27 LIMITATIONS AND OPPORTUNITIES OF SYSTEM DEVELOPMENT METHODS IN WEB INFORMATION SYSTEM DESIGN

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Abstract

This article addresses the question of whether traditional object-oriented system development methods can be applied in the transformation of organizations toward web-based dissemination of information. System development methods have traditionally been argued as valuable tools in the process of capturing the complexity of information technology, organizations, and the interplay between the two. Relatively little is known about the application of traditional methods in web-based information system design. This is due partly to the limited history of web use, but also based in the normative argument that traditional methods do not play a significant role in WIS design. Through an action research project, the application of two system development methods (OMT and RMM) is evaluated. The research suggests that system development methods and a "traditional" IT-system perspective are applicable as a tool to capture central properties of a web information system. However, the use is limited to an interior organizational perspective: that of the information provider. From the audience context, the system development methods used did not provide proper guidance. The research suggests that future research should pursue the goal of providing better support for making and capturing design decisions about IT, individual, and organizational use from the perspective of the audience side.

Keywords: Web information system, system design, development methods, action research, emerging development contexts.

1. Introduction

System development methods are important tools for organizations in the process of introducing new information technology. The history of IS research has yielded a set of methods that guide developers in capturing and describing essential features of future systems. In a normative fashion, system development methods (SDM) provide developers with guidance on the design process through concepts, values, principles, and material resources (Lyytinen 1987). The application of system development methods in practice is a future-oriented means to change organizational and individual use of IT through a focus on the development of new IT solutions (Mathiassen 1997). For the novice developer, a SDM provides a path to follow and rules to play by. For the experienced designer, a SDM provides a framework for reflection on the development process (Mathiassen 1997). In any case, a method provides a mental tool for framing and discussing the design of the future. This paper is about the role of SDM in the context of web-based dissemination of information.

The paper departs from a dichotomy between arguments in favor and disfavor of SDM as tools in the design and discussion of web-based information systems (WIS). One stream of arguments is in favor of an evolution of SDM toward the web. In this stream of thought, a WIS is simply a specialized instance of the entire class of information systems (e.g. Isakowitz, Bieber, and Vitali 1998; Rice et al. 1996). In the light of this argument, SDM should be usable for web information system for the same reasons as they are usable in traditional contexts. The SDM of today may not be totally adequate for the special peculiarities of the web, but they are good starting points. The other stream of argument is that the web and its use is so different from what we have done traditionally that SDM in their current form not are adequate tools to apply (e.g., Braa and Sørensen 1998; Ehn 1998; Vessey and Glass 1998). The truth may very well lie somewhere within these extremes, but a common feature of both streams of argument is that they are primarily normative in nature and lack the support of empirical evidence.

This paper empirically investigates the proposition that system development methods are a valuable tool in the process of creating a web-based information system. This is done through the researcher's engagement in the development of a web information system. The remainder of the paper is structured as follows: Section 2 provides an overview on the research method. Section 3 presents the departing point, the development context. Section 4 in a rationalized manner describes the process of developing a WIS. As a reflection on the performed process, section 5 presents a model of an IS development context for WIS. Section 6 relates this research to other research contributions on the future of SDM. Finally, section 7 concludes the paper and suggests future research.

2. Research Method

A practice oriented intervention-driven research approach was selected as research method. This was selected in favor of an experimental or quasi-experimental approach. Given the hypothetico-deductive nature of the proposition from which the research departs, an experimental approach also seems an obvious choice (Patton 1990). An experiment, positivistic in nature, has traditionally proved a usable research approach in such cases. The experimental approach was disfavored because of the richness of system development in action. System design is as much reflection-in-action (Mathiassen 1997). With the desire to understand the complex social process of applying a system development method, the breakdowns, solutions, and their rationale, the AR approach was favored over the pure experimental research approach. An experimental approach was not believed to provide the desired qualitative insight into the process. Secondly, the establishment of an experiment would create an artificial situation, which could negatively influence the generality of the research. The definition and framing of action research is complicated by the absence clear theoretical frameworks and detailed guidelines for defining AR projects (Avison et al. 1999). In this section, the research will be defined in terms of previous work by Susman and Evered (1987), Baskerville and Stage (1996), and Lau (1997).

Action research (AR) is an intervention-driven approach to research (Susman and Evered 1978; Vidgen and Braa 1997). It is a future oriented and situational research approach that implies the collaboration between researcher and actors of the situation under study (Susman and Evered 1978). AR in nature is longitudinal as it applies a process focus. There are competing definitions and interpretations of the term action research (cf. Lau 1997). The approach selected is defined as an action research approach exploring the assumption that the application of a SDM was a strategy that would support the design of an information systems for course dissemination (ibid.). Baskerville and Stage define four defining characteristics interpreted from Susman and Evered. They are intervention, collaboration, creating understanding, and that the research should generate a solution to the immediate problem understanding.

These four criteria were met through the researchers participation in the development of a prototype of a web site for supporting the dissemination of course information for an open university setting. A problematic situation and the sketch of a desired solution had been stated by the responsible people of the organization *a priori* to the research project. The researcher volunteered to enter the development project and contribute with his knowledge on system development methods. The use of the method was conducted in collaboration with the participants of the development project. Over a period of four months, a team consisting of the lecturer responsible for the open university, a secretary, and the researcher applied various SDM activities in the OU context.

Lau suggests the four dimensions of type and focus, assumptions, process, and presentation as four dimensions of the design of AR projects. In the terminology of Lau, the conducted research is defined as classical action research project building on an interpretive assumption that seeks to evaluate the applicability of SDM in web design practice. The research process was designed as predetermined by the SD methods but still open to emerged factors requiring a change in process. The process included only a single group and the extent of change was limited to this context (and its audience). In the

process, the researcher took the role as method expert, considering the participants as collaborators and to some extent co-researchers. The presentation style of the research is defined as an illustrative case presenting the rationalized process and the lessons learned.

The collection of research data was triangulated through the use of a researcher diary, discussions with stakeholders, and system development documentation. Along with the growing system documentation, notes taken by the researcher accumulated to an estimated 20 pages including figures. System documentation compromised 30 pages. A prototype consisting of more than 4,000 LOC in the Java programming language implemented part of the functionality required. Notes were taken as reflection-in-action and combined descriptive and interpretive elements. At the end of the project, the group held a final meeting where the researcher facilitated a discussion of findings and lessons on both the process and the product developed. This helped the OU staff define their future process and to clarify their goal further. It also validated the researcher's findings on the limitations of the application of system development methods. Two final outcomes of the research are identifiable: An evaluation of the usability of system development methods in WIS design, and a rationalized process proposal for others to explore or follow.

3. Point of Departure

The findings on method combination and application are based on a setting of an open university that wanted to create a web information system (WIS) to provide information for its students. Prior to the development project, the open university had 18 month of experience operating a "traditional" web system, based on use of the file system and standard web server. Over a this 18 month period, a "system" evolved into a coherent presentation in which the administration and lecturers of the open university provided material for the students. Over time, an increased awareness in the administration of the OU was established. The organization had problems in maintaining the information kept in the system. There were multiple causes and effects involved, of which the dominant were that information was not available as promised and that documents and links in the system were outdated and inconsistent with the reality on which the system tried to depict information. This awareness eventually lead to the formulation of the project that serves the role of empirical evidence of this research.

The existing Web system was operational, but as mentioned above, the solution was considered far less than optimal. The overall quality of the system was perceived as being too low. Rather than presenting a coherent updated structure, the system too often appeared to be inconsistent and giving promises of information not present. This lead to the definition of three overall design goals that the project should address.

The design goals expressed the desire to improve the operation of the web system in terms of *content, responsibility and automation*. The former needed an explicit address to reach a shared level of information between different courses. The responsibility for maintenance of data needed to be made explicit. Everyday life of operation was a negotiation about who should and who would not do what. Finally, the increased dynamic

mass of data and the increase in pages called for automation of trivial routines, such as the removal of outdated information.

The researcher decided to rely on the general method OMT (Rumbaugh et al. 1991) and combine it with the dedicated hypermedia methods RMM (Isakowitz, Stohr, and Balasubramanian 1995). OMT was selected as primary method because it is assumed to represent "best-of-breed" in general object-oriented methods and because the method has seen some acceptance among professionals. Secondly, OMT is a generic method (Vessey and Glass 1998) that in theory should match many application domains and system development project. model. RMM was selected more on individual preference of the researcher than methodological difference from OOHDM (Schwabe and Barbosa 1994), which was considered as an alternative to RMM.

4. Design Process

In a rationalized view, the design process consisted of three activities: The decision of programming environment, the creation of a data model describing static and dynamic data properties, and the creation of the interface and interaction aimed at the audience of the web information system. In terms of reflection over the conducted process, the design process had two main activities:

- *Interior Perspective Design:* In this activity, the system is modeled and discussed from "within" the organization that eventually will operate the system. In this activity, attention is given to the description of objects, their static and dynamic relationships, and their behavior. Design ideas are motivated in a possible need in the exterior context of the system, e.g., is it of relevance for the audience, but decided upon in terms of feasibility within the operating organization, e.g., is it possible for us to provide and maintain this information.

- *Exterior Perspective Design:* In this activity, the system is modeled and discussed from the "outside," e.g., from the perspective of the intended audience of the system. What information is relevant for the audience, how should information be presented to audiences in terms of macro and micro information carrying units? Given the data model created in the interior perspective design activity, presentation units and their interrelationship is modeled.

Uncertainty in the early phase of the project toward the technical infrastructure of the Web led the project group to the decision that system architecture and system ambition had to be decided early. This was done to avoid the risk of designing a system and then at a late state in the project realize that it was not possible to implement the design due to misunderstandings or constraints of the Web infrastructure.

A four-leveled system structure extending the three layered model of Mathiassen et al. (1997) with a navigational layer to make the hypermedia interface explicit in the architecture resulted in the architecture depicted in Figure 1.

A first lesson of the project is that the choice of architecture and programming environment became a driving factor for the remaining design process. The decision on

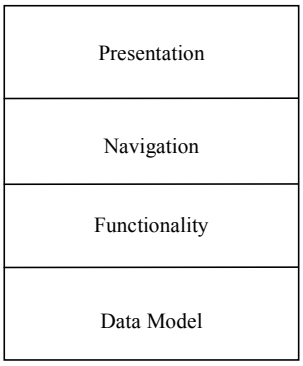


Figure 1. The Four-layered Architecture that Drove the Design of the WIS
(Adapted from Mathiassen et al. 1997)

architecture defined four separate design activities to perform: The elaboration of each of the layers in the architecture and the interplay between the layers. The perceived benefit of deciding early on system architecture was that, at any point in the process, there were no uncertainties on whether or not it was possible to implement a solution. Once the architecture had been decided upon, the remaining design task became to populate the architecture in more detail. In the spirit of OOA&D (Mathiassen et al. 1997), this was done in a bottom up fashion.

4.1 Interior Perspective

An object-oriented data model of static and dynamic relationships between objects and classes was created as prescribed by the OMT method. In addition, dynamics for the object classes were described in terms of events and actions. The model created was segmented into two components. One contains the general information about the education, another contains specific information about courses and classes. The final object model is depicted in Figure 2. Object dynamics were modeled using traditional state-transition diagrams (not depicted).

Creating the object model spawned a debate on just what objects were being modeled. The previous web solution was based on a document metaphor, as was the information circulated prior to "webification" of the information service. This lead to a debate in the development group as to whether the real world objects being modeled were documents or data entities. The researcher and senior lecturer perceived information as structured into classes and relations between these. The administrative staff perceived data as documents. Eventually the conflicting views were resolved as the architecture of the system was explained in details to the secretary and as the idea of separating data from navigation and presentation was understood. One immediate lesson to draw here is that to build an information system, one requires knowledge about what an information system is.

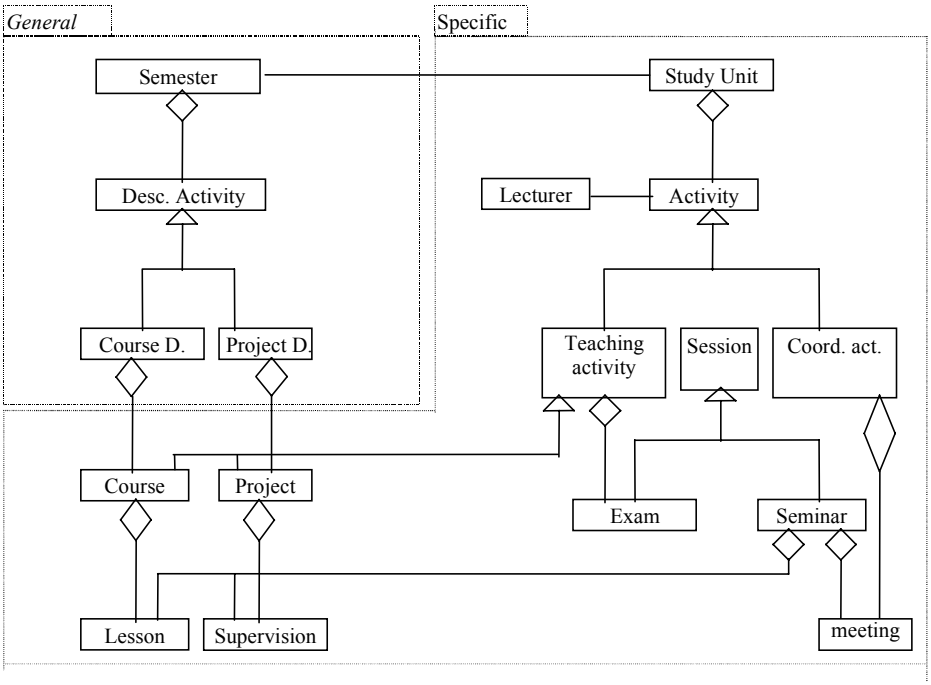


Figure 2. The Object Model Developed for the WIS

The increased focus on documents in web systems introduces confusion about what objects are being modeled. There is an extensive literature on document management systems and document repositories suggesting that documents are viable objects. In the object-oriented view of the world, a document presented to the user is a particular view on a set of object attributes. Dependent on what approach to documents to take, the project was facing decisions that would lead to very different solutions. Deciding on documents as objects would enable information providers to be in complete control of document design and a perception of the WIS as a simple document management system. Deciding on objects as classes in a traditional sense would enable the creation of functionality that extracted data from a model and generated documents in response to user queries. The project decided on the latter approach, documents as output rather than documents as data. This decision was made to enable reuse of data in different contexts.

A problem that arose in the process of dynamic modeling was that there is a large difference between "producer" users and "consumer" users of a web site. The former are the users responsible for maintaining the database, whereas the latter are the actual intended users of a WIS. The lesson to be learned here is that OMT in its foundation only supports the producer perspective. This relates to the observation that behavior of producers is expressible in terms of the objects. Once a data model is in place (e.g., Figure 1) it makes sense to discuss the behavior of producers in the light of the data model.

The project group benefitted from this activity because it led to a discussion about responsibility. With the consolidation of the data model, the project group had to decide on the interplay between objects and producer actors. This was a non-trivial balancing act between desired features in the data model and what was considered reasonable to require from producers of data (i.e., lecturers). As both the manager of the OU and the researcher were giving lectures on the open university, the requirements put forward were biased toward the limited resources available for producing and maintaining data.

4.2 Exterior Perspective

In this activity, a navigational model was constructed according to the prescriptions of RMM. A navigational model is an aggregation and abstraction over the data model. Whereas the data model reflects relationships between objects and classes, the navigational model reflects a design orientation toward the behavior of the audience. The navigational model defines an ordering of presentation nodes and the relationships between these. This allows designers to make navigational models different from the data model. The benefit of this is that the data model as perceived from the interior view can be abstracted into a different model reflecting the outside context. Over time, the data model can be kept stable and changes may independently be introduced to the navigational model (Mathiassen et al. 1997). Finally, the abstraction of the system into navigational and data model allows designers to create different navigational models for the same data model, in case there is a need to reflect different audience contexts for the same data model (Isakowitz, Stohr, and Balasubramanian 1995).

For each node in the navigational model where data could not be extracted directly from the model, e.g., in the case of a computation or the aggregation of different object attributes into new presentation units, a functional requirement was stated as an output and the required entities of the data model. Such "views" allowed designers to reduce the complexity of the data model and allowed designers to specify complex aggregations of data. A working draft model of the navigational model can be seen in Figure 3. Figure 4 illustrates how pseudo code was used to specify aggregates of information.

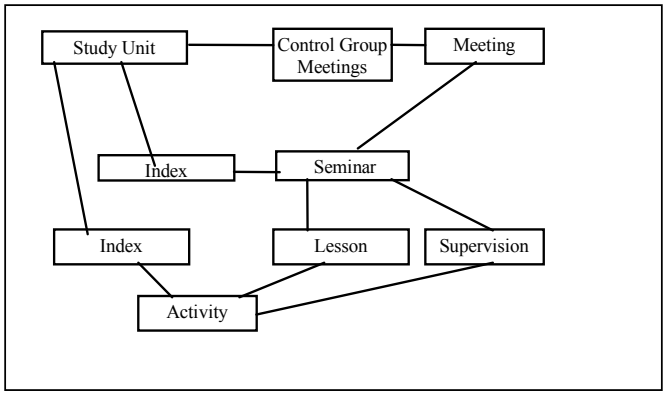


Figure 3. Navigational Model

```
View: Course overview
Classes:  track, course
Input: track-id
Function:
track tr = model.getCourse(track-id);
collection cou = agg.getCourses(tr);

output course.get("title");
for each c in cou{
 output link c.brief() to view.course(c.id);
}
```

Figure 4. Sample Pseudo Code for the Aggregation of Data from the Data Model

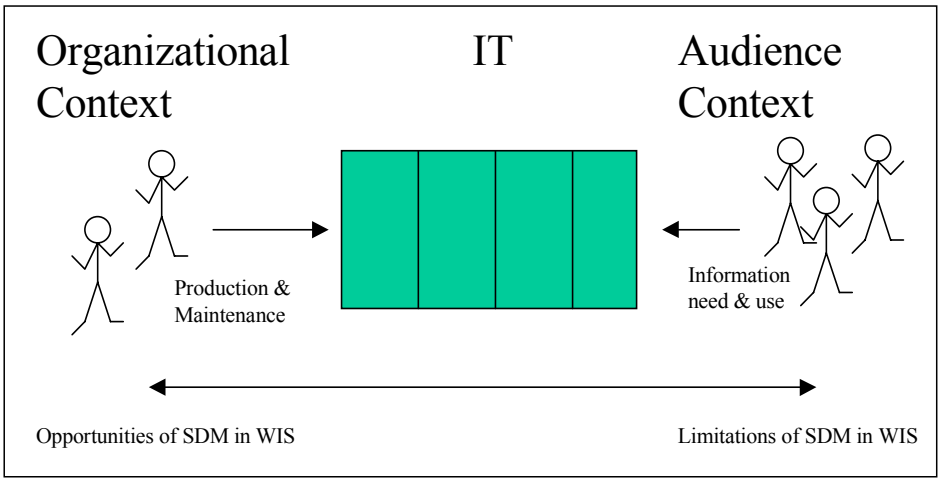
The project had a long and sound discussion on the navigational model. However, little guidance was found in RMM on how to actually make a model, except departing from the data model. Eventually the project by coincidence came across a book on the design of electronic documentation (Horton 1994). This provided examples of different structuring mechanisms of hypertext. Based on the inspiration from the book, the project team made its final decision on how to organize the navigational model.

The creation of the navigational model was the toughest challenge for the team and the project was not able to specify a solution using the guidelines of OMT and RMM. Eventually the project abandoned the model in Figure 4 and simply prototyped the desired interface directly on the web. By the end of the project, the group was still unsure whether this could be related to the inability of the developers to apply the navigational concepts or whether it was caused by the shift to object-orientation and in particular whether the use of aggregation and specialization caused problems for the project.

5. A Model for the Contexts of WIS

The project described in this paper illustrates why traditional system development methods are a usable tool in the design of web systems. The project departed from concerns on the operation and maintenance of a web site, concerns on the difficulty of dividing responsibility and maintaining the site with up to date information. As long as there is work going on "behind the service," work that is related to maintaining a database, there will be a need for system development methods like OMT.

However, the project also revealed problems in the design of the part of the system aimed at the actual users of the system, the target audience of the site. The absence of work tasks that can be described formally made OMT irrelevant in the design of the system properties aimed at the target audience. This was to some extent expected, and the dedicated hypermedia method RMM was introduced as a mean to deal with the specification of the interface aimed at the target audience.



In the organizational context, the IT-based system is defined by the organization's ability to produce and maintain data. In the audience context, the system is defined through information need and use. Design in practice is the iterative balancing of requirements as perceived from the two contexts. The object-oriented SDM applied proved to be most supportive in the organizational context and less supportive in the audience context.

Figure 5. A Model of the Different Use Contexts of WIS

The research suggests that a traditional distinction between producer and consumer communities could be introduced to web information system design. Figure 5 depicts a model of a web-based information system in context. The *organizational context* represents the organization responsible for operating the WIS, for producing and maintaining data. The *audience context* represents the society of users for whom the WIS is intended.

Discussing the lessons learned on SDM in the light of Figure 5 suggests that the use of SDM is an opportunity to capture the often complex interplay between the content generating organization and IT system. Once a WIS is abstracted to an information system based on a database concept, a hard SDM approach to modeling static and dynamic data properties applies well. Once data properties have been defined, the IT system can be perceived as an administrative information system from the organizational context.

From the perspective of the audience, the concepts of OMT and RMM provided only limited support. In OMT and similar object-oriented methods, user behavior to a large extent is modeled through the dynamics of objects. As this is modeled for the organizational context, there is only a weak coupling between object dynamics and the audience community. The dedicated hypermedia design method RMM was introduced to handle the inability of OMT to model the system from the audience context. The concept of navigational model did provide designers with a notation for describing the navigational model. However even with the notation at hand, decisions were difficult to make.

6. Related Research

Method engineering has been advocated as a move to approach the diverse development contexts that occur today. In essence, method engineering is the idea that once a specific problem or situation is identified, a specific method can be ”engineered” for this situation. This requires the existence of a library of method components and possibly a CASE environment that supports the method fragment selection and assembly (Harmsen, Brinkkemper, and Oei 1994). In some sense this is a formalization of what Mathiassen denotes as reflection-in-action: That practitioners do not follow a single method rigorously, but apply method fragments in response to the match between experience and a specific problem.

In the perspective of method engineering, this research suggest a model (Figure 5) of very different contexts that SDM should support. Although dating back to 1991, OMT is still a representative of the class of object-oriented methods, and there should be some generality in the observation that SDM are mainly applicable in the organizational context. This suggests that future research in method engineering should address issues of modeling a system from the perspective of the audience context.

There is a completely different chain of arguments based on communication research. In particular, the concept of genre is seeing increasing attention by IS researchers. There are competing definitions of genre, but a common definition is that a genre is a recurring type of communicative event. The introduction of genre theory to IS research is attributed to Yates and Orlikowski (1992). The concept has since then been elaborated, more recently in the context of web-based communication (e.g., Crowston and Williams 1997; Eriksen and Ihlström 2000; Watters and Shepard 1997). The power of genre is that it explains why design of (communicative) artifacts cannot be seen as independent of the established tradition of communication. Genre understanding reduces the infinite possibilities for structuring communication to a limited set of types of communication, thereby reducing the complexity of both creating and interpreting communication.

Genre theory explains why the project team experienced problems in modeling the system from the perspective of the audience context. As the web is a relatively new information infrastructure, a genre repertoire (Orlikowski and Yates 1994) has not been established in the organization. Over time this problem inevitably will be reduced as individuals and organizations develop a shared understanding of good design in terms of specific genres of WIS. It appears that the genre of course information dissemination has not reached a state of equilibrium yet. Until now, genre theory has primarily been an analytical tool. The research supports the argument of Brown and Duguid (1996) that genre may play a role as a tool in design within the audience context.

A third stream of argument that does not address the question of how to design web information systems is an artifact-oriented approach. Because of the almost infinite possibilities of restructuring practice, much research today is explorative in the sense that good ideas are presented, often along with their rationale. For instance, Sumner and Taylor (1998) present the design and design rationale of a novel approach to the dissemination of open university course information. From the perspective of SDM development and refinement, such contributions may be criticized for being to specific to provide support for the design process. However, if one takes the argument of genre design, such research contributions are exactly what is currently needed to disseminate

and institutionalize new digital genres. In the perspective of Figure 5, the suggestion is that the audience context is as much understood in terms of the already installed base of similar systems. As little as students probably would accept a completely new style of course information for each and every course, students will expect similarities among different IT systems providing the same type of information.

7. Conclusion

The article departed from the question of whether the concepts and guidance in system development methods can play a role in the design of information systems in the web era. If so, there is an opportunity in SDM as a tool for describing, understanding, and designing the complex interrelationships between IT, information systems, organizations, and societies. The research suggests evidence of both opportunities and limitations of SDM in a web context. As the situation for which a system was designed is characterized by an organization disseminating dynamic information to an audience, the research and its lessons may possess generality beyond this case.

The application of system development methods in general was considered useful and worthwhile. The object model helped the organization to define the scope of the system in terms of objects and attributes. The modeling of the dynamics of the objects led to constructive discussion and solutions on how to define responsibility between the different actors in the organization. The shift from documents to objects as the basis data of the system and the implementation of a function layer made it possible for the organization to define presentation views as pseudo-queries on a database, thereby reducing the need for manual checking of links and outdated information. The methods clearly helped developers in structuring and organizing the development project into activities and in specifying outcomes. Yet there were some limitations in and lessons from method application that emerged during the project.

Emerged in response to complications in a design process of a WIS, the sharp distinction between organizational and audience contexts is proposed as a means to structure the design of web-based information systems. The different contexts are proposed as departing point for future WIS design. The organizational context is the context from which a WIS is operated in terms of production and maintenance of data. The audience context is the context in which the provided information is "consumed." System development methods proved a valuable tool to address problems of data standards, procedures for data maintenance, and static and dynamic properties of data, but only in the context of the producing organization.

System development methods failed to provide guidance for the design of the system in the audience context. Although not documented in the empirical data, the research suggests that standards, styles, and established practice in the form of specific genre characteristics play a stronger role in this than SDM. This suggest that WIS design for the audience context must be understood not in terms of the activities to perform, but in terms of similarities between WIS serving the same purpose. Future research could address the issue of how to make genre awareness and analysis more design oriented and how to integrate it with existing system development methods.

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