

Workflow Automation in a Risk Management Framework for Pavement Maintenance Projects

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Abstract: This paper presents a Workflow Management System (WfMS) for procurement process automation in road pavement maintenance and management. It fits information infrastructure for monitoring and maintenance of pavements and roads. Through the two roles of administrator and major users (builder and subcontractors), the solution models the entire process. This way, risks of exceeding allocated budget, time consuming tasks, overcoming deadline, and time consuming quality control, as main issues in risk management, are reduced and controlled.

Keywords: workflow management systems, process automation and control, risk factors, pavement maintenance and control.

1 Introduction

Concerns in terms of pavements design and tests are described in [21] as an action that involves several mandatory steps to assure the best anticipated performance in service. As main steps, authors mention selecting the aggregates, asphalt and additives to be used, testing the asphalt mixtures with varying proportions of the ingredients as close to the field condition as possible, and selecting the optimum mix design. Impacts of geographic location (environment features) and construction type [6] and a flexibility in design, cases when this does not fully respect the standards established [17], has to be considered. Some authors like [16] gave a great importance to socio-economic perspectives and conclude that the direct and indirect environmental, economic, and social impacts, termed as Triple-Bottom-Line (TBL), were not addressed sufficiently. So, one of the main activities in pavement construction projects is the testing phase. The test results influence the material selection for the project. There are several ways to determine the current status of asphalt concretes intended to be used in construction projects, such as core drilling (as destructive method) or Marshall stability test [21] (as non-destructive method). Authors mentioned the Marshall stability test which is related to the tensile strength of the asphalt mixture [21] and [5] and recommended non-destructive testing methods for determining the

structural condition of an in-service pavement. Other testing proposed method for determining the material parameters of a fatigue cracking model based on Accelerated Pavement Testing were identified by [5] and [22]. Tests are also essential to determine several features that may influence the time at which the pavement starts to crack, as an essential component of pavement management for planning of maintenance and rehabilitation, where three major features are relevant in terms of the performance of an asphalt pavement [9]: permanent deformation or rutting results, fatigue cracking, and low temperature cracking.

Tests are also relevant for road safety in terms of vehicle handling when tire pavement friction is considered [10]. According to World Health Organization Statistics from May 2016, there are [23]:

- About 1.25 million people die each year as a result of road traffic crashes;
- Road traffic injuries are the leading cause of death among young people, aged 15-29 years;
- 90% of the world's fatalities on the roads occur in low- and middle-income countries, even though these countries have approximately half of the world's vehicles;
- Half of those dying on the world's roads are "vulnerable road users": pedestrians, cyclists and motorcyclists;
- Without action, road traffic crashes are predicted to rise to become the 7th leading cause of death by 2030.

Last stats for Romania according to World Health Organization Statistics are from 2013 and there are 1881 estimated number of road traffic deaths with an estimated road traffic death rate per 100.000 population of 8.7. From 179 analyzed countries, statistics are not encouraging and place Romania on the 5th place, according to the estimated road traffic death rate (per 100 000 population).

Selecting the correct model of pavement is a long term decision as this may affect many adjacent application domains as modeling of the user's path choice behavior, safety, pavement conditions and so on [15].

Many times, materials tracking from request to their use in projects is a difficult task for a real-time overview of supervisors. Besides test results, other factors are essential. Before project start, some parameters like costs, time and quality are defined: a. a budget is agreed and approved, in terms of costs; b. a deadline for completion is set, in terms of time; c. a set of materials and quality (number and special features for each material item) is defined, in terms of quality of work.

The focus of this paper is the development and integration of a WfMS for road pavement maintenance and management (PMMS), according to risk management factors. Section 2 provides several open source solutions for WfMS, part of them can be used as cloud solution and Section 3 presents material resource planning for PMMS, based on JobRouter® WfMS as a cloud computing or on premise offer. Last section formulates conclusions and future work.

2 Related work

The Workflow Reference Model (WfMC) includes five interfaces: Workflow Definition Interchange (Interface 1), Workflow Client Application (Interface 2), Invoked Applications (Interface 3), Other Workflow Enactment Services (Interface 4) and Administration and Monitoring tools (Interface 5) [3].

WfMS provide support in three functional areas [3]:

- build time functions for defining and modeling workflow processes and their activities;
- runtime control functions for managing workflow processes in an operational environment and sequencing activities;
- runtime interactions focused on human users and other application tools for processing the various activity steps.

Other authors joined these three functional areas in two core functional approaches: design time, build time functions and runtime gathering runtime control functions and their interactions. Functional perspective are several parameters: runtime and design time. Runtime parameters are: Research Scope, Installation Time, Documentation, Platform Independent, Easiness of Installation and Utilization, Web Based, Other Software Required, Middleware Platform, DBMS Integration, and Transactions Support. Design time parameters are: Process Definition Time, Documentation, Easiness of the Process Definition Web Based, Organizational Perspective and Workflow Language [19].

We pointed out several open source and Cloud solutions for WfMS, which are most popular and suitable for pavement maintenance.

The YAWL system is an open source workflow solution based on the YAWL (Yet Another Workflow Language) language, and is conformal to the WfMC reference model specifications.

It supports the control-flow perspective, data perspective, and is able to interact with web services. YAWL provides support for workflow patterns, and offers mechanisms that allow persistence, automated form generation and workflow administration. From runtime perspective the installation is simple and it provides a web based application which is user friendly. YAWL requires JRE and Apache Tomcat and is compatible with a middleware platform: SOAP. It allows exceptions treatment during process execution and offers integration with PostgreSQL as an alternative to Hypersonic, but not with all DBMS compatible. From Design time perspective. Graphical editor provided is not web-based, the definition of own sample process was simple but it does not support the organizational perspective [24].

JOpera offers an administration and monitoring tool, and it implements WfMC reference model. It offers a process definition application, and it is able to interact with other applications. From runtime perspective the system was developed with research purposes, based on Eclipse workbench, and is not a user friendly management environment. JOpera requires Java JDK and Eclipse, provides integration with the most popular DBMS and supports simple exception handling model. From design time perspective JOpera process editor is hardly to use for the definition of process longer, it does not support the organizational perspective. The workflow language is JOpera visual composition language [14].

ProcessMaker is an open source and/or on premise as a cloud solution, which implement WfMC reference model: offers an administration and a client application, offers a process definition application, automate document, approval-based processes across departments and systems. It can be a suitable solution for business users and process experts without programming experience. ProcessMaker contains two main components, a design environment and a run-time engine. The design environment includes tools to map processes, define business rules, create dynamic forms, and manage input and output documents. The run-time engine allows for started and run threads through the process [8, 18].

JBossjBPM is a flexible and extensible WfMS, which implement WfMC reference model: offers an administration/client application, can interact with other applications, and offers a process definition application. From runtime perspective: the installation and usage of this workflow solution quite simple, jBPM requires the installation of JDK and Eclipse with the JBoss IDE plugging, and a middleware platform (Java RMI or CORBA). It offers portability

for most popular databases and supports transactions, allows exceptions treatment and rollback during process execution. From design time perspective JBossjBPM uses BPEL in order to define processes, and the definition of sub processes is not supported. JBossjBPM supports two process definition languages: jPDL and BPEL [11].

Beside those positive features, we also pointed several inconveniences in risk management for pavement maintenance. YAWL and JOpera does not support the organizational perspective, which is the core approach in road maintenance. Due pavement maintenance involve company associations (consortium, collaborative approach) on various sections components, assimilated as sub-processes JBossjBPM is not suitable because the definition of sub processes is not supported.

Another open sources WfMS which have cloud solution are: Bizagi Modeler and a BPM Suite which support the organizational processes and life cycle, Joget Workflow as a web platform for development, deploy and run workflows for organization's business processes, Bonita, Enhydra Shark, JawFlow, JFolder, OpenWFE, RUNA WFE, WfMOpen [8], [19].

3 Workflow automations in PMMS

Risks identified by analyzing the life cycle of a pavement construction project are listed below, ranked according to the conveyed impact, as high, medium or low. High risks factors are: 1. obtaining the necessary funding, 2. exceeding the proposed deadlines, 3. budget over run for various reasons, 4. the deviation from the road axis, 5. instability phenomena, cracks or road crevices appearing in the road embankments, 6. road traffic. Medium risks factors are: 1. lack of personnel, 2. signing a contract with a collaborator, 3. inclement weather (rain, snow), and 4. deviations from the tender book and soils used for embankments. Our workflow intended to decrease high factors (from 1 to 3) and medium factor 2 by implementing an automation workflow for material resource planning, which can be used by companies and collaborators involved in road maintenance projects. Extended risk factors' classification was presented in another paper.

In this case are involved two main actors; user, which can execute own proper tasks according to role and project phase and administrator, which gives users roles and supervises all users and whole workflow of JobRouter® Web frontend offers web-based interface for all user groups (forms for users, reports for process owners or defined users/functions, and workflow designer for process designers). The application allows numerous ways to initiate processes (input as email, files, web service, and scan) and output formats (email, XML/CSV, PDF, logs) activities coordinated by JobServer and JobMail module. The application has a flexible infrastructure and interfaces to any system possible (ERP, file system, CRM, DB, external archive systems, FA) that allows various integration (Figure 1).

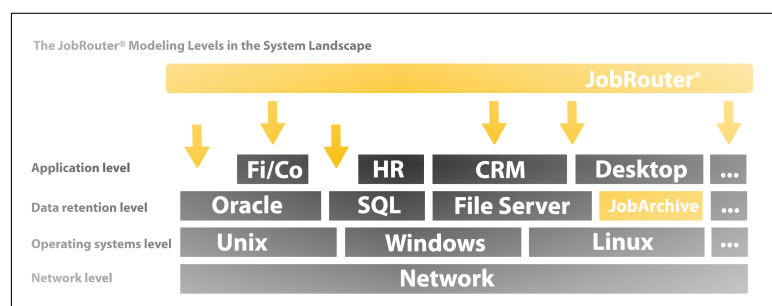


Figure 1: JMultilayer development solution [13]

Multilayer architecture (Figure 2) consists on Workflow Layer, Application Layer (which include interfaces with ERP, CRM, FA), DataStorage for various solution (Oracle, SQL, FS,

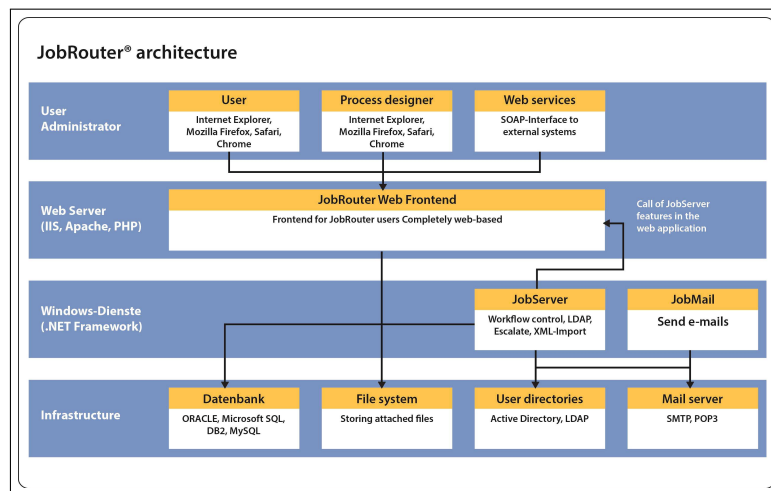


Figure 2: JobRouter® architecture [13]

Archive), and Operating System (Windows or UNIX). It allows users several advantages: each user interaction with the system is stored in the system database, each step can be postponed when this is applicable, each user can request additional information from another user when this is applicable, each generated file is stored and indexed into the application and it can be viewed using the application HTML5 viewer.

With an additional JobTimer module, a deadline can be defined for each process or for each step of the process and with a JobSub module each user can select a substitute for a specific period of time, when not available or on vacation.

Main benefits of the JobRouter® implementation are:

- the application is highly scalable and a stable process engine;
- the application allows multiple system activities for processing and converting data and documents (data maintenance, document conversion and recognition, programs run);
- the application has a fully integrated document archive.

For our main workflow we used: Microsoft Windows Server 2012R2 with Microsoft SQL Server 2014, Internet Information Services (IIS), Visual C++ Redistributable for Visual Studio 2013, Microsoft ODBC Driver 11 for SQL Server, IIS URL Rewrite Module 2.0, and JobRouter® Environment 3.9.5 (then updated to 4.0.0) ioncube_56 install package with JobTable, JobSub, JobPDF, JobSelect and JobArchive modules. The application was tested in all often used browsers and passed all tests for Google Chrome Version 51.0.2704.106 m (64-bit), Firefox 47.0.1, Internet Explorer 11 Version 11.0.9600.17416, Opera 38.0 Version 38.0.2220.41 and Safari 5.1.7 (7534.57.2).

Items appearing once on a material request, as the name of requestor, job function, site, contact details, direct supervisor or date, are stored in a process table with process identification fields as processID, step, status and stepID. Items appearing on several positions on a material request, as the name and characteristic of material, and requested quantity, are stored in a subtable with a subtable view. Several features, as contractors, subcontractors, environment and specific features in PMMS, workers and resources involved, and others, are also defined. This set of parameters materializes in a central database with project details. A centralized record database helps tracking project status and facilitates comparison of what was planned, what was performed and what remains to be improved. All information generated by any user of

the system during the workflow are stored in the database so queries to provide details about the work in a real-time status. Some prerequisites of the system configuration are applicable: when a new user is created in the system, all details as name, function, direct supervisor, site/sites, and contact details are defined; each user is assigned to a function and each function is assigned to a specific step in the workflow; each user can define a substitute for his own user or for his function, when it is not available or on holiday; for each site, relevant details are described (details in terms of costs, completion time and quantity/quality of materials/work); some templates for forms, emails, reminders and generated documents are defined. A CSV procedure is supported by the application, Active Directory Synchronization for application users or single sign on settings to ensure a minimum effort in use of the application.

Designed workflow involves the following steps (Figure 3):

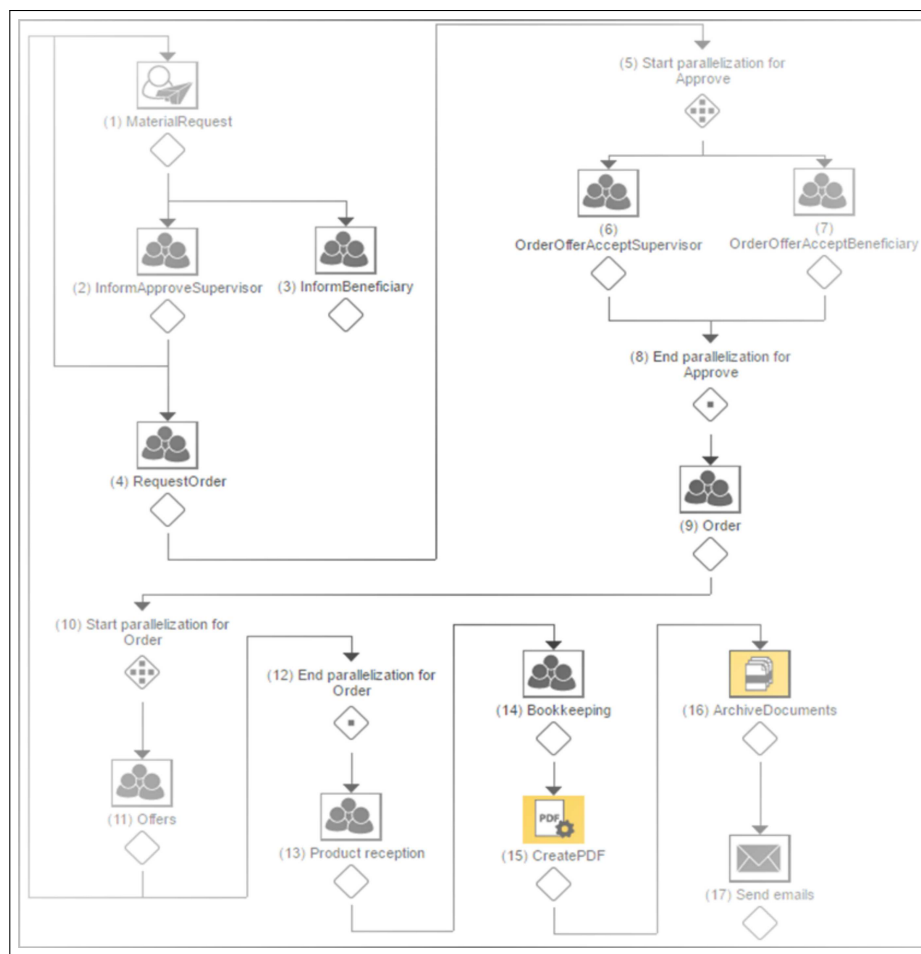


Figure 3: Material Resource Planning Workflow in PMMS

1. MaterialRequest - First step, a worker from a specific site, can start a material request using a standardized form interface. This form contains relevant details about the need and the list of materials; it also automatically retrieves information from the system about the requestor, construction site and other relevant details. The workflow follows then a sequential processing (second step is defined as subsequent step);
2. InformApproveSupervisor - Second step is activated after the first step is processed (the leading step); the supervisor receives the request with all details and he can decline or

- accept the request;
3. InformBeneficiary - The beneficiary is informed about the request, too; unlike the supervisor, the beneficiary does not influence the workflow, he is only informed without taking a decision of approving or not;
 4. RequestOrder - The request is submitted and send to suppliers; A step can be processed by a user or by a group of users; A processing time is defined (1-3 days in this case to make an offer, depending of each request amount);
 5. Start parallelization for Approve - In this parallelization step, the request is sent to the supervisor (site master) and to the beneficiary representative. Each one can approve, reject or request changes for each element of the request. In this parallelization, process is no longer sequential, steps 6 and 7 (starting this point) are simultaneously activated;
 6. OrderOfferAcceptSupervisor - The supervisor can approve, reject or request changes for each element of the request;
 7. OrderOfferAcceptBeneficiary - The beneficiary representative can approve, reject or request changes for each element of the request. Step (6) and Step (7) can be allocated to different users of functions and can be edited independently. Next step - Step(9) in this case - is activated only after Step(6) and Step(7) are completed;
 8. End parallelization for Offer - This is a join step where the status for each element is gathered and approved elements are forwarded in an Order to Step (9);
 9. Order - is activated only if both, site master and beneficiary representative, approved the material request and a new order is posted to the selected supplier;
 10. Start parallelization for Order - The order is received by selected supplier and requested elements are shipped;
 11. Offers - The supplier generates the invoice and each element of the request receives a new status. Some elements are billed and delivered, some of them are not in stock and for some of them similar products are proposed;
 12. End parallelization for Order - Each element status is gathered and billed elements are shipped;
 13. Product reception - Shipped elements are received by applicant specialized department;
 14. Bookkeeping - Details about the order are send to the bookkeeping department for payment and used in future specific accounting procedures;
 15. CreatePDF - Request order and clipped documents are stored in PDF files;
 16. ArchiveDocuments - Generated documents are automatically indexed and archived in the system for a quick later access. Centralized archive can be web-based accessible and emerging documents are clipped to the initial request order. A detailed overview for each order is accessible;
 17. Send mail - When this instance of the process ends, the initiator, the site master and the beneficiary representative are informed that requested materials were received and the bookkeeping department received all necessary documents for payment.

These steps are qualified in: User steps (1 to 10, 9-Order, 13 and 14), Start parallelization step (5, 7) and End parallelization step (8,12) as a beginning and ending sub-process and System Step (15-17). Each involved user can access on-time reports with relevant details about the order and status of order: accepted, declined, changed, received etc. (Figure 4).

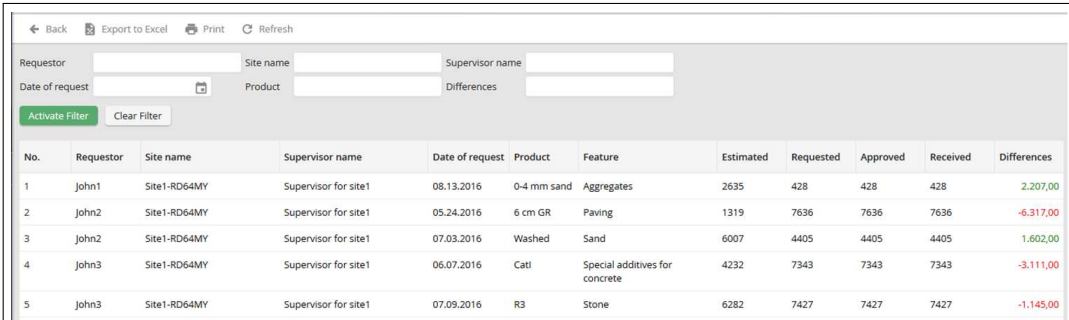
4 Experimental results

Generally, in the maintenance activity is working in teams, each team is coordinated by a manager of the process, called supervisor. There are cases where subcontracting situation often arises; in this case, a number of n companies are coordinated by a manager. The supervisor collaborates with the beneficiary and with the consultant that advises the quality of work. In Figure 3 is represented only the beneficiary because the consultant has no right to decide on material costs.

We selected the most enlightening case study in the process of asphalt (or bitumen) acquisition, used to repair malfunctions. Steps 2 and 3, respectively 6 and 7, are defined as parallel steps because the acquisition must be approved by both representative users, the customer and the process manager.

If case of curbs, fences, traffic signs, marking materials, etc. acquisitions, product acceptance is performed at a specific time t and their use in the maintenance process can be made at time $t + n$, where n is the number of days elapsed until the real use. For asphalt, if the reception was made, it must be used immediately to repair defective portions because it loses its qualities over time. This situation can lead to a quality risk of the work and time (delays in completion). In this case, step 13 occurs after the real use on the road or sidewalk, without delay. Delivery of the asphalt is made according to the specific needs and risk events occurred. Therefore, steps 9-12 are defined as parallel steps.

Table from Figure 4 shows process status for each material request type. We have 5 columns according to order status and product reception: Estimated, Requested, Approved, Received and Differences. Every step 9 automatically increases Approved values and every step 13 automatically increases Received value.



No.	Requestor	Site name	Supervisor name	Date of request	Product	Feature	Estimated	Requested	Approved	Received	Differences
1	John1	Site1-RD64MY	Supervisor for site1	08.13.2016	0-4 mm sand	Aggregates	2635	428	428	428	2.207,00
2	John2	Site1-RD64MY	Supervisor for site1	05.24.2016	6 cm GR	Paving	1319	7636	7636	7636	-6.317,00
3	John2	Site1-RD64MY	Supervisor for site1	07.03.2016	Washed	Sand	6007	4405	4405	4405	1.602,00
4	John3	Site1-RD64MY	Supervisor for site1	06.07.2016	Cat1	Special additives for concrete	4232	7343	7343	7343	-3.111,00
5	John3	Site1-RD64MY	Supervisor for site1	07.09.2016	R3	Stone	6282	7427	7427	7427	-1.145,00

Figure 4: Supervisor report

Differences are presented in suggestive color: red for material and green for suitable differences for materials and are used in risk management analysis as $RG=3$ for every red values (Figure 4).

Because all messages are sending immediately all steps from 1 to 15, we can have a duration from 5 days to 20 days maximum, depending on suppliers' response. A medium duration is 7 day taking into account 2 weekend days. Moreover, archived documents (step 14) offers possibility to make a complete risk analysis, linked with others risk factors (distress, product events and so on).

Conclusions

Developed application controls project environment risks and, most often, prevent exceeding allocated budget, reduce time consuming tasks and especially improves quality control. Comparing to previous experiences where no IT platforms were used in pavement construction projects, this solution improves all three mentioned parameters: time, funds and quality.

In terms of funds, it creates a centralized database where all material request is stored with related prices. In this way, a real-time tracking for material costs budget lines is performed. In previous cases without IT platform support, there were many cases when budget was exceeded because materials evidence was not available to all sites and reallocation of materials was cumbersome because it was not known if the extra materials on a site could cover the requirements from another site and new orders were performed. Also, there was no high control on costs and on approval chain. In terms of time, it reduces time for orders and approvals, so involved personnel can be relocated to other specific activities of the project. In previous cases without IT platform support, there were many cases when teams were not working because of the materials lack and they were expected materials not yet approved, due to a cumbersome approval and acquisition paper-based procedure. In terms of quality, it improved material quality check and provides support for on-site inspections. This type of application was a time-saving tool for on-site inspectors; it saved time and checked specification criteria when a new on-site inspection was conducted. In previous cases without IT platform support, there were many cases when same verifications were performed by same person because there were no evidence that planned set of materials were ordered and used in the project.

As future work, new workflows for travel in the country or abroad and for life management can be developed. In this way, if a user is away or on vacation, a substitute is automatically activated and respective user will not be included in the construction workflow. Sensors can be integrated to capture relevant data; Collected data can be integrated in several intelligent vehicle systems for user assistance and safety [20] or integrated in web-based systems for routing of pedestrians with different physical abilities within built environments [1] technologies that are also implemented in less developed countries. Concerns are also in terms of safety and security, to embed wireless communications technology on the pavement or surveillance technologies [4], [12] and to collect and transmit different data types, even trigger medical assistance support in case of emergencies [7].

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