

## **Summary Report**

**Public**

**ART**

**Contract RO-97-SC1007**

**Project Coordinator: National Technical University of Athens (Greece)**

### **Partners:**

- **Transport Environment Development Systems (TRENDS) - Greece**
- **Liapakis C. - Balis V. Consultant Engineers (GEOTECH UGP) - Greece**
- **Forschungszentrum Informatik (FZI) - Germany**
- **Josef Voegele AG - Germany**
- **Becker Bau Bornhoeved GmbH & Co. KG (BBB) - Germany**
- **Technical Research Centre of Finland (VTT) - Finland**
- **The City of Aalborg (AALBORG) - Denmark**
- **ANAS-Ente Nazionale per le Strade (ANAS) - Italy**
- **Universita degli Studi di Napoli "Federico II" (DIT) - Italy**

### **Reference period:**

**11.2. 1997 to 11.5.1998**

**Date: 15 May, 1999**

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COMMISSION UNDER THE TRANSPORT  
RTD PROGRAMME OF THE  
4<sup>th</sup> FRAMEWORK PROGRAMME**

## **Title**

Automated and Robotic-based Techniques; New Solutions for Road Construction and Maintenance

## **Objectives**

The project aims at exploring the potential for introducing automated and robotics-based technology in road infrastructure construction and maintenance (RICM) operations in order to reduce their execution cost improving simultaneously or at least without adversely affecting the conditions of safety, work quality, road user cost and non-road user cost. In parallel, the working conditions must be improved taking into consideration the losses in the number of jobs that these innovations may cause.

New techniques applied either to new construction work or rehabilitation and maintenance work could reduce the cost at several levels. First at the task level, second at the operation level, third at the management of an entire road section construction where several operations are executed, finally at the upper level of managing and funding the entire RICM program.

In this project, the basic objective is fulfilled at the operation level by integrating ART technologies within the RICM processes, and thus appropriately restructuring them.

## **Technical description**

The research identifies 29 RICM operations that could benefit from the use of automated or fully robotic technologies, making this selection out of a long list comprising almost all the RICM operations. Thus a short list is produced based on two key items: the operations' frequency and the budget allocated to them. This selection is based on the experience of those project partners who are road administrators, constructors or designers. A description of the selected operations is provided presenting the currently followed technical process, data on cost, performance, time duration or other indicative elements.

Subsequently, new road RICM operation scenarios are built so called ART road operation scenarios that consist of techniques and machines that incorporate automated and robotic-based technological systems. The work is constricted to a first estimate on the feasibility of automating the RICM operations, thus there is no a detailed design of the new scenarios, but a general description of the functions and key features that the RICM machines could be equipped with.

Methodologically the work proceeds by several steps. First the ART architecture is set up where all appropriate technological systems for automation are indicated, namely positioning systems, robotic systems and CAD systems. Based on their technological capabilities, appropriate configurations are discussed and some generic solutions are proposed for ART road scenarios. These scenarios incorporate automation at the machine and task level, while the important issue of acquiring automation at the operation management level is considered but not extensively discussed in the present context.

Regarding the positioning issue necessary for machine guidance, a system based on GPS technology using differential and RTK/OTF techniques appears to be suitable for road operations in the rural areas. Cases where this configuration might fail must be confronted by aiding the main positioning system with other auxiliary ones or still using conventional surveying methods. Contrary, for road operations in urban areas, this technology standing-

alone rarely could work. Alternative solutions are provided, emphasizing laser-based systems. Finally, an integrated system consisting of GPS and intelligent targets is discussed, based on a judgement that for several cases such a solution could be workable.

Regarding the robotic technologies that could be incorporated in ART machines, a selection is made on various available tools, sensors, communication machines, computing systems and software systems. Their capabilities are considered in order techniques to be studied that could be incorporated in ART machines. These techniques concern the following areas: kinematics, gripper systems/tools, drive technology, power supply, undercarriage, sensor technology, control, MMI, and information flow.

Furthermore, an assessment of the ART road operation scenarios is conducted, in an effort to measure the expected benefits and negative impacts when compared with the traditional techniques presently in use. The assessment is limited to capture only the direct impacts avoiding to include issues related to higher order effects, which influence in long term the economic or social life of the society as a whole.

Distinguishing the analysis between various groups directly involved in RICM operations, namely the road authorities, the road constructors (independently of their size and specialization), the labor force, the road users and the non-road users, a separate assessment is carried out for each one of them. For this purpose, the following assessment criteria are determined: the execution cost of each operation, the traffic safety, the working conditions, the socio-political concerns, the quality, the road-user cost, and the environmental impacts. Furthermore, these criteria are broken-down to attributes, which could measure every single element. Their composition gives the total effect of the relative assessment criterion. Third, for each major actor or affected group a set of criteria and respective attributes is determined in order to perform separate assessments.

Due to the fact that the road works are carried out in a variety of conditions and sites, only general ratings of the attributes can be done. Moreover, the new ART scenarios are described in theoretical sense and no experience from deployment is acquired. For these two reasons, any effort to perform a quantitative assessment is considered as loss of generality. Additionally, any exact calculation could be relevant only in few cases and become inaccurate for other site-specific conditions. Thus within the context of the present analysis, a qualitative assessment is conducted, identifying trends and general expected impacts rather than exact outcomes.

For three assessment criteria, namely traffic disturbance, traffic safety and working conditions, a separate discussion is performed, since they are site and traffic condition specific. Appropriate analyses are proposed for assessing them when detailed data are available of every operation. For this reason, these analyses are conducted only for the four operations studied at the level of the design scheme.

The research work ends up with the detailed design of 4 road operations of major and wide concern, namely the paving operation, the recycling operation, the pipelaying and the bridge rehabilitation, achieving results of immediate interest for industrial development.

## **Results and conclusions**

Based on the experience of the project members of the Users' Group, consisting of road administrators and constructors, a short list of RICM operations is produced (29 in number), which are considered that could benefit from the introduction of automated components or fully robotized. This selection is based on two key data items from the records of the above mentioned organizations: frequency and allocation of budget.

On the technological level, the project end up with the conclusion that several necessary components need further research or development refinement for being available to be used in RICM operations. Existing CAD systems for roadways do not fulfill data exchange requirements with positioning and computer systems installed on machines to monitor their motion and their tool movements. Furthermore, the positioning systems are still a matter of concern. In this project solutions are proposed, which can deliver the required data in most cases especially in rural areas. However, a further research is needed to specify the system for machine path monitoring within an urban environment. In rural areas, a three GPS-Antennas configuration is proposed, while in urban areas an integration of GPS with laser-based intelligent targets could be a promising solution. Finally, control systems aiming at rule-oriented control still need considerable research and development work.

Regarding the assessment carried out between conventional and ART scenario RICM operations interesting results came up. Specifically, the road authorities could benefit the most from the use of ART. The road constructors could benefit from the lower cost and the faster execution of the operation, in addition to the decrease of working accidents; however, depending on their scale and specialization they will experience varying levels of impacts. The labor force faces conflicting impacts, since compensation between better working conditions and lesser availability of jobs will be the consequence of using ART. Because the labor force is not a homogenous group but comprises a versatile of interests, the stand, that every working group will take towards that development depends on the qualifications its members possess and the type of work that are assigned. Finally, the road-users and non-road users will experience benefits varying according to the traffic circumstances that prevail in the greater area of the work site.

Deploying ART into the paving operation, a substantial improvement of all main operation features is expected, namely quality, performance and safety of workzone personnel. A comparative bar chart illustrates the better performance that can be achieved although the comparison is made in relation to the method of compact asphalt paving. However this method in order to be introduced requires the achievement of a high degree of automation.

Regarding the other three operations, ART in the pavement recycling operation will require about 25% less lorries to feed the recycler, a change of performance will be experienced as well as better quality and personnel safety. For the pipelaying operation is expected a 25% time reduction in excavating the trench and laying the pipes and diminishing risk for personnel working into the trench. Concrete reinforcement rehabilitation on bridges is a health impairing operation for working personnel. Since this operation requires a detailed, complex and painstaking involvement of experienced personnel, currently the ART deployment in this case is feasible as a tele-operation. The main advantage will be determent of health impairment to personnel.

### **Collaboration sought**

The strategy for exploitation of the results of each partner varies according to the nature of the partner.

The road administrators will write the specifications, which are necessary for the new technological environment either by their own departments or by assigning a contract to an engineering firm.

The industrial partners, i.e. VOEGELE, can proceed in the development of a machine prototype within its house since this partner is market oriented and needs to be competitive in its products.

The research group, i.e. DIT, NTUA, etc. will seek cooperation with industrial partners in order to transform the results of a pre-prototype research, as the ART-Project was, into the development of a prototype. In addition it could assist the road administrators in writing the necessary specifications for the new environment of carrying out the operations as well as designing the new workzone layout and determining the impacts on the road users.

### **Exploitation and dissemination plans**

Industrial partner VOEGELE will work out directly the results of the project in order to proceed to the development of a prototype for the paving and recycling operation.

Partner NTUA has integrated the results of the project into a course in one of its post-graduate programmes and seeking collaboration with industrial partners to proceed to the further development of the technical scenarios and design schemes resulted from the project. The same is true for all other research and consulting partners (VTT, FZI, DIT).

The road administrators can implement the findings of the project to redesign their specifications documents for the construction and maintenance programmes of their road networks.

In regard to dissemination plans, first the partners who own a www-site have built an ART-page, wherefrom the deliverables of the project can be viewed and downloaded. Second the partners will present the findings of the programme in common or individually at the next annual meeting of Transportation Research Board (year 2000), other related conferences and in a world surveying conference or international surveying journal especially the issues of vehicle positioning and monitoring.

European Commission can utilize the results of the project to finance specific prototype developments according to the perspectives set for each technical scenario to support European manufacturing industry compete world-wide.

### **Names and addresses of the coordinator and all partners involved**

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