Management of Large-Scale Projects Through a Federation of Web-Based Workflow Management Systems: Swissmetro Case Study

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Abstract

Swissmetro project is classified under large-scale project category. It is a multi-billions transportation project, a high-speed and high-frequency passenger transport system, working as a super underground transportation system, meets the new needs that are arising at the dawn of the third millennium. In this project all the activities will be outsourced. In other words, there are many actors will be involved in the execution of the project. One of the main problems that will face the management team is the coordination between different parties- sponsors, prime contractors, subcontractors, consultants, and suppliers- involved in achieving the project goal. The proposed business model seems the best solution to overcome the mentioned problem. Such a project cannot be managed efficiently and effectively without web-based models that automate the business processes and extend them outside the organisation, filling the information needs of project parties at all levels; from individual team members to high level managers. To survive, Swissmetro project management team will have to adopt newer and better methods for managing and controlling the execution of such a large-scale project. This paper proposes a conceptual framework model which builds a collaborative network that brings together any customer, any supplier and any partner. Regardless of which software they are running. The proposed web-based model is especially helpful in situations where project partners, e.g. main contractor and his sub-contractors, are located at different sites or even countries. The model is based on integrating a wide range of up-to-date IT applications. A workflow management system, a web-based project management system, mobile agents and dynamic database system are connected together to support the model. This paper shows how the Swissmetro project management team could manage, monitor, control and coordinate the execution of multiple workflows operating within, across or between organisations.

Keywords

Large-scale project - Project Management - Swissmetro – Workflow management system
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1. Introduction

A project is a problem scheduled for solution. This definition emphasizes the problem-solving nature of project business in general. Once the problem or objective is defined then the most suitable solution or work plan is allocated in accordance with predefined time constraints. By adding to this definition the pre-set budget, temporarily grouped organizations, a minimum of a decade's duration, a technologically nontrivial nature and global industrial and public collaboration, we have the main features of a large-scale project [1].

Large-scale projects contain thousands of workflows, hundreds of organisations, and different resource allocations. Numerous parties - sponsors, prime contractors, subcontractors, consultants, and suppliers - are involved in achieving the project goal [2].

Several documentary research findings regarding large-scale projects (e.g. Euro-tunnel linking England and France) indicate that some of the fundamental problems of failing to achieve the project goals in keeping with the set timetable and budget originate from [3], [4]:

(i) ignorance of what other project teams are doing; (ii) poor reactivity to sudden changes in the project environment, (iii) lack of discipline in design change control. Hameri [1] argues that those problems are communication-related issues.

Large-scale projects are usually based on temporarily grouped organisations, which require communication mediums and protocols to manage geographically distributed design, engineering and production activities. Yet communication is important not only when something must be accomplished. Controlling and measuring the communication flow within the project considerably enhances the potential for a more profound understanding of the project's status and level of progress. However, successful project management must not be performed as an isolated activity within the company. Rather, project quality management requires the involvement of and information sharing between project members [5].

1.1 Motivation

With globalisation and the networked world of today, there is a trend toward decentralized teams, multi-site projects [2] and dispersed structures of organizations. It is becoming increasingly difficult for project management systems to cope with Global-Large-Scale-Projects (GLSPs) effectively [6] in terms of control over execution and information sharing between all levels of project members.
Managing GLSPs effectively differs from traditional large-scale projects because time, distance and dependence on communication technologies in decision making adds complexity to interactions between project members [7].
As a consequence, managing GLSPs presents new, and in many respects, more difficult challenges. In an effort to manage their GLSPs effectively, companies have used a variety of information technologies, such as project management information systems, web-based project management software, Workflow Management Systems (WFMSs), videoconferencing, audio-

conferencing, and e-mail [2], [8], [9], [10]. However, each of those systems has its own limits and drawbacks.
E-mail and video-conferencing are helpful tools for communicating and holding a team meeting in which the members are geographically dispersed [11]. But those systems are tedious to maintain, and require the efforts of numerous support personnel to manage and exploit their outputs for analysis [2].

The goal of the WFMS is to control the workflow among all members of a group that are involved in a certain business process [10]. The WFMS is already being applied within companies in various domains and departments (e.g. manufacturing: an exchange of data and process information between the consumer, manufacturer, and suppliers of raw materials). What we still lack is the utilization of this system across companies [8]. Information and communication systems based on open and platform-independent architectures are able to overcome the geographic boundaries of workplaces.

Although there are many commercially available Project Management Software (PMS) packages, most have deficiencies in both the content and structure of their databases. Typically, these databases are proprietary and only suitable for access and update by the project management system itself [5]. Thus, the limitations of the databases and the incapability of the system to interface with other systems from which existing data files have been created are the main drawbacks of the current generation of project management systems. In addition to that, PMSs are useful in the early project phases of planning and definition. For procedures that require the capability to integrate time, cost, and performance information, to distribute this information through the Internet, and to do it quickly and efficiently, PMSs seem the only practical means. But once the project begins, PMSs provide little assistance in controlling the quality of execution of individual tasks (inspection functions). In practice, however, inspection functions, which make sure that tasks are executed according to specifications and standards, are carried out through standard and repeatable processes (e.g. receiving intermediary results from the contractor, checking those results, giving the order to the contractor to continue, receiving final results, checking them, confirming the completion of execution, in addition to managing the circulation of different documents related to the activity under execution). However, the WFMS seems the best tool for supporting those processes, especially in GLSPs where the execution of hundreds of activities must be controlled simultaneously.

The PMS and WFMS must be inter-operable and compatible. They must be fully interfaced with each other and with other systems being used on the project [12].

Both a review of current systems and other studies [13], [14] confirm that most of the current systems are not based on the latest technological advances in computing and IT [13]. Any system developed today must be flexible enough to allow for the integration of a range of emergent IT technologies, to the greatest extent possible. Correct system architecture will also 2], [13].

As a result of the current system limitations, there is a dire need for reliable and efficient systems that allow geographically dispersed organizations to manage, monitor and control their GLSPs and to share the project information more easily and with less expenditure of time and effort.

This paper proposes a conceptual framework for a Web-Based Information and Project Management (WBIPM) model that enables the GLSP management team *first,* to monitor and control the execution of multiple workflows operating synchronously within, across or between organisations and *second*, to coordinate information flow from the time of its creation until its elimination and to share this information among all project members.

This model builds a collaborative network that brings together any customer, supplier or partner, regardless of the software they are running. The proposed web-based model is especially helpful in situations where project partners are located at different sites or even in different countries.

The model is based on integrating a wide range of up-to-date web-based IT applications. A workflow management system, web-based project management software, mobile agents and a dynamic database management system are interconnected to support the model. The authors believe that integrating the functions of those IT applications will lead to overcoming the aforementioned limitations.

The model yields benefits for all parties in the project. Some of those benefits, in addition to the abovementioned, are: immediate electronic updating of the project progress status, efficient and easy communication between all project parties, immediate availability of project information, and measurement of project performance.

Those benefits allow GLSP management teams to identify problems while they are small, meet deadlines, ensure quality control and manage the costs of the project, all of which helps to minimise project risk.

In the following section, we will introduce and describe the generic architecture for the WBIPM business model. An overview of the four main entities and their roles will be given, in addition to a comparative study of the function of the WFMS and the project management system (PMS). With this in mind, we will present and discuss the concept and process management of the WBIPM model in section 3. in section 4, a case study approach has been chosen from the construction industry to demonstrate how the model would support the execution phase in a large-scale project. Finally, section 5 will offer some conclusions.

2. A generic Architecture for the Business Model

One possibility for developing this model was to create its tools from scratch. But this would have been a major mistake as it would have discarded all the existing work and know-how developed by numerous R&D projects. Therefore, our position was to try to combine the most interesting aspects of the existing IT applications and tools, and to add the necessary elements whenever required.

The overall model architecture is shown in Figure 1. The Management Team (MT) of the GLSPs sets up the E-platform. The goal is to enable project members to browse it, through a user-friendly graphical interface, and see all the information and data related to the tasks they have to perform. All that project members need to gain access to the E-platform is a web browser, such as Internet Explorer or Netscape, which is available on any computer with Internet access, and a password provided by the MT. As shown, this E-platform contains four main entities that integrate and cooperate to produce benefits for all project partners.

The first entity in the architecture is a web-based project management software package. In the design of the proposed model, existing project management software is used as a planning and monitoring tool. It has the capability for planning, budgeting, and controlling the projects and functions as a means for collecting, organising, storing, processing, and disseminating the information.

The second entity is a central web-based, object-oriented database management system (OO-DBMS) that serves as a repository for all the dispersed project data and project-related information. OO-DBMS involves the data itself and the software that controls the storage and retrieval of data, and also provides mechanisms for storing and organising data in a manner that facilitates the satisfaction of sophisticated queries and eases data manipulations.

The third entity in the structure is the workflow management system (WFMS). It is designed to assist the GLSP management team (MT) in carrying out work procedures through more effective use of organizational knowledge of resource requirements and flow of work. The workflow technology has been reported to be effective in specifying, executing, and coordinating the flow of tasks within a distributed environment, while reinforcing flexibility [16]. In the proposed model, the WFMS is used to ensure that task execution is achieved in keeping with desired requirements and specifications.

The fourth entity in the structure is a mobile agent (MA). It is endowed with sufficient intelligence to act autonomously in certain circumstances and can be empowered to make responsible decisions on behalf of its principals. The aim is to reduce the time and effort required to update the database and the project management software.

In the following paragraphs, we start by introducing the four abovementioned entities of the business model structure and their usefulness.

2.1 Project Management Software

In the proposed model, a web-based project management software package is used. It provides the means for monitoring the network of tasks, e.g. identification of tasks, identification of resource requirements and costs, establishing priorities, planning and updating schedules, and measuring project performance [2].

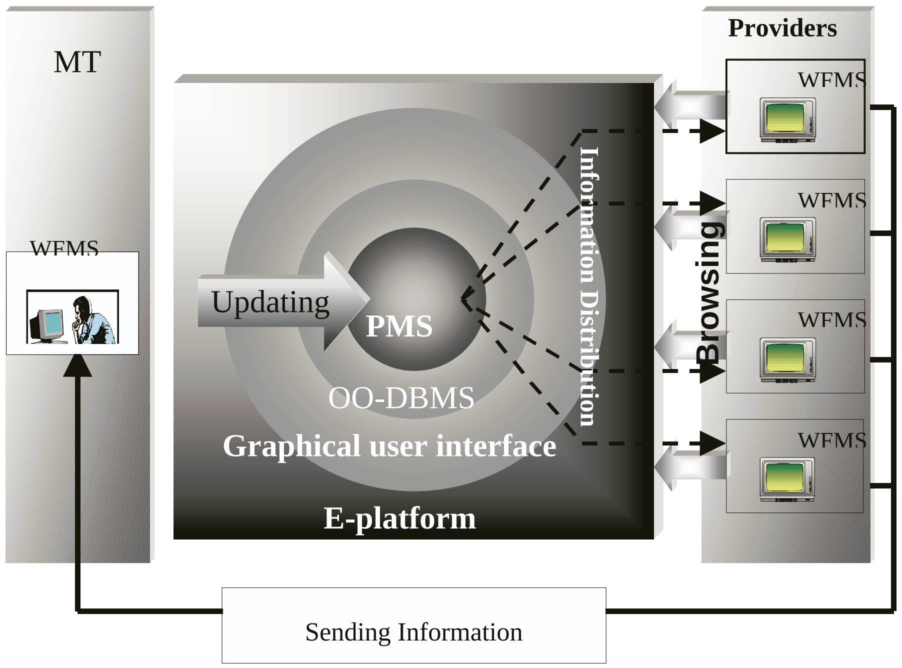


Figure 1: The Architecture of the WBIPM Model

The monitoring function must ensure that management receives reports in sufficient detail and frequency to enable them to identify and correct problems while they are small. The reports include information on overall project performance, such as percentage of work completed, milestones reached, budgeted cost and actual cost, and so on. This software has the following features and capabilities:

i- Scheduling and network planning: using a network-based procedure (PERT and CPM). ii- Resource management: performs resource loading, levelling, allocation, or multiple functions. iii- Budgeting: associates cost information with each activity. iv- Cost control and performance analysis: the system is able to compare actual performance (actual costs and work completed) with planned and budgeted performance.

However, once the MT configures the project management software on their local computer, they (MT) up-load it to the E-Platform so that it will be available for all project members. The project management software in our model is able to integrate network, budget, and resource information and allow for quick review and easy periodic updating, they filter and reduce data to provide information on summary, exception, or “what if” questions under various scenarios while the project is under way [15], [2].

2.2 Database Management System

The database layer contains structural information such as constituent tasks, their dependencies, expected duration, and the responsibilities, resources and routines associated with them. The database also contains real-time information about the current status of the project as well as historical data [10].

The current generation of PMSs and WFMSs use the relational database management system (RDBMS). The relational database model is a logical representation of the data that allows the relationships between the data to be considered independently of the physical implementation of the data structures.

Today, E-business applications are demanding more complex types of information and the database that supports them must deliver complex-data scalability, and extensibility. The traditional RDBMSs are not best suited for Web data because they understand only limited and simple types of data (integers, dates, floating-points, character strings, date/time, and money). To overcome those limitations, our model uses a central web-based, multi-user, object-oriented database management system (OO-DBMS). The object database specifically focuses on complex transactions, unlike the RDBMS. It allows for the addition of complex data, functions and access techniques to the core engine. This database will serve both the project management and WFMS. Access to the database is provided for multiple, simultaneous users. The main advantage of having a central web-based OO-DBMS is that the data required for the project members can immediately be taken from this database, and the results derived from the execution of the tasks and activities can immediately be transferred back to the database. The features of this database are specifically suited to the demands of our model. It pages for real-time complex search capability to allow users to combine decision support with transaction processing, gateways to legacy relational databases to support linking back-end data to the WBIPMS and giving it content veneer.

2.3 Workflow Management System

The importance of workflow and process technologies is increasing today as we see a convergence of communications connectivity and software tools for collaboration among computer systems [16]. Workflow Management Systems (WFMS), which provide the tools and functionality to design, implement, and automatically coordinate the execution of business processes, have also received great attention in recent years [17].

In the WFMS, the procedures for performing the business process are standardized by a set of sequential rules. Each task, when finished, automatically initiates the next logical step in the process, until the procedure is complete [10].

Modern WFMSs allow resources to execute the work steps from anywhere thanks to web-enabled access for enhanced end-user access. Work is also under way for enabling interoperability between different WFMSs, allowing inter-organizational processes to be executed over heterogeneous systems [18], [19], [20] and “wide area” workflow management [21], [22].

In this model, the WFMS has two main functions. First, controlling the quality of execution through a standard process, and second, automatically updating the OO-DBMS as to the status of execution.

2.3.1 Tasks in PMSs and WFMSs:

This section aims to distinguish between tasks in PMSs and WFMSs. Tasks have long been considered the fundamental building blocks in both project management and business processes. The differences lie in the network of tasks.

In PMSs, tasks are connected on an ad hoc basis and deal with a one-time effort for a unique, and specific goal. On the other hand, in business processes, tasks are aligned on a more steady state basis where the primary goals are the achievement of efficiency and consistency. The business process originated from the practical needs of introducing consistency and repeatability in handling diverse business transactions. While there are a seemingly wide variety of requests and the possible combination of tasks to fulfil these requests, the underlying assumption is that there is similarity among tasks. By deducing the similarities of tasks, task patterns can be introduced. In this way, processes can be effectively carried out by repeating these established patterns [10].

2.4 Mobile Agent Technology

An agent is described as a problem-solving entity that has the properties of Autonomy, Pro-activity/Goal-Orientation, Reactivity and Social Ability [23]. Individual agents can be endowed with sufficient intelligence to act autonomously in certain circumstances and can be empowered to make responsible decisions on behalf of their principals [24], [25]. The aim of using MAs in the proposed model is to reduce the time and effort required to complete transactions.

Groups of agents participating in multi-agent systems can collaborate through federations to solve problems too large or complex for individuals to address by themselves [24]. This supports close coupling and tight integration between the GLSP management team (MT) and provider organisations.

Adding mobility to software agents increases even further the potential of applications in the e-commerce area. To accomplish their goals, the mobile agents (MAs) act not only autonomously, by negotiating on behalf of their creators, but can also decide to move from one place (e.g. WFMS, marketplace, etc.) to another as necessary [26]. In addition, they are adaptive and capable of learning from both past actions and their environment, in order to cope with changing network conditions and evolving user requirements [27].

In the proposed model, the above features permit MAs to overcome the limitations of direct negotiations between the MT and its workflow providers in the execution phase. The benefits of using MAs in our business model are:

- MAs may provide value-added services by maintaining databases about activities and services. This information can then be selectively directed to the MT and other project partners and providers.
- Updating the data and information in WBIPMS.
- Managing the information traffic flow between the MT and its workflow providers.
- Filtering of incoming information.
- Profiling users according to the working practices and preferences of MT and providers.

2.4.1 Agent-based Workflow Systems

In the proposed model, an agent-based workflow system is used to facilitate integration and communication between different types of WFMSs. Most WFMSs utilized client/server architecture. The workflow server is a central component whose reliability is a problem because all clients must maintain a connection to this server. Furthermore, especially in inter-organizational workflows where heterogeneous WFMSs are used, the communication be-

tween the systems is difficult and their standardization is lacking. To overcome this problem, an agent-based workflow is used. The agent-based workflow is a workflow in which agents perform, coordinate, and support the whole workflow or parts of the workflow. In the agent-based workflow system, there exist different agent types that manage the workflow.
Work has already been done on this topic [28], [29], [30]. Such a workflow-instance agent knows all the tasks that needed to be done as well as the time of their execution. The agent searches for subjects capable of executing the next task. When a subject is found, the agent moves directly to it and provides the data items needed so that the subject can fulfill the task. This approach has the main advantage that no central server is required during the run time of a workflow, which has a positive effect on the reliability of the system. Another important advantage for using mobile agents in workflow systems based on web services is the suitability of asynchronous communication in this environment.

3. Conceptual Framework of the WBIPMS Model

In this paper, a web-based information and project management (WBIPM) model that will serve both the workflow and the network of tasks is proposed. The model supports monitoring the network of tasks, controlling workflow execution, managing resources and sharing the information.

Basically, the model ensures that the WFMSs of the MT and its providers communicate among themselves for controlling the execution of workflow, automatically updating the PMS database on-line while project execution in progress, and sharing up-to-date information with project members.

To enable timely and effective project control, the project must be systematically tracked and observed. This requires setting up project control, monitoring and reporting functions. Those functions are composed of three main phases. The first phase is controlling the execution of workflow; the second is monitoring the network of tasks, and the third is reporting and information sharing. Those phases are shown in Figure 2.

Controlling the execution of workflow is a repetitive process. Whatever the task (construction tasks, manufacturing, software development, etc.), the process of inspection is the same. This repetitive business process is supported by the WFMS. This phase is important in GLSPs, where hundreds of tasks are executed asynchronously. Without such a model, the MT must make an appreciable effort to control the inspection functions and make sure that tasks are executed according to the standards and specifications. Figure 3 shows the interaction between the WFMSs of the MT and its provider in handling this phase.

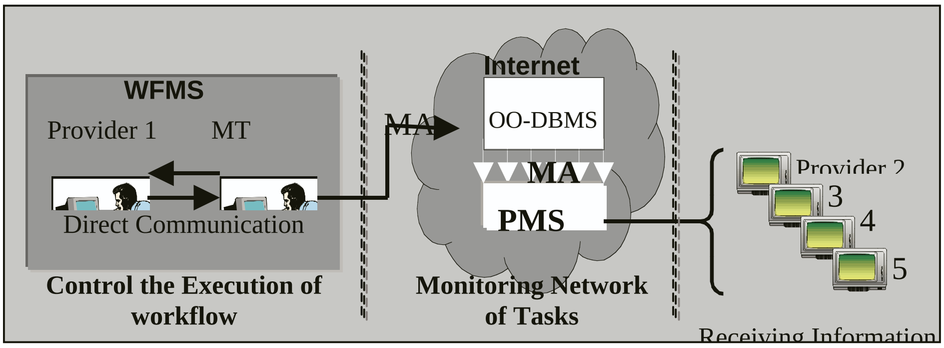


Figure 2: The Three Phases of the WBIPM Model

As shown, all communication between the MT and its providers will be conducted directly through their WFMSs. This is to ensure two main points. First, task execution is under control. Second, the current information from all project sites is entered into the project database. The WFMS of the MT is the only way to update - automatically via the MA - the web-based OO-DBMS as to the state of progress. The idea behind this is: (i) to avoid multiple data entries, each using its own data modelling and structure, and (ii) to overcome the difficulties of information co-ordination across the project.

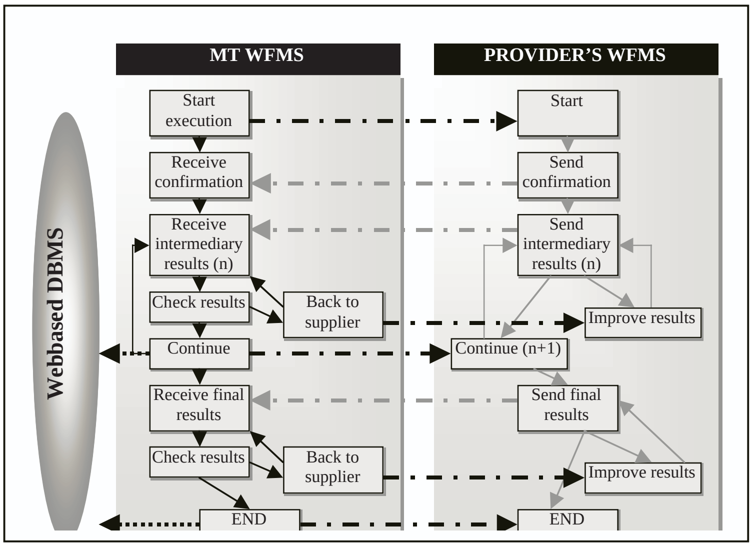


Figure 3: The Communication between the WFMSs of MT and his Provider

Obviously, milestones and progress statuses that are reported through the WFMS affect the PMS. As soon as the OO-DBMS is updated, the MA will make the necessary changes in the PMS, such as percentage of work completed, milestones reached, a comparison of actual and planned costs, and so on.

The third phase in this model is reporting and information sharing. The on-line updated-PMS provides quick and different levels of review that can be understood by different levels of people, namely project managers, task leaders, and project members. The model ensures that timely information outputs are distributed to the people who need them. The information includes revised budgets, modified schedules, and recommended action. Full and summary reports can be prepared in HTML, Doc, and/or Excel format. At the same time, all project members can navigate, filter, sort, and explore information over the Internet using their Web browsers.

To enable effective reporting and information sharing, two activities must be carefully handled. The first is the balance between reporting too much or too little data. Too much data is costly to collect and process, and will be ignored; too little does not capture the project status and allows problems to go unchecked. The second is the time of reporting. Project members should receive reports at the right time to enable them to identify and correct problems while they are small.

4. Swissmetro Case Study

This section provides a description of a scenario where the business model presented above is reflected. The phases carried out during the process of the model are identified and illustrated in a real-life scenario.
Swissmetro project is classified under large-scale project category. It is a multi-billions transportation project, a high-speed and high-frequency passenger transport system, working as a super underground transportation system, meets the new needs that are arising at the dawn of the third millennium. However, the Swissmetro project is currently in the phase of research and development.

In this project all the activities will be outsourced. In other words, there are many actors will be involved in the execution of the project. Some of the main problems that will face the management team are the controlling of execution and the coordination between different parties- sponsors, prime contractors, subcontractors, consultants, and suppliers- involved in achieving the project goal. To survive, the MT has to adopt newer and better management systems for managing such a project. Our business model seems the best solution to overcome the mentioned problems.

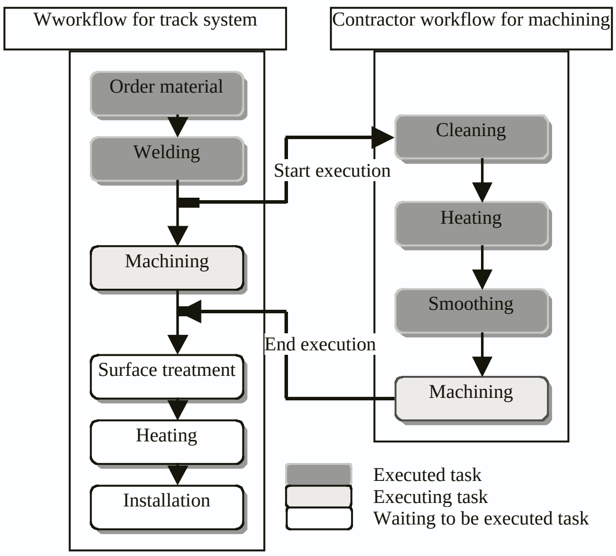
One of the activities in Swissmetro project is the track system. The track system consists of six sub-activities or tasks. These tasks are: ordering material, welding, heating, machining, surface treatment, and installation. This section shows how the MT uses the proposed model to control the execution of the machining task and to coordinate information flow from the time that it is created until it is eliminated and shares this information between project members. The workflow of the track system and the sub-workflow of the machining activity are illustrated in figure 4.

In the following, we assume that the MT of Swissmetro have already configured the PMS on their local computer, and then up-loaded it to the E-platform. The configuration includes setting-up milestones along the execution process, scheduling and network planning, and budgeting.

Once the date for start execution the machining task comes, the PMS sends an order to the contractor to start the execution. At the same time, the WFMSs of the MT and the contractor will be activated to start controlling the quality of execution of the machining task.

As agreed in the contract, the contractor sends intermediary results and reports, about the sub-workflows (e.g. cleaning and heating) to the MT who will check the results first and then gives the permission to the contractor to continue executing the next status. In the end of the execution phase, the MT receives the final results and reports. The MT checks them and sends ending confirmation. All the communication between the MT and the contractor is done directly through their WFMS, with keeping the E-platform automatically informed about the progress status. So that, the OO-DBMS will be update automatically, and all the information will be available to the rest of project members. At the same time, the PMS informs the contractors, who involved in execution the track system, about the progress in the machining task.

The WBIPM facilitates the coordination between the contractor who executing the machining task and the other contractors who have been waiting to start executing the next tasks (e.g. surface treatment, and installation).



Figu

Figure 4: Workflow of the Track System and Machining

5. Conclusion

Nowadays, with globalisation and the trend toward decentralized teams, more projects have team members that are geographically dispersed, which poses problems for GLSP tracking and control. One way around this problem is use of web-based systems to control the project and gather and distribute project information.

This paper has proposed a conceptual framework for a Web-Based Information and Project Management (WBIPM) model that will serve both the workflow and the network of tasks. The model supports monitoring the network of tasks, controlling workflow execution, resource management and information sharing.

Specifically, the model enables the project management team of the GLSPs first, to monitor and control the execution of multiple workflows operating synchronously within, across or between organisations and second, to coordinate information flow from the time it is created until it is eliminated and to share this information among project members.

The model brings benefits to all parties in the project. Some of those benefits are: immediate electronic updating of the project progress status through a single point entry for project data, efficient and easy communication between all project parties, immediate availability of project information, and measurement of project performance. Those benefits allow the management team of GLSPs to identify problems while they are small, meet deadlines, ensure quality control and manage the costs of the project. The tight follow-up processes that are inherent in the model will lead to minimized project risk.

Although the proposed model provides the means for reducing GLSP risk, the authors are planning to extend the model to cover risk management issues (e.g. risk measurement, impact and consequences, and appropriate ways of dealing with risks) and to customise the WFMS to track risk response and handle risk management.

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