Towards a conceptual reference model for project management information systems

Frederik Ahlemann

Information Systems 2, European Business School, International University, Schloss Reichartshausen, 65375 Oestrich-Winkel, Germany

Abstract

Project management information systems have changed considerably over the last decade. They no longer focus on scheduling and resource management alone. Instead, they have become comprehensive systems that support the entire life-cycle of projects, project programs, and project portfolios. In this context, project-oriented organizations are facing a new challenge: the design, implementation, and operation of project management information systems have become increasingly complex. Numerous processes have to be considered, diverse stakeholder interests taken into account, and corresponding software systems selected. The reference information model (RefMod[PM]) presented in this article addresses this challenge and aims to accelerate the set-up of project information systems. RefMod[PM] was developed with the help of 13 domain experts from German and Swiss enterprises. Furthermore, it is based on an analysis of 28 commercial project management software systems. RefMod[PM] has already been applied in several projects and is the basis of the forthcoming German DIN norm for a standardized project management data model.
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1. Introduction

Project management information systems (PMIS) are widely regarded as an important building block in today's project management [1]. The nature of these systems has changed considerably during the last decade; they are, in fact, still developing from single-user/single-project management systems to complex, distributed, multi-functional systems that no longer only cover project planning [2]. Information systems research has to date only partly reflected this PMIS evolution. Typical fields of research are (1) algorithms in respect of operation research problems related to project management (e.g. [3–5]), (2) the assessment and comparison of commercial project management solutions and corresponding assessment frameworks (e.g. [6–8]), (3) the development of prototypes to test new kinds of functionality (e.g. [9–11]), and (4) research into

the usage of project management software systems (e.g. [12–14]). Two specific problems are very rarely addressed: PMIS are become increasingly complex. Therefore, firstly, information system designers are facing a growing number of business processes that have to be supported with project management software. Secondly, information system users have difficulties in setting up corresponding organizational systems and selecting corresponding software products. An expert survey by Meyer indicates that only in approximately 20% of cases do organizations have information systems in place that support multi-project programme and portfolio management [13, p. 9]. In contrast, approximately 99% of organizations use information systems for scheduling and time management [13, p. 13]. The potential of existing PMIS is clearly not being exploited at all.

This article addresses these issues by presenting a reference information model for enterprise-wide project management that covers all project management processes that are related to planning, controlling, and coordinating

projects (RefMod^PM). The model can be used for the design of project management software, the set-up of the surrounding organizational system, as well as for the definition of software requirements that are essential to select a commercial project management software system. RefMod^PM covers both single-project management and multi-project management. It is based on a single, uniform information system architecture called M-Model and makes use of the Unified Modeling Language (UML) Version 2.

This paper is structured as follows: section two describes the conceptual and terminological foundation of this article and presents a review of existing approaches to reference modelling in respect of PMIS. A brief description of the research design and the sources of the construction process are provided in section three. Section four outlines the architecture of the reference model, the M-Model. A more detailed exemplary excerpt of the reference model is presented in section five, which is then compared to the modelling approaches presented by other authors. In section six, examples that illustrate the model's application are described, followed by concluding remarks that summarize the paper.

2. Foundation and related work

2.1. The role of information models in the development of information systems

Information systems (IS) are socioeconomic systems that comprise software, hardware, and the surrounding organizational system. Models play an important role during the design and implementation of information systems. Depending on the phase or level of IS design and implementation, three different types of such information models can be distinguished:

1. *Conceptual models* help with documenting, analyzing, and understanding the requirements that an IS needs to meet. These models do not take any technical aspects into consideration and focus on the problem that needs to be solved or the processes that need to be supported.
2. Conversely, *design models* specify the general architecture of the information system by describing larger technical building blocks called components. Such components are not, however, analyzed in detail.
3. *Implementation models* depend on specific technologies and are closely related to software programming.

In general, information models describe the static or dynamic aspects of information systems. Consequently, models are distinguished as those presenting information structures, i.e. data structures (data models), and those presenting information processes (process models). In a nutshell: data models lead to the design of databases, whereas process models are generally used as a basis for the programming of functionality.

There are several graphical languages available for the modelling of IS. One of the most prominent and widely used is the Unified Modeling Language (UML) [15]. UML allows class diagrams to be used for data modelling and activity diagrams for process modelling.

The design and implementation of information systems should be regarded as a construction process and is a topic of design science that explores how researchers can construct high-quality artefacts that are good solutions to practical problems [16,17].

2.2. Reference models

There is no mutual understanding of the term "reference model" [18, pp. 8,19]. Generally, one can distinguish between approaches that regard models as direct representations of reality and approaches that follow a constructivist paradigm. The latter regard a model as a construction of one or various modellers. This paper is based on the above-mentioned constructivist understanding of the term model. In accordance with this and in keeping with Thomas, a reference model is defined as an "information model used for supporting the construction of other models" [19, p. 491]. The use of reference models is frequently based on the expectation that they can

- accelerate the development of information systems (a time aspect),
- reduce the associated costs (a cost aspect),
- help to communicate innovative ideas and best practices (a quality aspect), and
- reduce the risk of failure (a risk aspect) [20].

Although widely accepted in business informatics, the term reference model is not always applied. The terms "standard model," "framework" or "architecture" are frequently used as synonyms. In the following sections, we discuss all the variant forms as long as they meet the characteristics of the definition presented above, are conceptual by nature, and contain at least semi-formal information models.

2.3. Previous project management reference models

Approaches to the conceptual modelling of project management information systems have been published since the 1980s. Raymond, for example, describes a data modelling approach and illustrates it with an entity relationship model consisting of 25 entity types that describe the core data structures for single-project management [21]. This data model is not, however, regarded as a normative artefact or as a general recommendation for information system designers.

One of the first reference information models for project management in the architecture, engineering, and construction (AEC) industry was published by Froese, who called it a "standard model" [22]. Proprietary object-oriented mod-