific results, postgraduate courses, short courses and e-learning projects.

CANaH is one of the principal sources of knowledge that will be embedded in the e-learning products of the project and will lead WP2 on the study of current practices and definitions of curriculum principles. Highly qualified personnel mainly from the area of urban system management contribute in the formulation of the educational content and are responsible for pilot training and the final conference. CANaH also leads WP8 on Dissemination.

Pamukkale University: Founded in 1992 as a national university, Pamukkale University (PAU) has currently over 26000 full-time students in her 6 Faculties, 8 Vocational Colleges, and 3 Institutes. The university has proven its strength in education and graduated students over sixty programs in subjects ranging from Engineering, Art and Sciences, Economic and Administrative Sciences, and Education to Medicine. Pamukkale University is located in the centre of a region which includes industry, natural wonders and cultural heritage all together. The Civil Engineering department has been very active in the field of earthquake related research since its establishment. Researchers have been involved in many international, national and local projects which cover large spectrum of topics from theoretical-computational to experimental. The department is also one of

the most active departments in Turkey on the assessment of pipeline systems, especially using geographical information system (GIS).

PAU contributes to several work packages of the project related to its expertise. PAU is already involved with extensive research activities regarding earthquake assessment of pipeline systems; vocational training projects such as PROWAT (a Leonardo da Vinci Project related to water loss); and training and teaching activities as its one of the primary task. As a result, PAU takes part in the following work packages: expertise in PM methodologies, expertise in training methodology principles, courseware content providers and providing vocational training. PAU also leads WP3 on Specifications of the Training Methodology.

HS Data Ltd: H.S. Data Ltd is an IT Solutions Integrator, employing more than 40 highly skilled professionals and operates in major vertical sectors, such as Banking, Insurance, Education, Utilities and Government. H.S. Data's solutions fall into four major areas from IT Consolidation and Infrastructure to Networking and Security, Office Automation and Professional Services. H.S. Data integrates existing IT systems within an organisation/project using Enterprise Application Integration (EAI) technologies and related systems. In addition, H.S. Data offers a comprehensive portfolio of vendor-independent implementation, support and maintenance services as well as specialised custom development. H.S. Data has acquired in depth expertise in delivering total IT solutions in e-Learning and Training through Government projects. To complement our expertise, H.S. Data have developed partnerships with many global market leaders including, Microsoft, HP and many others.

HSD has expertise in IT integration and e-learning environments and GIS applications. The principal roles of HSD in the project are: a) contribution to the development of the e-learning platform, b) contribution to the development of the training simulator, c) lead WP9 on Exploitation of the end-product, and d) support for pilot training in Cyprus.

TRAINING 2000 – ITALY: Training 2000 is a VET organization (Vocational Educational and Training) certified in the Marche region for regional training, with experience in adult education. At the EU level, Training 2000 is involved in research and development of new methodologies in training (blended learning) applied within the LLP programme. Since 1992, Training 2000 has been involved in international projects with partners from most European countries in which it has covered activities related to training of trainers, training for engineers and technicians of municipalities in waste and water management, pollution control. Training 2000 is continuously promoting adult training in the region, for apprenticeship, employed, unemployed people, social-economic disadvantaged groups, immigrants. At national level, cooperates with Associations of Industries and SMEs, Universities, training providers, Associations, Ministry of education and labour.

Training 2000 participates in most of the workpackages in the project. Specifically, Training 2000 contributes to the identification of current training needs of the target groups providing preventive maintenance (PM) in urban water distribution networks. They also contribute to the specifications of the training methodology and perform pilot training courses in Italy. They are responsible for the translation of the courseware material into Italian and they are the leading partner of WP7 on Quality Assurance. Training 2000 is also heavily involved in the dissemination and exploitation activities. In cooperation with the Italian network ATO3 which is the leading authority in water distribution in the province of Macerata, Italy, they undertake extensive testing of the e-learning platform, the training simulator and the courseware in WP4, 5 and 6 respectively.

Denizli Municipality: Denizli Municipality have been operating since 1876 and is responsible for urban and regional planning, public relation, social and cultural services, environmental management, infrastructure, traffic, environmental health, landscape. Main aim of the municipality is to improve all services provided and to make Denizli a place in which people want to work, live and invest. The water works department of the municipality manages the water supply system of Denizli with about 80 personnel. Denizli water supply system consists of about 2000 km of drinking water pipelines and serves about 500000 people. In recent years, large investments have been undertaken to improve the water supply system.

The role of Denizli Municipality in the project is to bring practical experience (methods, skill levels, etc.) to the project, complementing theory with practice. The Municipality contributes to the collection of the material and the development of the courses as well as in the participation in the testing of the training simulator tool and the web-based courseware. They also invite potential trainees (water utility employees, engineers, etc.) to participate in the pilot training sessions.

Water Board of Lemosos: The Water Board of Lemosos is a non-profit, semi-government organisation charged with the responsibility of supplying potable water to the town and environs of Lemosos which has a population of 170000. The main activities of the Water Board are: planning and execution of technical projects, operation and maintenance of the water production and water supply systems and all associated financial services including collection of water revenues and determination of water tariffs. The main objectives of the Board are to provide an adequate supply of water of high quality to meet domestic and industrial requirements, to plan and execute development projects and to maintain of the water distribution network. The efforts made and importance placed by the Water Board for proper network management is reflected in the reduction of the non-revenue water and in the improved operational performance of its network.

The role of Water Board of Lemosos in the project is to bring practical experience (methods, skill levels, etc.) to the project, complementing theory with practice. WBL contributes to the collection of the material and the development of the courses and participates in the testing of the training simulator tool and the web-based courseware. They also invite potential trainees (water utility employees, engineers, etc.) to participate in the pilot training sessions.

Contributing partners: The following partners are actively contributing to the development of the course content and its dissemination in their countries:

- Water Authority, Marche region, www.ato3marche.it
- ANCE Abruzzo, www.ance.it
- Università Politecnica delle Marche - Dipartimento di Idraulica, Strade, Ambiente e Chimica, www.isac.univpm.it
- Van de Meer & van Tilburg innovation consultants, www.innovation.nl
- Vitens Water Supply Co., www.vitens.nl
- ECO-ONE, www.kolumbus.fi/eco-one
- SYKLI Environmental School of Finland, www.sykli.fi

4. WORK PACKAGES

WP1 - Project Management: The aim of this work-package is to deal with all issues concerning the day to day operational management of the project including the financial management, project monitoring, completion of bilateral contracts and agreements with partners, IPR issues and reporting to the European Commission.

WP2 - Study of current practices and definitions of curriculum principles: In this work-package the participating domain experts exchange current national practices on maintenance on water utility networks. The outcome is a set of skills, principles, rules, practices and operation plans which form the backbone on which state of the art practices including the elements of Reliability analysis and GIS are embodied in the PM training curriculum relating to i) domain knowledge on preventive maintenance, ii) organisational knowledge on planning and rehabilitation of the network.

WP3 - Specifications of the Training Methodology: The formal specifications for the courseware are defined and documented based on the outcome of WP2. Attention is focused on:

- formal specification of the course model
- formal specification of the web-based e-learning environment
- definition of standards for the e-content of the courseware.
- the simulator and its integration into the course model are based on these specifications and are part of WP5.

WP4 - Development of the e-learning platform: This work-package focuses on the development of the e-learning environment that hosts the training courses. This must serve two types of users, trainers/course creators and trainees and must therefore provide functionality for handling learning content, editing features for combining assets into courses, web delivery of courses, course and trainee management facilities, friendly interactive course presentation and multiple choice tests (environment, authorization mechanism, etc.). Key features of this platform are i) the support offered for self-taught courses, cost of maintaining and updating, ii) customization and asset handling mechanisms, iii) automatic assessment capabilities.

WP5 - Development of the training simulator: This work-package is developed in parallel with WP4. This WP constitutes the practical part of the project and will be provided on a supplementary CD for off-line use. This system contains three agents. The innovative software will serve both trainers and trainees and must provide functionality for training on the use of the simulator.

WP6 - Development of the courseware: During this work-package the partners use the e-learning platform and the project-built library of learning material in order to contribute to the course on preventive maintenance of water networks, each partner concentrating on one or more aspects of the subject and always giving the topical flavour and special conditions and requirements of every country. In the pilot training phase, a group of selected maintenance engineers and personnel will go through the courseware that has been produced and provide feedback on the use of the system and the training process. It is foreseen that after the pilot phase all partners will have become sufficiently familiar with the use of the system and auxiliary material to be able to adapt it to their own needs.

WP7 - Quality Assurance and Validation: The aims of this work-package are threefold:

- to ensure that the project outcome follows the specified standards, to provide responsive mechanisms so that any shortcomings are identified quickly and to take the necessary corrective actions
- to enrich all testing activities with quality standards
- to provide a final project validation report on the methodology adopted, learning goals and achievements of the project

WP8 – Dissemination: Dissemination activities are horizontal and organized in the following tasks:

- development and continuous update of a Dissemination Plan
- dissemination activities

WP9 - Exploitation of Results: This work-package refers mainly to the sustainability of the project. The goal is to ensure that the results will be exploited and utilised by interested parties after the end of the project.

5. OUTLINE OF THE COURSEWARE

Module 1: Urban Water Supply Networks

- Sources of water (All types of water sources: surface water (no regulation), surface water by diversion dam, surface water from storage dam/reservoir or off stream reservoir, springs, lakes and pools, groundwater, groundwater mining, rainwater harvesting, brackish water treatment, desalination water, recycled water, long distance conveyance).
- Reservoirs (Surface reservoirs/dams, off-stream reservoirs, pressure regulating reservoirs, groundwater reservoirs, lakes, pools, service reservoirs/tanks, water towers, home tanks).
- Main conveyance network (Pressured water mains, low pressure water mains, canals and ditches, tunnels, water conveyance by vessels).
- Water treatment plants
- Water distribution network (Open (tree) distribution network, closed (looped) distribution network, mixed distribution network).

- Protection equipment and techniques (Pressure reducing valves, air vents, air vessels, non-return valves etc.).
- End users' facilities (Water meters, water discharge regulators).

Module 2. Network Mapping

- GIS, CAD and other technologies (Customisation of GIS and CAD in water network mapping).
- Attributes (Attributes and information required with geographical reference).
- System update (Procedures, practices and timing for the system update).
- Organisational aspects (Organisational structure and expertise for network mapping).

Module 3. System Hydraulic Modelling and Analysis

Methods for modelling and analysis of:

- Open (tree) system
- Closed (looped) system
- Mixed system
- Extensions and changes in the system
- Simulation of future scenaria
- Software availability (Software packages available with limitations and guidelines for users).

Module 4. System Performance Assessment

- Types of losses
- Ageing of pipes
- UFW & Non-revenue water
- Performance indices
- Public perception of quality of services
- Vulnerability with regards to Natural Hazards (Preparedness planning against the major natural hazards).

Module 5. Criteria and Objectives

- Water sufficiency (Continuous and intermittent operation, Cuts in water supply, Rations).
- Water quality (Quality requirements, quality measurements and organisational requirements).
- Energy requirements (Energy consumption, monitoring of energy consumption per m³, alternative sources of energy, guidelines for energy saving).
- Reliability (Percentage of time of successful operation (Index vs time)).
- Robustness (Flexibility measures for future changes (Index vs time)).
- Environmental impacts (Possible environmental impacts for the entire process from the source to the user and back to the environment).
- Economic and financial measures (Economic appraisal road map of water supply systems, financial measures for achieving sustainability of operations, economic incentives for water saving).

Module 6. Technical Options

- Business as usual (destructive management; Destructive vs proactive management: benefits and costs).
- Pressure management (Pressure zoning, night operation, water and energy saving through pressure regulation).
- Leakage identification & quantification (Basic steps for identifying leakage, methods, equipment and personnel required. Economics of leakage identification. Optimised procedure).

- Pipe and appurtenances replacement (Guidelines for replacing pipes and appurtenances. Optimal procedure for replacement of appurtenances with or without inspection).
- Organisational development (Organisational structure for leakage control and pipe and appurtenances replacement).
- Operations development (Long term and short term scheduling of operations (personnel, timing, economics of operations)).
- Monitoring and Automation (Manual and automatic monitoring of system performance. Identification of procedures which may be enhanced by automations).

Module 7. Societal Options

- Campaigns (Organisation of seasonal and occasional campaigns. Preparation of leaflets, messages, adverts).
- Educational programmes (Organisation of educational programmes tailored for the staff, NGOs and interested people).
- Pricing policy (Rationalisation of pricing policy. Pricing policy supporting weak groups. Special pricing policy for the various sectors of consumption (e.g. industry, tourism, commerce, state organisations). Bonuses and penalties for users).
- Public Participation (Organisation of regular meetings. Review reports. Occasional presentations. Framework for public participation).
- External audit for the quality of services (Audit requirements (quality of services and status of the system). Specification of external audit).

Module 8. Best Practices

- Guidelines for estimating demand
- Guidelines for design and construction
- Guidelines for optimal operation
- Guidelines for repairs and maintenance
- Specifications of material quality

Module 9. Evaluation Questions

6. ANTICIPATED RESULTS

The end-product consists of multilingual web-based courseware for training programs for preventive maintenance of urban water utility networks.

The courseware is available on the web and off-line in the form of CDs in 4 languages (English, Greek, Italian and Turkish).

The second major product is the training simulator which is also be available on a CD accompanied by a user manual. The end products of the project are expected to be universally applicable.

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