Vol. 4 | No. 4 | 2016

SciKA

International Journal of Information Systems and Project Management

ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X

Available online at www.sciencesphere.org/ijispm

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International Journal of
Information Systems and Project Management
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The mission of the IJISPM - International Journal of Information Systems and Project Management - is the dissemination of new scientific knowledge on information systems management and project management, encouraging further progress in theory and practice.

The IJISPM publishes leading scholarly and practical research articles that aim to advance the information systems management and project management fields of knowledge, featuring state-of-the-art research, theories, approaches, methodologies, techniques, and applications.

The journal serves academics, practitioners, chief information officers, project managers, consultants, and senior executives of organizations, establishing an effective communication channel between them.

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- management of complex projects
- audits
- innovation
- ethics
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- project initiation
- project planning
- project execution
- project control and monitoring
- project closing
- criteria and factors for success
- project manager role
- project manager skills
- portfolio management
- program management
- managing organization - structure
- tools and techniques
- project evaluation
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Editorial

The mission of the *IJISPM - International Journal of Information Systems and Project Management* is the dissemination of new scientific knowledge on information systems management and project management, encouraging further progress in theory and practice.

It is our great pleasure to bring you the fourth number of the fourth volume of IJISPM. In this issue readers will find important contributions on the understanding of promoter-stakeholder relations in complex projects, information security management, thematic grouping for email messages and formal modeling of information systems.

The first article, "Understanding dyadic promoter-stakeholder relations in complex projects", is authored by Janita F. J. Vos, Albert Boonstra and Marjolein C. Achterkamp. The authors propose a Bilateral Double Motive framework of stakeholder cooperation in complex projects. The framework analyses and explains dyadic promoter-stakeholder relationships at a micro level by acknowledging both transactional and relational motives. The framework's usefulness is demonstrated by illustrating its explanatory power in two instances of cooperation and two of non-cooperation within two health information technology projects. The study contributes to project management theory through its combined focus on transactional and relational motives. Further, the study contributes to practice by providing a tool for planning and evaluating cooperation in health Information Technology projects and similar complex multi-stakeholder environments.

As Knut Haufe, Ricardo Colomo-Palacios, Srdan Dzombeta, Knud Brandis and Vladimir Stantchev state in the second article "A process framework for information security management", securing sensitive organizational data has become increasingly vital to organizations. An Information Security Management System (ISMS) is a systematic approach for establishing, implementing, operating, monitoring, reviewing, maintaining and improving an organization's information security. Key elements of the operation of an ISMS are ISMS processes. However, and in spite of its importance, an ISMS process framework with a description of ISMS processes and their interaction as well as the interaction with other management processes is not available in the literature. Cost benefit analysis of information security investments regarding single measures protecting information and ISMS processes are not in the focus of current research, mostly focused on economics. This article aims to fill this research gap by proposing an ISMS process framework as the main contribution. Within the framework, identified processes are described and their interaction and interfaces are specified. This framework helps to focus on the operation of the ISMS, instead of focusing on measures and controls. By this, as a main finding, the systemic character of the ISMS consisting of processes and the perception of relevant roles of the ISMS is strengthened.

The article "Thematic grouping for messages in major events" is authored by Wallace Pinheiro, Ricardo Fernandes and Luciene Souza. The process of information evaluation may compete with the decision making process by requiring the limited cognitive resources. In the case of Major Events, such as the Football World Cup or the Olympic Games, the thematic grouping of every information may be overwhelming. The theme switching caused by information associated with a different thematic group may be modelled as an interruption in multitasking set-ups. Thus, automating the thematic grouping of information may facilitate the decision making process by reducing the theme switching for a decision maker when he reads a set of messages. In this article were used clustering techniques with multi-criteria to group the messages in themes. These criteria were implemented as configurable operators. To achieve a better comprehension of those parameters, the authors introduced the concepts of Thematic Strength (TS) and Thematic Density (TD). The evaluation of the strategy was made over a set of operational messages available in the Pacificador system during the 2014 FIFA World Cup.

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The article "Formal approach to modeling of modern information systems" is authored by Bálint Molnár, András Benczúr and András Béleczki. Most recently, the concept of business documents has started to play double role. On one hand, a business document (word processing text or calculation sheet) can be used as specification tool, on the other hand the business document is an immanent constituent of business processes, thereby essential component of business Information Systems. The recent tendency is that the majority of documents and their contents within business Information Systems remain in semi-structured format and a lesser part of documents is transformed into schemas of structured databases. In order to keep the emerging situation in hand, the authors suggest a theoretical framework for modeling business Information Systems and a design method for practical application based on the theoretical model that provides the structuring principles.

We would like to take this opportunity to express our gratitude to the distinguished members of the Editorial Board, for their commitment and for sharing their knowledge and experience in supporting the IJISPM.

Finally, we would like to express our gratitude to all the authors who submitted their work, for their insightful visions and valuable contributions.

We hope that you, the readers, find the International Journal of Information Systems and Project Management an interesting and valuable source of information for your continued work.

The Editor-in-Chief,

João Varajão

University of Minho

Portugal

João Varajão is currently professor of information systems and project management at the *University of Minho*. He is also a researcher of the *Centro Algoritmi* at the *University of Minho*. Born and raised in Portugal, he attended the *University of Minho*, earning his Undergraduate (1995), Masters (1997) and Doctorate (2003) degrees in Technologies and Information Systems. In 2012, he received his Habilitation degree from the *University of Trás-os-Montes e Alto Douro*. His current main research interests are in Information Systems Management and Information Systems Project Management. Before joining academia, he worked as an IT/IS consultant, project manager, information systems analyst and software developer, for private companies and public institutions. He has supervised more than 50 Masters and Doctoral dissertations in the Information Systems field. He has published over 250 works, including refereed publications, authored books, edited books, as well as book chapters and communications at international conferences. He serves as editor-in-chief, associate editor and member of the editorial board for international journals and has served in numerous committees of international conferences and workshops. He is co-founder of CENTERIS – Conference on ENTERprise Information Systems and of ProjMAN – International Conference on Project MANagement.

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Understanding dyadic promoter-stakeholder relations in complex projects

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J. Vos, A. Boonstra and M. Achterkamp, "Understanding dyadic promoter-stakeholder relations in complex projects," *International Journal of Information Systems and Project Management*, vol. 4, no. 4, pp. 5-23, 2016.

International Journal of
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Abstract:
In this study, we propose a Bilateral Double Motive framework of stakeholder cooperation in complex projects. The framework analyses and explains dyadic promoter-stakeholder relationships at a micro level by acknowledging both transactional and relational motives. We demonstrate the framework's usefulness by illustrating its explanatory power in two instances of cooperation and two of non-cooperation within two health information technology projects. The study contributes to project management theory through its combined focus on transactional and relational motives. Further, the study contributes to practice by providing a tool for planning and evaluating cooperation in health Information Technology projects and similar complex multi-stakeholder environments.

Keywords:
issue impact; promoter-stakeholder cooperation; project stakeholder management; reputation; salience.

DOI: 10.12821/ijispm040401

Manuscript received: 8 March 2016
Manuscript accepted: 19 April 2016

1. Introduction

In this paper, we present a generic framework on promoter-stakeholder cooperation at a micro level, in the context of health information system projects (HISP). With this framework we aim to contribute to both practice and theory of project management.

The practical problem that we address is as follows. Promoters of complex projects, such as project managers, general managers, and implementers, face the challenge of managing relations with the project's stakeholders during the various phases of the project [1, 2]. There has to be decided with which stakeholders it is most important to cooperate to ensure the success of the project. It raises a balancing act of involving the right stakeholders at the right time [3]. On the one hand, involving too few stakeholders can lead to a lack of support and to a lack of the necessary knowledge since adequate support and sufficient expertise is a prerequisite for effective project outcomes, e.g. in terms of system design, implementation, and use. Conversely, involving too many stakeholders can lead to unworkable situations and dysfunctional compromises that may harm the project and ultimately lead to failure. The framework that we propose provides a systematic means to consider and evaluate cooperation in HISP projects. Promoters can use this framework to develop a well-grounded action plan for stakeholder management. Stakeholders can use this perspective to more comprehensively assess promoter initiatives and their possible contributions [4]. This framework can be used before the start of a project by those responsible to help assess its potential success and determine the critical factors in its implementation and improvement, and also during the project to analyze changing circumstances. Although we present a generic framework that can be applied in different settings, we demonstrate its explanatory power in four vignettes derived from the context of health information systems, being a fluid complex multi-stakeholder environment [5].

The contribution of this study to project management theory is an increased understanding of stakeholder involvement in complex projects by proposing and applying a theoretically grounded approach to promoter–stakeholder cooperation at a micro level. In doing so, we answer the question which factors determine dyadic promoter–stakeholder cooperation in complex projects. The study builds on existing stakeholder models and adds to these by proposing a combined focus on both transactional and relational motives for cooperation. The approach also highlights the bi-directionality since both promoter and stakeholder perspectives are included when considering their mutual engagements. This study draws on Mitchell et al. [6] by adopting a management perspective on the identification and analysis of stakeholders.

We have structured our argument in the following way. First, in the theoretical background section we embed stakeholder theory within project management literature to clarify the underlying theoretical basis of the framework. Here, we also discuss the relevance of the framework in health Information Systems (IS) contexts. After presenting the framework, we clarify in the method section that we use four vignettes to explain two instances of cooperation and two of non-cooperation. In the results section we show how different parts of the framework contribute to our understanding of these different levels of cooperation. Finally, we discuss in detail how the framework contributes to the literature and to practice.

2. Theoretical background

In identifying the main actors involved in organizational change, two categories are distinguished over the years, namely promoters, those who provide leadership in the project (also labeled as project leader, implementer, or champion) and other stakeholders, those who need to adapt to the change (also labeled as user or project member). Promoters are responsible for creating a vision, specifying a desired outcome, and then making the change happen [7-9], and the other stakeholders are responsible for implementing, participating, adopting, and adapting to the change [10]. Obviously, implementation requires extensive interactions between these parties engaged in the change.

Most project management studies take a unilateral perspective, i.e., focus on either the promoter side [9], or on the other stakeholders in the project [11]. In this way not only the role of one of the actors is neglected [12], there is also a risk of neglecting the crucial interactions between promoters and stakeholders [7]. The framework that we propose overcomes

these limitations by not only focusing on the interactions between promoter and stakeholder, but also adopting a bilateral perspective (promoter and stakeholder).

2.1 Stakeholder theory

Stakeholder theory can be considered managerial in the sense that it not only predicts cause and effect relationships, but also includes notions and recommendations for structures and practices of stakeholder management [13, 14]. This is why the theory is a valuable source for providing insights on stakeholder management in complex projects [15, 16]. The obvious first notion is the stakeholder definition of Freeman [17, p. 46]: any group or individual who can affect or is affected by the achievement of the organization's objectives. From the outset of its evolution, stakeholder theory has had a clear focus on value creation [14, 18]. To achieve the organization's objectives and thus to create value, various transactions with a great number of stakeholders are required. In this way the theory emphasizes transactional motives for stakeholder management.

To distinguish and prioritize between the stakeholders, a major topic in stakeholder research focusses on the classification of stakeholders based on transactional motives [19]. In this respect, the literature's prevailing stakeholder classification model is the salience model of Mitchell et al. [6]. Salience is described as the degree to which managers or promoters give priority to competing stakeholder claims. Mitchell et al. [6] address the question of how promoters choose their stakeholders and how they prioritize among competing stakeholder claims. Promoters, they argue, perceive the various stakeholder groups in different ways: they give a stakeholder high priority if they believe that a stakeholder has a legitimate claim, one that calls for immediate action (i.e. is urgent), and possesses the power to influence the organization's activities. A stakeholder who is believed to possess these three attributes (i.e. legitimacy, urgency, and power) is labelled as a definitive stakeholder.

More recently, authors emphasize the relevance of collaborative relationships with stakeholders in value creation; stakeholder management should represent the organization's ambition for joint value creation [14, 20]. This leads to explicit attention for the relevance of relational motives in stakeholder management [21-23]. We acknowledge that both transactional and relational motives play a role in stakeholder management of projects and integrate both types of motives in the framework [24].

2.2 The research context: IS projects in Healthcare

IS projects is one of the fields where researchers adopt a stakeholder approach [25, 26]. In traditional IS projects, stakeholder management was translated in 'user participation'. Many researchers have argued that user participation is linked to system success [27, 28]. The main reason is that users possess knowledge that is necessary to develop effective information systems. Another motive for user participation is that it contributes to user 'buy-in'. This means that users feel responsibility for the success of the project and that they develop ownership through participation [29]. Despite this confined interpretation of stakeholders, this already confirms the relevance of collaborative relationships with stakeholders, as recognized in the stakeholder theory.

During recent decades, these confined notions of stakeholders have been eroded by new trends in IS projects, such as package installations, outsourcing, enterprise resource planning, customer relationship management and e-business applications. Information systems tend to increase the scope from smaller, internal, and functional areas to enterprise wide systems and systems that cross company boundaries. These developments affect the complexity of the project in terms of the number of stakeholders involved, as well as their ability to influence the system [30-32]. Recent studies therefore, indicate that common problems during IS projects are not technical, but stakeholder related. Different stakeholder groups have diverse expectations of a system or identify different implementation barriers [25, 26, 33], which may give rise to conflicts between them [57]. Therefore, successful IS projects require that promoters cooperate effectively with important internal and external stakeholder groups [34]. For promoters, this raises the question which stakeholders are important, while stakeholders may ask themselves when cooperation is beneficial or most relevant.

However, there is a lack of research on how promoters of a project can select stakeholders to cooperate with. Some studies have developed models that help identify [3] and categorize [32] stakeholders, particularly in an IS context. The proposed framework of this study adds to these models by aiming to explain promoter-stakeholder cooperation. Analyzing the perspectives of both promoters and stakeholders is a complicated task but essential for understanding the cooperation necessary for developing acceptable information systems. This is especially true in modern health information systems, which makes this an ideal context for examining promoter-stakeholder cooperation [35].

The healthcare sector can be characterized by a broad range of stakeholders from diverse institutional backgrounds and with varying interests who work together in various ways to provide cure and care related services. Doctors from various disciplines are typically users of health IS and hospital administrators are the primary recipients of management information derived from them. In addition to these groups, nurses, support departments, a hospital's IS staff, patients, other providers of healthcare, insurers, and regulatory agencies are all stakeholders [32]. Many stakeholders of IS projects in healthcare are often relatively autonomous, and can be found inside and outside a healthcare organization. Dealing with this stakeholder landscape is an integral part of implementing health IS [36]. As such, in this sector, the issue of stakeholder cooperation is especially relevant as well as complex. Once a wider group of stakeholders is an integral part of the health IS, it is increasingly difficult to determine which part of this 'sociology of technology' should be included in the promoter-stakeholder interactions during the various phases of the project. Stakeholders have to decide to which extent they wish to participate in the project; therefore, these projects are more sensitive to, and impacted by stakeholder activities and pressures. Due to their autonomy, stakeholders in healthcare IS can easily resist the adoption of information systems and it has therefore been suggested that promoters of IS projects have to carefully manage the stakeholder relations regarding the IS project [31].

3. The bilateral double motive framework

3.1 Introduction of the framework

The key feature of the Bilateral Double Motive (BDM) framework is its 2x2-perspective on stakeholder cooperation (see Fig. 1). Promoter-stakeholder cooperation represents a focus on the interactions between promoter and stakeholder and describes the extent to which the promoter and a stakeholder collaborate on a project-related issue, with both parties aiming to achieve an outcome that creates mutual value, thereby concurring with recent developments in the stakeholder theory [14]. The extent of cooperation can range from no cooperation at all to a high degree of cooperation [37]. A high level of cooperation not only means that the promoter and the stakeholder spend considerable time together, in various forms of interactions addressing the issue, but that they also acknowledge each other's interests in that respect. This interaction can be in the form of discussions, consultations, and other forms of decision-making.

The framework builds on the stakeholder salience model [6] but adds to that by also including the stakeholder perspective. Promoter-stakeholder cooperation is perceived as a two-way activity in which both promoter and stakeholder determine their mutual engagements. Therefore, the first two-way perspective is a bilateral one, believing that these interactions depend on the willingness of both sides to cooperate. Willingness represents each actor's intentions toward cooperation.

While promoters and stakeholders might be motivated by issue-based reasons leading to single-issue interactions (as addressed in the salience model), they might also pursue establishing lasting relationships in which a series of sequential and cooperative exchanges are created. The first type of motives are transactional [17, p. 69], the latter relational [21, p. 397]. In the case of transactional motives, the issue determines an actor's timeframe: solving an issue in a beneficial way is the key driver in considering cooperation. With relational motives, the actors have a long-term perspective: they value cooperation over an issue as an investment in a lasting relationship [38]. Rather than being motivated by the solution of an issue, an actor (either the promoter or the stakeholder) is motivated more by the perceived benefits of having a cooperative relationship with a counterpart. The BDM framework also adds this relational perspective to the salience model. This leads to the second two-way perspective: the double motive perspective.

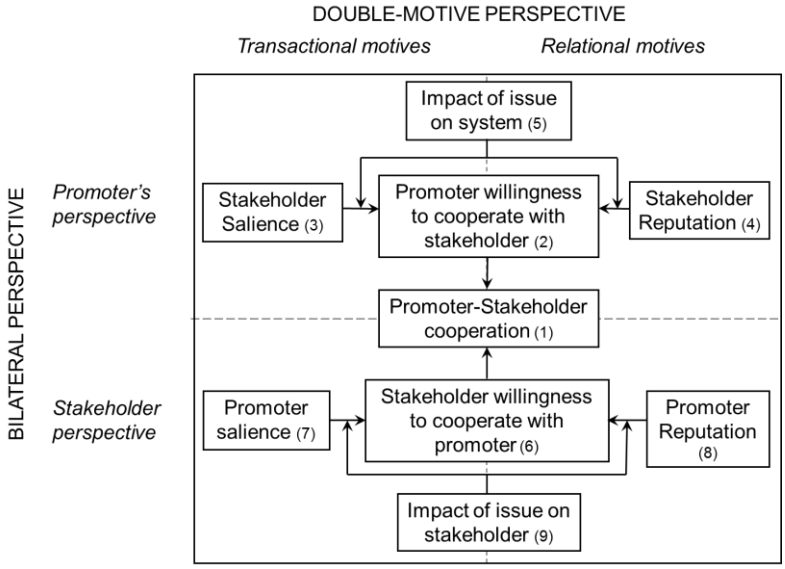

Fig. 1. Bilateral Double Motive (BDM) framework

3.2 Promoter perspective

Our aim of explaining promoter-stakeholder cooperation requires an investigation of factors that determine the willingness of both actors to cooperate. In further explaining the framework's building blocks, we start with the promoter part of the framework (i.e., the upper half). Promoter willingness (block 2 in Fig. 1) refers to how the promoter perceives stakeholders and then decides, based on this perception, how to interact with them. A promoter's transactional motives concern the perception of stakeholder characteristics that can ensure the cooperation is beneficial for the outcome on a specific issue. Mitchell et al. [6] elucidate the transactional motives present within their model in their key message: that managers give a high priority to stakeholders with salient claims. As a claim is linked to a specific issue (revealed in the salience model by its urgency), the promoter's transactional motives to pursue cooperation with a specific stakeholder on a specific issue thus depend on their perceptions of this stakeholder's salience (block 3) regarding the issue.

In the relational dimension, the promoter is motivated more by the perceived benefits (for the organization or for the promoter) of having a cooperative relationship with this stakeholder. These benefits may concern gains on anticipated future issues (maybe related to a later stage in the project's lifecycle or its wider context), but can also be more general assets, such as offering key resources and capabilities needed for the system. We use stakeholder reputation (block 4) as an indicator of the perceived value of a relationship with the stakeholder, and we assume that stakeholder reputation is based on both the potential benefits of the relationship (the relational assets – indicated by the promoter's power and legitimacy over future issues) and on the likelihood that these assets can be accessed (the perceived willingness to share the relational assets – indicated by the promoter's reliability).

Finally, we assume that the promoter's motives for cooperating on an issue may change over time and thus can switch from transactional to relational, or vice-versa. We use the promoter's perception of impact (block 5) in weighing transactional and relational motives. We assume that, when it comes to high-impact issues, the promoter is concerned that the salient stakeholders are involved whereas, particularly with low-impact issues that may function as an investment vehicle for establishing cooperative relationships, the importance of stakeholder reputation will be emphasized.

3.3 Stakeholder perspective

In a similar vein, stakeholders face the same dilemma as the promoter: they also have to decide whether or not they are willing to cooperate with this promoter regarding this issue (block 6). Just as the promoter, the stakeholder may have two motives for this willingness to cooperate: an attempt to influence the promoter's actions and outcomes regarding the specific issue; and the potential benefits of developing a relationship with the promoter (i.e., relational reasons). As counterpart to the promoter perspective, we use promoter salience, promoter reputation and issue impact on the stakeholder as factors influencing the stakeholder willingness to cooperate.

4. Method

4.1 Unit of analysis

To examine the explanatory power of the framework, we exclusively focus on bilateral relationships within the stakeholder landscape, between the promoter and a stakeholder. By comparing four different bilateral relationships – where the two actors interact on the basis of a specific project issue – we demonstrate how transactional and reputational factors determine the degree of cooperation to resolve that specific issue. This implies that one relationship in the project, rather than the project as a whole, is the unit of analysis. We argue that studying bilateral cooperation is relevant, both for empirical and for methodological reasons. The empirical reason is that within the stakeholder landscape, a promoter has to consider and decide upon individual and stakeholder specific relations [39, 40]. The methodological reason is that in order to understand the whole, we have to understand the parts. In that respect, the BDM framework is a response to the approach of general stakeholder mappings [e.g. 6]. We add insight at the micro level to these mappings' overall view on the stakeholder landscape.

Of course, these bilateral relations take place in the context of the project at hand. By focusing on the perceived promoter and stakeholder characteristics (salience and reputation), the BDM framework not only examines the micro level, but also captures specifics of the project; these perceived characteristics can be viewed as proxies for the wider context in which the bilateral cooperation takes place. For example, a promoter's assessment of a stakeholder's power (i.e., part of this stakeholder's salience) is dependent on the context. The stakeholder's power may be based on this actor's expertise in certain fields. However, if more members in the project environment would have comparable levels of expertise, the promoter would attribute less power to this stakeholder. Not only stakeholder and promoter characteristics, but also impact of the project issue serves as a proxy for the context. Issue impact places this particular cooperation in a larger setting: the issue is part of a project including multiple issues [40], and the stakeholder's and promoter's assessment of the issue impact is relative to the impact of these other issues. The BDM framework thus addresses the micro level cooperation between two actors on a particular issue, while taking into account the project context in which the cooperation takes place.

4.2 Research design

To substantiate the explanatory power of the framework, we have opted for a research design focused at four distinct promoter-stakeholder relationships with each relationship having a specific project issue at hand. We label these project situations 'vignettes'. Vignettes are mostly used in experimental research and then are hypothetical scenarios to trigger respondents' answers to questions [41]. Similar to a vignette design, in our research, we started with explicating the specific project situation (i.e. relationship including the issue at hand) before the actual data gathering could begin.

Further, we used replication logic [42, 43] to determine whether the framework's components can explain the contrasting results. The selection of vignettes was based on a combination of (1) relevance (a complex project including stakeholder-related issues), (2) cross-case diversity (so gaining better understanding through contrasting explanatory factors), and (3) accessibility to promoters and stakeholders of the project. We derived such data from various IS healthcare projects that were ongoing during the data-collection period (2013-2014). The selection process resulted in four vignettes related to: (1) standardization of an Electronic Health Record (EHR); (2) confidentiality within an HER;

(3) standardization of a system for Enterprise Resource Planning (ERP) in a healthcare context; and (4) adoption of an ERP in a healthcare context.

The four vignettes serve as an illustration of the BDM framework's usefulness. The vignettes are specifically selected to demonstrate how different levels of cooperation can be explained by various degrees of salience and reputation of both promoters and stakeholders. We adopt a confirmatory approach by applying the framework to challenge the assumption that unilateral, transactional motives are sufficient to explain stakeholder cooperation. The nature of this study justifies a qualitative design [43, 44] that also allows for describing promoter-stakeholder cooperation within its context.

4.3 Data gathering

To enhance construct validity, we followed a data collection protocol including interview questions, written reports, minutes of meetings, policy plans, and observations [44]. The collected data were stored in a database. The collection of documents enabled triangulation, so providing stronger substantiation of the constructs [45]. The documents have been used to validate information from the respondents, and to understand how was dealt with issues. Primary data on the actual degree of promoter-stakeholder cooperation were derived from semi-structured interviews with both promoters and stakeholders, after the issue for each of these respondents was explicated. The issue thus served as a real life vignette allowing the respondents to immerse sufficiently enough in the situation [41, p. 361]. The confidential semi-structured interviews consisted of open-ended questions derived from the research model [46]. Using semi-structured interviews also reduced the variation caused by the situation and context in which the interviews were held. Applying the same interview protocol with each stakeholder and promoter ensured that the interviews with the various participants were nearly identical. This improved the reliability in the cross-case analysis [46].

The interviews were conducted at two organizations. The first two vignettes took place at a residential care organization for the elderly in the Netherlands. This multidisciplinary organization has various facilities specializing in helping elderly people to meet their specific needs. For example, the organization has facilities that specialize in physiotherapy, occupational therapy, and speech therapy. The organization employs 930 practitioners and also receives support from about 485 volunteers. The two vignettes concerned a project to replace physical (paper-based) patient records with a new EHR. In the first vignette, the interviews were conducted with the promoter, who was also the implementer, of the EHR and a care coordinator and, in the second vignette, with the promoter and a speech therapist (a specialist within the organization). The third and the fourth vignettes both involved an organization that provides prostheses. The organization has approximately 340 employees at several locations across the Netherlands. The main location primarily houses staff functions such as the IT department and administrative departments, while the other locations provide care to the organization's clients. The employees at these locations are highly specialized in their own field and provide custom-made prostheses. The two vignettes focused on the standardization and the adoption of a new ERP system. Given that the existing ERP was no longer supported, the management had decided to adopt a newer version with fewer custom-made functionalities. A project team had been established to ensure that the re-implementation of the ERP went according to plan. In the third vignette, a team member and the promoter (project leader) were interviewed to discuss the issue of standardizing processes through the ERP. The fourth vignette focused on how the updated ERP system was adopted by the users. Here, two key users and the promoter were interviewed.

4.4 Data analysis

The interviews were recorded and transcribed. This enabled pattern matching across the transcripts [46, 48] to relate the responses from the promoters and from the stakeholders to the research model. A coding schema was used to list the various codes derived from the components of the BDM model [49]. More specifically, during the coding, the transcripts were read to reveal word repetitions, keywords in context, metaphors and expressions that indicated contrasts between the promoter and the stakeholders. We discussed our individual interpretations and this resulted in additional insights into the perspectives of the promoters and stakeholders and led to refined and more comprehensive interpretations of the promoter-stakeholder cooperation. The analyses included both within-case analysis and cross-case

analysis to enable both an understanding of the unique patterns of each vignette to emerge and to see the structure behind these initial impressions [45].

5. Results

Table 1 presents an overview of the results of the four vignettes. The low, moderate, or high assessment of each element of the BDM framework is based on the responses of the promoters and stakeholders in the various vignettes. Below the table, we discuss the results in more detail. In this section, we pay attention to using parts of the BDM framework to understand the level of stakeholder-promoter cooperation.

Table 1. Analysis of the four individual vignettes

BDM framework elements	**Vignette 1: Standardization issue**	**Vignette 2: Confidentiality issue**	**Vignette 3: Removal of custom-made functionalities**	**Vignette 4: Adoption issue**
Promoter perspective				
Impact of issue on system	High (risk of implementation failure)	High (rejection of the IS)	Moderate/low (most operations will remain the same)	High (encountered significant difficulties when the system went live)
Stakeholder salience	High (powerful in knowledge and legitimacy)	Low (fairly irrelevant)	High (represents an important business unit)	High (had indirect power and strong legitimacy)
Stakeholder reputation	High (important position in the organization)	High (competent and expected future cooperation)	High (relationship improved and important for future issues)	Moderate (thought it was going well)
Willingness to cooperate with stakeholder	High (crucial in solving the issue)	Low (the speech therapist was not relevant in solving the issue)	High (needs stakeholder to gain project support)	Moderate (mainly because of stakeholder's legitimacy)
Stakeholder perspective				
Impact of issue on stakeholder	High (personal stake plus her practitioners using the IS)	Low (the issue had hardly any impact on her)	Low (did not really affect him)	High (now need to carry out more actions, takes more time)
Promoter salience	High (IT knowledge)	High (only has IT-related skills and has communication issues)	Moderate (helpful but indecisive and hesitant)	Low (promoter has no knowledge of the system, stakeholder prefers to cooperate with the other promoter)
Promoter reputation	Moderate (has only power and knowledge in the IT field. Has communication issues)	High (only skilled in IT, but seen as offering valuable future benefits)	High (useful for future issues)	Low (incompetent, again stakeholder rather cooperates with other promoter)
Willingness to cooperate with promoter	High (it was imperative for her to solve the issue)	High (future benefits made her willing to cooperate)	High (liked to work on the project)	Low (did not see the need to cooperate with the promoter)
Resulting Cooperation				
Level of cooperation	High (consultations, discussions, problem-solving)	Low (limited cooperation, promoter cooperated with other stakeholders)	High (cooperation was intense, they communicated a lot about the issue)	Low (almost no cooperation, cooperated with other promoter)
Part of BDM framework necessary for understanding the level of cooperation	Salience perspective: Promoter cooperates with high-salient stakeholder on high impact issue	Salience perspective: Promoter does not cooperate with low-salient stakeholder on high impact issue	Double-motive perspective: Promoter cooperates with low-salient, but high-reputation stakeholder on low impact issue	Bilateral perspective: Stakeholder does not cooperate with low-salient and low-reputation promoter on high-impact issue

5.1 Vignette 1: Standardization issue resulting in cooperation through stakeholder salience and high impact

The introduction of the EHR meant that the practitioners had to work with standard terms, or codes, in describing the clients' health problems. Before the implementation, problems could be individually described in a free text format. The EHR, on the other hand, would only allow a choice from a standard list of one-word descriptions. The practitioners believed in applying personalized care to each client. Consequently, in the eyes of the professional staff, the new system hindered this way of providing care, and this resulted in staff resistance to the system. In this vignette, the stakeholder was the care coordinator of one of the organization's facilities.

Impact of the issue - The promoter perceived the issue as having a very high impact, believing that the EHR's potentially higher efficiency and improved information flow could be at risk if this issue was not resolved. As he put it: *"Seen from a management perspective, it (standardization) was the core of EHR"*. According to the stakeholder, the impact of the issue was also very high: she had a stake in the system through her role and, additionally, her employees had to work with the EHR while facing major changes in their work routines.

Transactional motives - The transactional motives were high, for both the promoter and the stakeholder. The promoter rated this stakeholder as very salient. The promoter needed someone to solve the issue at hand, meaning someone to rally the employees such that they would accept the change. The promoter argued: *"[The stakeholder] was really very important. (…) She was the one who eventually had to get them to go along, also in the advice towards the board, as in: 'guys, this is a good plan'. If she and a colleague had not supported in the way they did, then the [EHR implementation] could not have been achieved"*. Further, according to the stakeholder, the promoter was the only person she could approach to address the issue. She argued that he was the only one who had the knowledge necessary to solve the issue: *"You can also see how knowledge is divided unequally, his expertise is highly technical"*.

Relational motives - The promoter recognized the high reputation of the stakeholder, that her position in the organization was powerful: *"I think that a lot of people – including the top management members – value her opinion very highly"*. The stakeholder on the other hand did not in general perceive the promoter as the ideal candidate to work with, although she perceived him as highly salient with the issue at hand. She commented: *"sometimes it happened that you did not comprehend each other, and you simply were not talking the same language"*.

Cooperation - Both actors recognized the valuable contribution that the other could add to an important issue, and both were willing to cooperate. Further, they recognized each other's complementary knowledge and resources. As a consequence, cooperation between the promoter and the stakeholder was high. They communicated, held discussions, and consulted each other regularly in order to resolve issues. As the stakeholder put it: *"Sometimes you have to make compromises. That is something we both have trouble with… But in the end, we worked together in a constructive manner"*.

BDM framework in vignette 1 - The cooperation achieved was, based on the prevailing transactional and management view perspective as assumed in the salience model [6], as expected. The promoter cooperates with a salient stakeholder on an issue that has a high impact in the project. The upper left part of the BDM framework is sufficient to understand this situation.

5.2 Vignette 2: Confidentiality issue leading to non-cooperation through low stakeholder salience

The second vignette involved a confidentiality issue that emerged due to the implementation of the new EHR in this organization. Before this system was implemented, individual patient files were stored in a desk by each practitioner. In general, these files were only accessed by the individual practitioner caring for the patient. However, the new EHR would allow all medical staff to view what was written about a specific patient. According to the promoter of the EHR system, this led to resistance, particularly among those practitioners who perceived this information to be private. In this vignette, the promoter of the EHR and a speech therapist who had to work with the system were interviewed.

Impact of the issue - The promoter perceived the issue as important. He argued that, if the issue was not resolved, the EHR might be rejected by the dominant coalition of stakeholders, resulting in project failure. The promoter explained: *"I think that the risks, and luckily you don't realize this in advance, were pretty big. Namely, that the system would not have been accepted, and that you end up with an unworkable product, that was a possibility"*. The stakeholder, surprisingly, did not really recognize the issue in the same way as the promoter. For her, cooperation with the stakeholder was about making sure that the implementation went well and that various minor issues were adequately resolved. This indicates that she perceived the issue as having a minimal impact.

Transactional motives - The promoter did not perceive the speech therapist as a salient stakeholder in this issue. He stated that the stakeholder was charismatic and an important role model for her colleagues when it came to using the system. However, the promoter argued that there are more powerful stakeholders to consider. The stakeholder, on the other hand, considered that she was working with the promoter to solve the issue, and that the IS directly affected her work. The stakeholder considered the promoter to be legitimate and to have the necessary power, but that communicating with him was problematic.

Relational motives - Both parties had strong relational motives to cooperate with each other. The promoter saw the stakeholder as a competent employee with a respectable position within the organization. He also believed that having a good relationship with the stakeholder would benefit the cooperation process: *"You have a relationship with each other and that makes it easier, I think. Then there is also some mutual acceptance and goodwill"*. The stakeholder is convinced that the promoter will involve her in future decisions, simply because that is his job as the head of the IT department. While communication issues might remain a problem, the stakeholder is confident that this hurdle will eventually be overcome. Additionally, she appreciates the way the promoter looks at issues, as this often casts new light on the problem.

Cooperation - In terms of cooperation, this vignette contrasted with the former in the sense that cooperation was limited. The promoter did not perceive the stakeholder as sufficiently salient for this issue, which resulted in a low willingness to cooperate with the stakeholder. The promoter explained: *"She was not that important compared to other stakeholders. I eventually did not work with her a lot"*. The stakeholder did want to cooperate because she recognized the promoter as *"the one who knows the system inside out and, if we run into a problem, he is the one who can find a solution"*. However, because the promoter prioritized other stakeholders, the cooperation between her and the promoter was limited.

BDM framework in vignette 2 - Although the outcome is the opposite to that found in the first vignette, the degree of cooperation achieved in this second vignette is in line with that expected from the prevailing transactional and promoter perspective assumed in the salience model [6]. In vignette 2, the promoter chooses not to cooperate with a low-salience stakeholder on an issue that has a high impact on the project outcomes. Again, the upper left part of the BDM framework is sufficient to understand this situation.

5.3 Vignette 3: Removal of custom-made functionalities issue resulting in cooperation through high stakeholder reputation

The third vignette took place in an organization that provides prostheses to clients that suffer from a disability or a missing body part. The issue in this vignette study concerned the re-implementation of an organization-wide ERP system. The existing customized ERP system was no longer supported and it was becoming difficult and also expensive to maintain all the functionalities of the system. The management consequently decided to update the existing version of the ERP system and to remove most of the custom-made functionalities. However, employees in the operations department were concerned that this would result in a misfit between the system and their current working processes. In an attempt to resolve this issue, the promoter cooperated with a representative of the operations department.

Impact of the issue - Both parties assessed the impact of the issue as not that substantial. The promoter argued that the impact of the standardization was moderate as *"most operations continued in the same manner"*. While the promoter recognized that the demands of the users were important, he commented that he could not meet every need expressed.

According to the stakeholder, the standardization did not have a huge impact on his work. As he explained: *"I had some ideas about the system, so I really liked the project. But the impact is not very high"*. The stakeholder was quite surprised when he found that the changes were not as shocking as he had expected.

Transactional motives - The promoter perceived the stakeholder as salient, and therefore had strong transactional motives to cooperate with him. This high salience was mainly due to the fact that the stakeholder represented a large group of users from the user department. Given the size of this department, they also had the largest say during project meetings, and their vote was often decisive. The stakeholder had a slightly different view on the promoter. He perceived the promoter as helpful, but also indecisive and hesitant. He argued: *"If you are talking about the word 'leader', as in leadership, then no… I find it difficult to judge, but the promoter is a gentle person who will never show himself as having a very strong personality"*.

Relational motives - Both parties had relational motives for cooperating with one another. Although they had no previous experience of working with each other (mainly because the promoter had only worked at the organization for six months), they recognized that this cooperation could help improve their relationship when it came to future issues. The promoter believed that, due to this cooperation process, *"the barrier to contacting each other about something new has been lowered"*. When the stakeholder was asked whether he found a healthy cooperation also useful for future issues, he responded: *"Look, we shared this experience so we now know what we can expect from each other. If I need something, or I need an opinion about something, I can always send him an email or call him. He will then investigate the issue and work on that for me, so from my personal point of view that's very handy"*.

Cooperation - While the impact of the issue was limited, and the stakeholder was not fully convinced of the promoter's salience, cooperation went well. One might have assumed, because the issue did not have a strong impact on either party, that it would not be sufficiently interesting to establish cooperation. Nonetheless, both parties saw the benefits of cooperation based on relational motives. For example, the promoter explained that he was *"certainly prepared to cooperate with the project group members. Especially because through such a group, or via these people, you can only create more support"*. This support could help the promoter if other issues arose during the change project. The stakeholder explained that cooperation would improve his relationship with the promoter, which in turn could provide him with personal benefits during future issues.

BDM framework in vignette 3 - While cooperation in the first two vignettes could be explained using the salience perspective, vignette 3 has less straightforward results. In this third situation, the issue was assessed as relatively insignificant by both parties, maybe suggesting that cooperation on this issue was not really necessary. Nevertheless, the relational motives of the promoter and of the stakeholder to cooperate were classed as high. As such, the positive cooperation process seems to have resulted from the recognition that cooperation on this issue could benefit both the promoter and the stakeholder when future issues arose by improving their relationship.

In this vignette, the double-motive perspective (i.e., that cooperation depends not only on transactional motives but also on relational motives) helps to explain the cooperation: not solving an issue as such, but developing a relationship with a high-reputation stakeholder contributes to cooperation. As such, the upper right part of the BDM framework helps explain the level of cooperation.

5.4 Vignette 4: Adoption issue resulting in non-cooperation through low management salience and low management reputation despite the high impact

The end-users were required to adopt the new system and therefore had to attend several training sessions. The key-users had to facilitate the end-users' adoption process, and also test new functionalities before the system went live. The issue that arose was how the wishes of the key-users and end-users could best be incorporated into the new system.

Impact of the issue - The adoption issue had a significant impact on both the promoter and the stakeholders. The promoter explained that, when the system went live, it became evident that users were not well trained. Exercises that had been carried out were either insufficiently realistic, or employees had already forgotten how to cope with certain

aspects of the system. According to the promoter, this resulted in considerable disturbance, and some aspects of the system had to undergo readjustments after going live in order to "smooth the difficulties". As such, the promoter recognized that the implementation process had not been flawless, and that the impact was more severe than first thought. For the stakeholders, the new system changed the way they did their work and so it had considerable impact. One of the key-users explained that due to the standardization *"some tasks became even more cumbersome, but that's something you also hear from the group; that the logic isn't always there"*.

Transactional motives - The promoter perceived the stakeholders as a very legitimate set of people. He explained that he saw them as *"captains of a group; if they feel comfortable with a new system, their subordinates will also be more inclined to use it"*. The key-users were also a "platform, a sparring partner, and a mirror" and, by including them in the decision-making process, the organization was able to gain more support for the system. While the promoter perceived the stakeholders as salient, the stakeholders had a completely different story to tell. When one of the key-users was asked if she had cooperated a lot with the promoter, she responded that, in fact, she did not cooperate with him at all. Rather, she cooperated with a different promoter. The key-users explained that the ICT specialist, rather than the project leader, was "the one who really made it happen". When one of the key-users was asked how she would describe the promoter, she responded: *"Well… this might sound degrading of course… but I do not think he has sufficient knowledge and practical experience where it concerns the organization"*.

Relational motives - In relational terms, it was quite difficult for the promoter to assess the key-users' reputation. This was mainly because the promoter had only joined the organization when the project was initiated. Due to this, he could not make any judgments based on previous experiences. When he was asked how the relationship had developed through the project, he responded: *"well, content-wise I am not really into the project, but I guess it has gone well"*. Nevertheless, he was aware that cooperation might be necessary in addressing future issues, and that he had to *"maintain an optimum atmosphere"* as this would provide better support for the project. The stakeholders were clear that it would not be beneficial for them to cooperate with the promoter. Given his incapability to provide them with correct answers to their questions, he was also perceived as incompetent.

Cooperation - Given the impact of the issue on both parties, and the promoter's willingness to cooperate, one might have assumed that cooperation would eventually work itself out. However, the stakeholders had such a negative perception of the promoter that they eventually decided to bypass the promoter and to cooperate with a relevant ICT specialist who was able to address the issue instead. As one of the key-users explained, *"the promoter led the meetings, but… the ICT specialist answered all the questions"*.

BDM framework in vignette 4 - Whereas the first three vignettes can be explained by looking at the respective promoter's motives, this is not sufficient in vignette 4. In the studied situation, the promoter, because of the stakeholder's high salience, was willing to cooperate over this high-impact issue. However, cooperation failed because of the stakeholder's low willingness to cooperate with this specific promoter.

Including the bilateral perspective can explain this state of affairs because it suggests that not only the promoter but also the stakeholder need to be willing to cooperate. In our situation, the stakeholder had neither transactional nor relational motives to cooperate with the promoter regarding the investigated issue, and this resulted in a low willingness to cooperate with him. Explaining this situation requires the lower part of the BDM framework.

5.5 Cross-case analysis

The above analysis of the four vignettes illustrates that both promoter motives (indicated by stakeholder salience and reputation) and stakeholder motives (indicated by promoter salience and reputation) determine the degree of cooperation. While the salience perspective [6] is reflected in the first two vignettes, the BDM framework paints a fuller picture. In vignette 1, the willingness of the promoter to cooperate can reflect the stakeholder's high salience. However, the BDM framework also enables us to include the willingness of the stakeholder to participate because the issue had a high impact for her and the fact that she similarly rated the promoter's salience as high. In vignette 2, the cooperation failed due to the low willingness of the promoter. The BDM framework adds the additional insight that the

stakeholder would have been willing to cooperate, albeit based only on future benefits. In vignette 3 the relational perspective and in vignette 4 the stakeholder view helps in understanding the extent of the cooperation or lack thereof. The assumption that unilateral, transactional motives are sufficient to explain stakeholder cooperation is thus challenged.

Furthermore, the effect of the impact of the issue on cooperation is illustrated in all four vignettes. With high-impact issues (vignettes 1 and 4), cooperation is directed at addressing the issue through transactional motives; here, the salience of a cooperating partner forms the leading selection criterion. With a low-impact issue (vignette 3), solving the issue is less crucial but it provides a vehicle to manage and enhance the relationship. In this situation, the reputation of potential partners becomes an important selection criterion. Finally, vignette 2 illustrates an issue that has an unequal impact on the two parties. Whereas the promoter assessed the issue as having a high impact, and consequently used salience as the criterion in deciding not to cooperate with the stakeholder, the stakeholder, perceiving the issue as of low impact, would have been willing to cooperate based on the promoter's reputation.

6. Discussion and conclusions

The implementation of strategic information systems in healthcare environments appears to be an excellent context in which to apply stakeholder management approaches. The effective implementation of information systems in healthcare is critical, because human wellbeing and sometimes even lives are at stake, while many stakeholder groups, with different interests, affect the implementation, adoption, and use of these systems [1]. Therefore, the detailed, deliberate and well-considered management of stakeholders, by promoters of healthcare information systems, is of strategic importance [30, 31]. Ignoring stakeholders with good reputations, or involving stakeholders with low salience and a poor reputation, may lead to overruns in both time and money, unproductive conflicts, and project failure. Provided the promoters of health IS understand the stakeholders' positions, views, roles, and reputations, it is likely that they will involve stakeholders in a deeper and more insightful way [50]. The same is true for stakeholders who assess the salience and reputation of promoters of health IS projects.

6.1 Theoretical contributions

The framework presented in this paper contributes to the analysis of an issue's impact as well as the salience and reputation of both promoters and stakeholders before and during the potential cooperation on an issue within the project. In so doing, this paper confirms the value of taking stakeholder salience into account when managing a project [6, 15], especially when promoters cannot exclude powerful stakeholders or force them to join [35]. The framework helps unravel and detail factors that explain, predict, and evaluate cooperation in fluid multi-stakeholder environments such as information system projects in healthcare. Further, the BDM framework enables to compare the position of stakeholders, and to explain under which conditions fruitful cooperation can be expected.

The framework builds on the influential existing work of Mitchell et al. [6] by adding the salience of stakeholders based on a transactional perspective and by introducing reputation as a second important explanatory factor in cooperation. The importance of a stakeholder's perceived reputation highlights that promoters of information systems seek cooperation with those they evaluate as reliable and influential, both in the past as well as into the future. The examples illustrate that it is an oversimplification to assume that only transactional perspectives determine stakeholder management, or that stakeholder management takes place only on the project and not on the issue level. Not only do the transactional characteristics of a current issue explain effective promoter-stakeholder cooperation, previous cooperation and expected future cooperation also play important roles.

Another important feature of the framework that has been demonstrated by the vignettes is the bilateral perspective. Many stakeholder models only take a management perspective and are thus unilateral in their approach [14] or do not distinguish between the different roles that promoters and stakeholders have [e.g. 37]. By clearly distinguishing between the promoter and stakeholder perspectives, our framework helps expose factors that determine cooperation between these two types of actors. The four vignettes clearly illustrate that promoters and other stakeholders each

independently assess the issues and each other's salience and reputation before deciding whether to cooperate in resolving an issue. The four vignettes show how the different degrees of cooperation are determined by the different viewpoints and perceptions of promoters and stakeholders.

A third feature of the framework is the importance attached to an issue's impact. The framework suggests that promoters assess the impact of an issue both on the system and on the stakeholder. Such an assessment steers the selection of stakeholder(s) for cooperation: salient stakeholders in the case of high-impact issues, such as in vignette 1, and ones with a good reputation when the issue has only a low impact, such as in vignette 3. The implication is that promoter-stakeholder cooperation can be of value even on low-impact issues. Here, the investment may establish cooperative relationships that can be of future benefit, and management can put such issues on the agenda in order to drive cooperation.

A final aspect highlighted by the framework is the significance of adopting a dynamic perspective. Strategic health IS projects are fluid and lead to constantly changing stakeholder environments [30]. The framework can be instrumental in determining when and how an issue should emerge and be addressed through cooperation between the promoter and one or more stakeholder groups. Both the promoter and the stakeholders perceive the impact of an issue and assess the salience and the reputation of the potential collaborating partner. Based on these assessments of the perceived impact, as well as the salience and reputation of promoter and stakeholders, a cooperation might begin. Further, re-assessments of impacts, salience, and reputations will take place during the cooperation process, potentially leading to increasing or decreasing degrees of cooperation.

The BDM framework enriches the existing project management literature on stakeholder management by providing greater insight at a micro level into how and why actors cooperate. By unraveling relational as well as transactional motives, the framework explains why stakeholders are involved in problem-solving and decision-making. The future-oriented motives of an actor are a relatively novel way of explaining cooperation. As such, this can be perceived as an extension to the stakeholder salience model of Mitchell et al. [6]. Furthermore, the bilateral perspective sheds more light on how the process of collaboration is undertaken. Rather than identifying stakeholders merely as passive bystanders, the bilateral view contributes to the existing literature by recognizing that stakeholders can take active roles, which may change over time. In other words, the bilateral view provides a more comprehensive understanding at a micro level of promoter-stakeholder cooperation.

The research also suggests a broader view on complex projects. They can be managed from different perspectives including rational, emergent, participative and political perspectives [51]. While much of the traditional project management literature focuses on rational and linear perspectives [1], the proposed framework highlights the emergent, participative and political nature of complex projects by focusing on the dependency on the quality of promoter-stakeholder cooperation [4, 52, 53]. Encouraging cooperation based on an analysis of stakeholder's power and legitimacy enables a fuller use of the available resources which will lead to more effective outcomes and higher acceptance rates. We expect that multi-dimensional project management approaches that incorporate social, technical, as well as contextual perspectives will be more effective.

6.2 Implications for practice

The proposed BDM framework suggests four lessons for promoters and stakeholders of complex projects. First, promoters of such projects could apply this framework to analyze the stakeholder environment and so identify stakeholder's power and interests in order to determine the project's most important challenges and tensions. This understanding forms the basis for a deliberate strategy to manage stakeholder cooperation. If the promoter seeks to cooperate but the stakeholder perceives the promoter's salience or reputation as low, steering groups should strengthen its commitment to the project as well as the leadership of the project, e.g. by increasing the financial recourses or by strengthening the project team [54, 55]. Second and simultaneously, stakeholders can use the framework in assessing proposals for change. By assessing the impact of issues and their own and the promoters' interests, salience and reputation, stakeholders can evaluate and prepare for their possible involvement and potential contribution to a project. If the stakeholder seeks cooperation but the promoter perceives this stakeholder's salience or reputation as low, more

effort could be spend to increase power or legitimacy, for instance, by forming coalitions with more authoritative or powerful stakeholders. An alternative strategy for these stakeholders is to highlight their reputation by pointing to future issues where their support is required. Third and based on the first two lessons, good perceived reputations can lead to a high level of cooperation, even if the issue is not considered very significant, as illustrated in vignette 3. In this example, both the promoters and the stakeholders found it worthwhile to cooperate and to strengthen their trust in each other in order to address future issues with even more confidence. Achieving easy 'quick wins' on minor topics can result in an even higher reputation of project leaders and medical professionals. A fourth lesson concerns the implementation process. This study proposes that complex projects can lead to higher acceptance rates if promoters recognize the emergent nature of such projects and rely on participation and cooperation with potential users and other stakeholders on multiple related issues. Managing complex projects thus becomes a balancing act between linear and technical as well as participative and political activities.

As such, the BDM framework can be useful at the start of a project, during its implementation as an iterative activity, or at the end in evaluating promoter-stakeholder cooperation. It is likely that this framework can be effectively applied in similarly complex multi-stakeholder environments outside healthcare IS. Promoters engaged in stakeholder management in other contexts could also use this framework to gain a deeper understanding of the transactional and relational aspects of promoter-stakeholder relationships in order to consciously decide on an appropriate stakeholder management strategy.

6.3 Limitations and future research

The results and discussion should be viewed in the light of the study's limitations. One limitation of this research is the relatively low number of vignettes. A deeper understanding of promoter-stakeholder cooperation would be achieved by extending the empirical basis of the research by including richer and more contrasting cases. This could strengthen the results and the evidence of the framework's validity. Another limitation is inherent to qualitative studies: the subjectivity of the researchers in interpreting the data. It is always possible that data are misinterpreted, consequentially biasing the results. Third, aiming explain dyads, this study was exclusively focused on a single promoter and one stakeholder (or stakeholder group). Although group phenomena can be studied in dyads [56], the interrelatedness of stakeholders may lead to the involvement of certain stakeholders, and the exclusion of others, which may subsequently change the whole stakeholder landscape. For example, once stakeholders become involved in a project, they may become more valuable to other stakeholders. These shifts among stakeholders and their interrelationships may influence the dynamics of promoter-stakeholder cooperation.

Future research could broaden the scope of the model by including more stakeholder groups and their mutual interactions. Studies might examine the implications of this interrelatedness for stakeholder analysis and management. What are the effects of cooperation between promoters and stakeholders on other actors? If the relationships among stakeholders are affected, how does this influence the promoter-stakeholder relationship? Moreover, future studies could include a large number of contrasting cases. They might also include cases drawn from other contexts than health IS. Finally, carrying out quantitative studies to validate the BDM framework could suggest interesting new avenues for further research.

6.4 Conclusions

We believe that the proposed framework highlights perspectives that are neglected in other approaches, especially the importance of stakeholder reputation, the impact of the issue, the bilateral perspective, and a process perspective. We hope that suggesting this framework contributes to new research directions and to a more advanced approach for analyzing complex stakeholder settings both in health information systems and beyond.

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IJISPM

International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at www.sciencesphere.org/ijispm

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International Journal of
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ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at www.sciencesphere.org/ijispm

K. Haufe, R. Palacios, S. Dzombeta, K. Brandis and V. Stanchev, "A process framework for information security management," *International Journal of Information Systems and Project Management*, vol. 4, no. 4, pp. 27-47, 2016.

International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
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Abstract:
Securing sensitive organizational data has become increasingly vital to organizations. An Information Security Management System (ISMS) is a systematic approach for establishing, implementing, operating, monitoring, reviewing, maintaining and improving an organization's information security. Key elements of the operation of an ISMS are ISMS processes. However, and in spite of its importance, an ISMS process framework with a description of ISMS processes and their interaction as well as the interaction with other management processes is not available in the literature. Cost benefit analysis of information security investments regarding single measures protecting information and ISMS processes are not in the focus of current research, mostly focused on economics. This article aims to fill this research gap by proposing such an ISMS process framework as the main contribution. It is based on a set of agreed upon ISMS processes in existing standards like ISO 27000 series, COBIT and ITIL. Within the framework, identified processes are described and their interaction and interfaces are specified. This framework helps to focus on the operation of the ISMS, instead of focusing on measures and controls. By this, as a main finding, the systemic character of the ISMS consisting of processes and the perception of relevant roles of the ISMS is strengthened.

Keywords:
information security; IT security management; ISMS; process framework.

DOI: 10.12821/ijispm040402

Manuscript received: 15 May 2016
Manuscript accepted: 30 August 2016

1. Introduction

Information security is an integral element of fiduciary duty. The purpose of information security is to protect an organization's valuable resources, such as information [1]. Information security is also identified as a subset of Information Technology (IT) governance [2]. In relevant standards and frameworks as well as in the scientific literature, the continuously increasing dependency of nearly all organizations on appropriate secure information processing was stated practically in the last years [3]–[5]. Standards for the management of information security and collections of best practice measures were developed and established in the literature, e.g. [6]. Important standards for the development and operation of an ISMS (hereinafter referred to as "ISMS") are the ISO 27000 series.

Over the last few years, cost benefit discussions have influenced information security practice [7]. The value of information must justify protection costs. Adjustment and cost-effectiveness are key elements of a successful ISMS [1]. Knowledge of the mission is needed to align the ISMS processes to the organization and its mission [8].

Taking into account that business alignment and cost-effectiveness are important for the successful operation of an ISMS, research contributions must address both problems by allowing the simplification of the identification of necessary and appropriate ISMS processes as core elements of every ISMS.

IT and its management are also some of the hot topics for practitioners and researchers alike [9]–[11]. In a scenario, in which security management has also been pointed out as one of the most important topics in the discipline, there is no specific process framework for security management which clearly differentiates between ISMS processes and of the security measures controlled by ISMS-processes. Furthermore, a detailed description of ISMS processes and their interaction as well as the interaction with other management processes – as already identified in [12] – does not exist.

This problem is further exasperated because information security management is a complex issue [13]. Current research activities focus on economics and cost benefit analysis of information security investment regarding single measures protecting information. The ISMS and the ISMS processes themselves are not in the focus of current research [14]–[16]. So, such a holistic but detailed framework of ISMS core processes as core elements of every ISMS needs to be developed.

This specific process framework for security management needs to clearly differentiate between ISMS core processes, supporting processes and management processes, as well as the security measures controlled by ISMS-processes. Adjustment and cost-effectiveness are key elements of a successful ISMS [1]. A detailed framework of ISMS processes (input, output, interfaces) and their interaction at an activity level help to ensure an appropriate interaction of the ISMS processes. To fill this research gap, in this paper a holistic but detailed framework of ISMS core processes as core elements of every ISMS is proposed.

The remaining of this paper is structured as follows: in section 2 authors give an overview of the most relevant standards on the topic. In section 3 authors describe the applied research methods and in section 4 authors illustrate the proposed ISMS process framework and discuss the contained processes. Section 5 gives an overview of the results from the evaluation of the framework. Section 6 summarizes the main findings and gives an outlook on future research activities.

2. Background

In relevant standards and frameworks as well as in the literature, the continuous increasing dependency of nearly all organizations on appropriate secure information processing was stated [17]–[19]. Standards for the management of information security and collections of best practice measures were developed and established [5], [20]–[22]. Beside national standards like NIST SP 800 series in the US [23] or the IT security guidelines from the Federal Office for Information security in Germany [22], the most important standards for the development and operation of an ISMS are

the ISO 270xx, ITIL and COBIT [24]. The same standards were identified in an ISACA study [25, p. 26] as most used standards for IT governance and IT management, followed by CMM and CMMI, PRINCE2 and PMBOK.

2.1 ISO 27000 series

The International Organization for Standardization (hereinafter referred as "ISO") and the International Electrotechnical Commission (hereinafter referred as "IEC) formed a joint technical committee – ISO/IEC JTC 1. The sub-committee SC 27 of this committee has a working group WG 1 which develops and facilitates international standards for ISMSs. ISO 27001 as the international standard from ISO/IEC JTC 1 SC27 WG1 for information security management systems (herein after referred as "ISMS") is the security standard in enterprises [20], [26].

ISO 27001 contains the requirements for planning, implementing, operating, and improving an ISMS. Requirements are formulated in a general manner to fit for all organizations independent of their size, objectives, business model location, et cetera. In ISO 27001 absolutely no requirements are formulated for any specific technology [27] but the standard contains requirements for ISMS core process. Therefore, this standard forms the basis to identify ISMS core processes.

The ISO 27000 series do not only contain ISO 27001. Another common standard for information security of the ISO 27000 series is ISO 27002 [21], containing controls that should be implemented with the ISMS. ISO 27002 is linked with ISO 27001 with an Annex of ISO 27001 listing the controls of ISO 27002. Further ISO 27000 series standards are:

- ISO 27000 – ISMS – Overview and vocabulary;
- ISO 27003 – ISMS implementation guidance;
- ISO 27004 – Information security management – Measurement;
- ISO 27005 – Information security risk management;
- ISO 27006 – Requirements for bodies providing audit and certification of ISMS;
- ISO 27007 – Guidelines for ISMS auditing;
- ISO 27008 – Guidance for auditors on ISMS controls;
- ISO 27010 and following – sector specific standards;
- ISO 27030 and following – standards for technical controls and guidelines for controls of ISO 27002.

2.2 ITIL

The IT Infrastructure Library (ITIL), specified in [28]–[33], is a best practice framework for IT service management. IT service management is the management of all processes that co-operate to ensure the quality of live IT services, according to the levels of service agreed with the customers [34]. The primary objective of service management is to ensure that IT services are aligned to the business needs and actively support them [28]. ITIL was developed by the Central Computing and Telecommunications Agency – today Office of Government Commerce – and is today available in the third version. ITIL contains five books:

- Service strategy [32] – is a guideline for designing and implementing service management as strategic asset. Service strategy ensures the management of costs and risks of the service portfolio. While not only focusing on operational efficiency, it also ensures holistic and sustainable services;
- Service Design [28] – provides instructions for the development and design of services and processes. Design principles and methods are presented to transform strategic goals in a portfolio of services and service assets;
- Service Transition [33] – contains information about the development and improvement of capabilities regarding the implementation of new or changed services into production;
- Service Operation [31] – is focusing on the operation of IT services regarding efficiency and effectiveness;
- Continual Service Improvement [29] – contains instructions for the recurring improvement of design, implementation and operation of IT services (continual improvement process).

ISO/IEC 20000 [35], [36] is the international standard for service management containing the requirements of a service management system while ITIL provides a body of knowledge for achieving those requirements [28].

2.3 COBIT

Control Objectives for Information and related Technology (COBIT), specified in [37]–[40] is a control framework to help an organization ensure alignment between use of information technology and its business goals [41]. COBIT is based on five key principles [37]: Meeting stakeholder needs; Covering enterprise end-to-end; Applying a single, integrated framework; Enabling holistic approach; Separating governance from management.

COBIT also contains a process reference model, generic process capability attributes and a process assessment model which describes how to execute a capability assessment in an efficient and effective way. COBIT will be analyzed with the aim to use or adapt the process reference model for the use with ISMS core processes. Furthermore a COBIT 5 Professional Guide for Information Security [40] is provided which focusses on information security and provides more detailed and more practical guidance.

Mappings and integrations between/of COBIT, ITIL and ISO/IEC27000 series are available [42], [43]. In this article, the COBIT family is used to identify ISMS core processes and to integrate maturity levels in the ISMS core process framework.

3. Research methods

According to Susanto et al. [44] the most important and most widely accepted international initiatives for the development and operation of an ISMS are ISO 27000 series, ITIL [28]–[33] and COBIT [38]. These initiatives are also relevant in aspects like information and security management [10]. To obtain an agreed basis of ISMS processes of these standards, multiple process reference models need to be harmonized. To harmonize multiple process reference models a systematic stepwise approach presented by Baldassarre [45] was used in a mapping study by Haufe et al. [46]. For the analysis of the identified security management standards, an adaptation on the Models and Standards Similarity Study method by J. A. Calvo-Manzano et al. [47] was used. The method was as follows:

1. Select the models and standards to be analyzed;
2. Choose the reference model – as reference model the ISO 27000 series is chosen because resulting from the focus of this standard series the widest coverage of ISMS processes is expected;
3. Select the process;
4. Establish a detail level – as all analyzed standards are international standards and are applicable to all organizations independent of their size, objectives, business model, location, et cetera – the contained information about ISMS processes are generic. Therefore, a similar level of detail is chosen to analyze the standards;
5. Create a correspondence template – instead of a detailed correspondence template a process profile template was created;
6. Identify the similarity among models – the process templates were completed with information obtained from the standards;
7. Show obtained results.

Also the following basic criteria for ISMS core processes were identified and confirmed in a previous study [48] by the authors:

- Criteria 1 – Regularity – interrelated and interacting tasks are repeated on a regular basis;
- Criteria 2 – Transformation – inputs are transformed into outputs;
- Criteria 3 – Operationally – process is carried out while operating the ISMS;
- Criteria 4 – Accountability/responsibility – information security officer is the process owner or process manager and the process is a core competency of the ISMS;
- Criteria 5 – Value generating – delivers apparent and direct value to the stakeholder.

For the identification of processes, the following method was used:

1. Initially the ISO 27000 series were analyzed regarding mentioned processes;
2. ITIL and COBIT were analyzed (matching) regarding ISMS processes which were already identified in the ISO 27000 series as well as regarding additional possible ISMS processes. A matching table regarding the possible ISMS processes was created for ITIL and COBIT [46]. In the context of the matching the following questions were asked (based on Calvo-Manzano et al. [47]):
    a. Is there any information about ISMS processes in the other standards related to ISMS processes of the reference standard (ISO 27000 series)? What is the additional information that could help to carry out the ISMS process of the reference standard?
    b. Is there any information about possible additional ISMS processes in the other standards? What is this information/what is the possible additional ISMS process?
3. The results from steps one and two were summarized in a mapping table which is documented in Haufe et al. [46].

The detailed approach of the mapping study is also described in Haufe et al. [46].

4. Process Framework

As a result of the mapping study the following processes were identified as ISMS processes:

Table 1. ISMS processes

Process/criteria	**Process category**
Process/criteria	Process category
ISMS planning process	Management process
Information security governance process	Management process
Information security risk assessment process	ISMS core process
Information security risk treatment process	ISMS core process
Resource management process	ISMS core process
Process to assure necessary awareness and competence	ISMS core process
Communication process	ISMS core process
Documentation and records control process	ISMS core process
Requirements management process	ISMS core process
Information security change management process	ISMS core process
Process to control outsourced processes	ISMS core process
Performance evaluation process	ISMS core process
Internal audit process	ISMS core process
Information security incident management process	ISMS core process
Information security improvement process	ISMS core process
Information security customer relationship management process	ISMS core process
Configuration management process	Support process

ISMS processes and their interaction at a high level basis are shown in Fig. 1. ISMS process framework. Some interfaces are not illustrated to enable a better readability of Fig. 1. ISMS process framework: Every ISMS process provides input for the documentation and records control process; The ISMS planning as well as the configuration management process provide input for every ISMS process.

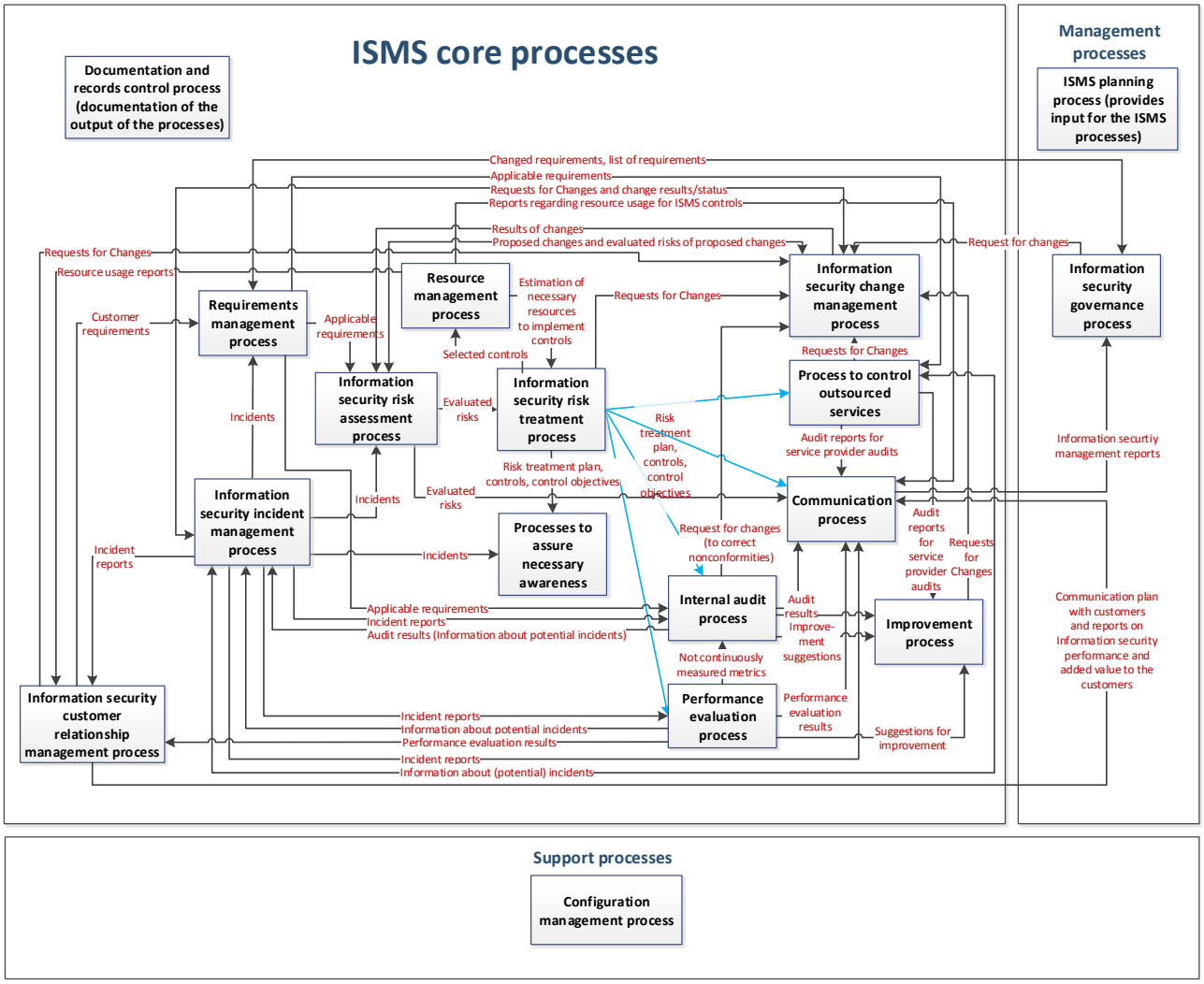

Fig. 1. ISMS process framework

The **ISMS planning process** is the process of ISMS specification and design from inception to the production of implementation plans. **Documentation and records control process** is the process to identify, create, update and control information determined to be necessary for the effectiveness of the ISMS.

Key to reach the ISMS objectives is an up-to-date understanding of the needs and expectations of interested parties relevant to information security and the ISMS. This is realized within the **requirements management process**, which

provides identified legal, statutory, regulatory and contractual requirements for the risk assessment process, the internal audit process and the process to control outsourced processes.

In the **risk assessment process**, risks are identified, analyzed and evaluated. The output of this process are documented and evaluated risks in a list of prioritized risks including threats, vulnerabilities and risk owners, consequences and business impact, likelihood and comparison against risk criteria as well as evaluated risks of proposed changes, which are input for the communication process and the information security risk treatment process.

In the **information security risk treatment process** risk treatment options including control objectives and controls are identified and selected. Output of this process are list with selected controls and control objectives, a risk treatment plan including acceptance of residual risks, a control implementation plan and requests for changes to information security change management process, which are used as input in various ISMS processes.

Resources needed to implement the controls as well as to run the ISMS processes are identified, allocated and monitored in the **resource management process**. Output of the resource management process are planned/documented resources to implement and run selected controls, categorization of controls regarding who funds the control, planned and documented resources to run the ISMS core processes, reports regarding resource usage of ISMS core processes, and for the information security customer relationship management process: reports on resource usage. The implementation of controls always results in changes, which can be managed within a general change management process of the implementing organization or – if the change focuses on an ISMS element – within the **information security change management process**. The information security change management process is the process to control changes of ISMS elements and review the consequences of unintended changes. This process only focusses on change management of the ISMS. Output of this process are necessary changes (for documentation and records control process), proposed and necessary changes as well as results of changes (for and from risk assessment process), initiation of risk assessment when significant changes are proposed or occur and the results of changes to information security incident management process, as they were initiated by that process.

The **information security incident management process** is for detecting, reporting, assessing, responding to, dealing with and learning from information security incidents. Output of this process are identified incidents which are used in various ISMS processes including the information security change management process and the process to ensure necessary awareness.

In the **information security awareness process** an information security awareness, training and education program is developed and implemented to ensure that all personnel receive the necessary security training and/or education.

As services are outsourced, these services need to be determined and controlled, which is realized within the **process to control outsourced services**.

The **performance evaluation process** contains monitoring, measurement, analysis and evaluation of two main criteria. First, the performance of the security controls and second the performance of the ISMS processes. Performance measurement differs from performance audit (internal audit) regarding effectiveness and efficiency of the ISMS and implemented controls which is performed independently within the **internal audit process**.

Results from the performance evaluation process, the internal audit process as well as results from the service provider audits from the process to control outsourced services are used to improve effectiveness, efficiency, suitability and adequacy of the ISMS and the controls. This is realized within the **information security improvement process**.

Results of nearly all ISMS processes are centrally communicated within the **communication process** to stakeholders outside the ISMS. This includes the communication of risks and information security management reports. Those reports as well as identified requirements are input for the **information security governance process**, which ensures an alignment of the ISMS with the objectives and needs of the governing stakeholders.

Beside the information security governance process, which forms the interface between the ISMS and its stakeholders, the operational management of the customer satisfaction level as well as the continuous demonstration of the added

value of investments in information security need to be realized. This is done within the **information security customer relationship management process.**

The ISMS processes are discussed in more detail in the following subsections.

4.1 ISMS planning process

In the ISMS planning process, inputs like the vision of the stakeholders are transformed into outputs like the management approval for the ISMS or the ISMS scope. Some of the outputs of this process – like management approval, scope definition – need to be checked in a regular basis regarding their actuality and appropriateness, but the process itself is primary an initial process which is carried out once as a project [49, p. 5]. The regular activities like renewing the management approval are also integrated in the management review and improvement processes. The ISMS planning process is clearly a process of the plan phase in the Plan Do Check Act (PDCA) cycle which means that the process is not carried out while operating the ISMS (DO phase).

The ISMS designing process is value generating for the top management while it builds the basis for establishing the ISMS, provides objectives for the ISMS and ensures an ISMS which fulfills the requirements of the top management.

4.2 Information security governance process

Information security governance from a holistic perspective is required to cultivate an acceptable level of information security culture and minimizing information security risks [50]. The management should initiate management reviews to continually improve the suitability, adequateness and effectiveness of the ISMS [20, p. 9]. Output of the management review contains decisions related to governing the ISMS. Taking into account the objective to governing the ISMS, the information security governance process must be repeated on a regular basis.

Inputs like management reports are transformed into decisions related to the governance of the ISMS and related change requests.

The information security officer is operationally involved in the process with compiling and presenting management reports. This process is carried out to govern the ISMS. Therefore, it is not a process of the operationally level. However, the owner of this process is the top management, as top managers are responsible to initiate the review process and to provide objectives and requirements to manage the ISMS. Information security governance process objectives for the ISMS are defined and the achievement of the information security objectives are monitored at a general level. However, top managers review and decide relevant aspects on this process.

Results of this process like informed and efficient management decisions represent a direct value for the top management (stakeholders) as they ensure that the ISMS is operated as intended by the top management and will achieve their objectives as top managers. As a result of this this process is a core competence for top managers.

Given the fact that this process is not a core competence of the ISMS and objectives for the ISMS are defined as well as the achievement of the information security objectives are monitored at a general level, this process is categorized as a management process.

This process is also part of the service management system. The integration of an ISMS with a service management system enables synergy effects based on the integration of these two processes.

4.3 Information security risk assessment process

The information security risk assessment process is the overall process of risk analysis and risk evaluation. The information security risk assessment process should be monitored, reviewed and repeated regularly [51, pp. 22–23]. Several iterations of this process are often conducted [51, pp. 9–10]. Inputs from ISMS planning process, information assets and previous process results are transformed into documented and evaluated risks and risk owners. The information security risk assessment process as part of the information risk management process is an integral part of an

ISMS and should be applied to the ongoing operation of an ISMS [51, p. 3]. The information security risk assessment process is a source of value for the top management while it provides a set of documented risks as well as a documented evaluation of those risks to help the decision making.

Again, this process is also part of the service management system [35, pp. 18–19]. One more time, synergy effects appear when the integration of ISMS and service management is made possible.

4.4 Information security risk treatment process

The information security risk treatment process is the overall process to identify and select risk treatment options as well as control objectives and controls. As this process is part of the risk management process, it should be monitored, reviewed and repeated regularly [51, p. 4].

In the information security risk treatment process, documented and evaluated risks are transformed into a risk treatment plan. The information security risk treatment process as part of the information risk management process is an integral part of an ISMS and should be applied to the ongoing operation of an ISMS [51, p. 3].

The information security risk treatment process is value generating for the top management while it provides a documented risk treatment plan.

The information security risk treatment process could also be a management process. Management processes define the objectives of the organization as well as control and monitor the achievement of the objectives at the level of the core processes and the overall organization. They contain project-, quality-, security- and risk management as well as strategic planning. From the viewpoint of the ISMS, the information security risk treatment process is not a management process, because it defines objectives of controls and not objectives the organization. So, it has an operational character.

4.5 Resource management process

The resource management process is the process to identify, allocate and monitor required resources to run the ISMS core processes as well as to implement and run the selected controls. A resource management process is also part of the ISMS planning process. This process focusses on the resources necessary to operationally run the ISMS. No specific information about the process is contained in ISO/IEC [20] and [49].

The resource management process needs to be carried out on a regular basis, because it is integrated in the ISMS and continuously supports the ISMS processes. This process is also supporting the controls by means of the identification, allocation and monitoring of required resources. So, this is not a one-time task.

The resource management process could also be a supporting process. Supporting processes provide and manage necessary resources without delivering direct customer value. They support core and management processes. Typical supporting processes are human resources, financial management and IT management. But from the viewpoint of the ISMS, an efficient resource usage provides also a direct value in means of financial terms to the stakeholders of the ISMS. This is achieved by providing information like necessary resources to implement and maintain a planned control which are necessary in the decision-making process for the risk owners. Consequently, the risk owners are the direct customers of this process. Taking this into account, the results of this process provide a direct customer value.

While integrated in the context of an overall resource management process, the operational resource management process of ISMS resources is therefore defined as a core process of the ISMS. This process is also part of the service management system. While planning the integration of an ISMS with a service management system, this enables synergy effects by planning an integrated instead of two separate processes.

4.6 Process to assure necessary awareness

The process to assure necessary awareness consists on the development and implementation of an information security awareness, training and education program. Objectives of the process are to ensure that all personnel receive the necessary security training and/or education. Employees shall be aware of the information security policy, their contribution to the effectiveness of ISMS including the benefits of improved information security performance and the implications of not conforming with ISMS requirements.

Of course this process needs to be carried out regularly, because requirements, risks and controls as well as the employees/personnel are continuously changing. This process also transforms inputs like awareness requirements, policies and security objectives into awareness plans, materials and, finally, an adequate awareness level of all employees.

While the process is designed in the ISMS planning process, it is carried out while operating the ISMS by an information security training team as part of the ISMS-Team. Often controls or changed controls are accompanied by awareness measures to inform all employees about the changed security controls.

Ensuring that all employees have the necessary competence (as part of this process as it is documented in ISO/IEC [20]), rather seems to be the responsibility of the human resources department. Given that the process to assure necessary awareness focusses only at the awareness of the employees.

The process generates a direct value to the management because only well trained and aware employees can act as defined in the policies and standards of the organization to achieve the objectives of the organization.

4.7 Communication process

Risk communication is the process to achieve agreement on how to manage risks by exchanging and/or sharing all information about risks between the decision-maker and other stakeholders. Risk communication should be performed continually [51, p. 22]. In the risk communication process inputs like information about risks and information needs of stakeholders are transformed into risk communication plans. Information needs of the stakeholders are satisfied.

The communication process, as part of the information risk management process, is an integral part operating an ISMS.

The risk communication process is value generating for the top management while it directly satisfies the information needs of the top management.

4.8 Documentation and records control process

Documentation and records control process is the process to identify, create, update and control information determined to be necessary for the effectiveness of the ISMS. As updating and maintaining the relevant documentation is part of the process, it must be carried out regularly.

In the documentation and records control process output of other ISMS, processes are transformed into appropriate and managed documentation. While processing records and other operational documentation, the process itself is operationally too.

In practice, document management is often not the core competency of ISMS staff. Nevertheless, to manage an appropriate documentation and records is a responsibility of the information security officer, because this documentation enables him or her to provide evidence of an appropriate ISMS.

Providing access to information necessary to assess an appropriate ISMS seems not to be a direct value delivery to the stakeholders. But ensuring an appropriate documentation and records enables achieving the maturity level “defined” and is a prerequisite of further maturity levels. Having an ISMS with a defined maturity level in place could be a direct value for the stakeholders. Providing access to information necessary to proof an appropriate ISMS is also a direct value

for the information security officer, because he or she is responsible to proof an appropriate ISMS to the top management. Furthermore, well managed documents with the use of the documentation and records control and the communication process, enable the employees to have access to relevant ISMS documents which will lead to a higher security level.

This process is also part of the service management system. Again, synergy effects appear when the integration of ISMS and service management is made possible.

4.9 Requirements management process

Requirements management process is the process to ensure an up-to-date understanding of the needs and expectations of interested parties relevant to information security and the ISMS. As it is necessary to continually keep the identified requirements up-to-date, this process is performed regularly. The process transforms inputs like stakeholder expectations and other constraints into documented and assigned requirements. Information security requirements identification is performed while operating the ISMS. Identifying all relevant requirements for information security is not only the responsibility of the information security officer – it is also one of the core competencies of the ISMS. Identified and assigned requirements are a prerequisite to generate a direct value to the stakeholders. From the perspective of the ISMS, having an up-to-date and assigned list of relevant requirements is key to implement and maintain an appropriate information security level. So, this is a direct value from the perspective of the ISMS and its stakeholders.

4.10 Information security change management process

Information security change management is the process to control changes of ISMS elements and review the consequences of unintended changes. This process only focusses on change management of the ISMS. As the operational environment of the organization changes in a regular basis, ISMS elements like security measures also need to be changed regularly.

Input like proposed changes and needs for changes are transformed into implemented and documented changes. Changes occur at all levels – strategic, tactic and operational. Taking into account the focus of this change management process on changes of ISMS elements, the information security officer should be the owner of this process. Because of the focus of this process, it must also be a core competency of the ISMS.

While every change managed by the change management process is intended to improve or maintain the information security level of the organization and information security has a direct positive impact on the business of the organization [52], the change management clearly provide a direct value for the stakeholders.

This process is also part of the information security management processes of the service management system [35, pp. 18–19]. One more time, synergy effects appear when the integration of ISMS and service management is made possible.

4.11 Process to control outsourced services

The process to control outsourced services is the process which ensures that information provided to external service providers is processed in compliance with the information security requirements of the outsourcing organization.

This is mainly achieved by analyzing drafts or final contracts in order to check if security requirements are met and if the development of requests for changes regarding requirements stipulated in contracts are performed. Finally, it is intended to check the conformance of the planning and execution of service provider audits regarding compliance with information security requirements. The process to control outsourced services needs to be repeated on a regular basis.

Within the process to control outsourced services, inputs like requirements are transformed into specific phrases in contracts or request for changes.

The process to control outsourced services is focused on ensuring information security and it is a specialized part of the broader management of providers. The management of providers also includes quality- and performance management (monitoring of key performance indicators), SLA-management and contract management as defined in the supplier management process of the ISO/IEC 20000. Due to the specialization of the process to control outsourced services, this process is carried out while operating the ISMS and clearly within the core competency of the ISMS.

Like the general management of information security, this process ensures an adequate level of information security and is, therefore, value generating.

This process is also part of the service management system [35, pp. 18–19]. Again, synergy effects appear when the integration of ISMS and service management is made possible.

4.12 Performance evaluation process

The performance of an ISMS should be monitored regularly [49, p. 63]. The performance of controls like continuity controls should also be verified regularly [21, p. 73]. Both, the performance evaluation of ISMS processes as well as the performance evaluation of controls are realized within the performance evaluation process.

This process is also part of the service management system [35, p. 16], where it is used to monitor trends and performance against service targets. One more time, synergy effects appear when the integration of ISMS and service management is made possible.

Inputs like control lists and control objectives are transformed into monitoring/measurement activities as well as records of those activities and, finally, in management reports.

According to ISO/IEC 27003:2010 [49, p. 63], the measurement process should be integrated into the ISMS cycle. The seamlessly integration of this process in the ISMS cycle requires that this process is a core competency of the ISMS.

Results of this process like management reports are a direct value for the top management (stakeholders) as they support decision making of the top management [49, p. 63] regarding ISMS-related decisions and improvement of the ISMS [53, p. vii]. Additionally, performance evaluation is one of the critical success factors of the ISMS [54, p. 11].

4.13 Internal audit process

The results of this process are inputs for the regularly evaluation of the ISMS this process must performed in a regular basis [49, p. 41,55].

Inputs like control lists, control objectives and incident reports are transformed into audit plans, audit reports and, finally, in management reports. Internal audits regarding information security controls are an integral part of the check phase in the PDCA cycle of the ISMS. Like the measurement process, the internal audit process should be integrated into the ISMS. So, it is clearly a part of the ISMS and performed while operating the ISMS.

While this process is performed within the operation of the ISMS, the information security officer could be owner of this process. But to ensure reliable and independent results, this process should be divided in:

- Internal audit of information security controls – for which the information security officer is the owner;
- Internal audit of ISMS-processes – for which the top management is the owner.

This division is necessary because independence if the key criteria which differentiates the internal audit process from the performance evaluation process (measurement and monitoring). Therefore, in the following, the internal audit process contains only the internal audit of information security controls. The seamless integration of this process in the ISMS cycle requires that this process is a core competency of the ISMS.

Results of this process like audit and management reports are a direct value for the top management (stakeholders) as they support decision making of the top management [49, p. 63] regarding ISMS-related decisions and improvement of the ISMS [53, p. vii]

This process is also part of the service management system [35, pp. 18–19]. Again, synergy effects appear when the integration of ISMS and service management is made possible.

4.14 Information security incident management process

Information security incidents should be detected and responded to in a timely manner [49, p. 63]. While it is not clear when and how often information security incidents occur, information about potential information security incidents is gathered regularly [55] and a continual proactive identification of information security incidents is conducted [56].

Potential information security incidents and gathered, information related to them is transformed into incident reports and changes are the basis for updating risk evaluations and training/awareness controls.

Information security incident management process (active prevention and detection of information security incidents) is a success factor of an ISMS [54, p. 7,11] and part of an operational ISMS [49, p. 31].

While this process is an integral part of an ISMS, the manager of the information security incident management process is the information security officer because the information security officer is made responsible for dealing with and communication of information security incident by the top management.

The information security incident management process is value generating, because security incidents have negative impact on trust in the organization and trust in the organization has a positive consumer impact [52]. Also, the top management has a direct benefit from the process resulting from the reduction of information security risks [54, p. 11].

This process is also part of the service management system [35, pp. 18–19]. One more time, synergy effects appear when the integration of ISMS and service management is made possible.

4.15 Information security improvement process

Continuous improvement of the ISMS and the information security controls are stipulated by ISO 27001 [20, p. 9]. Improvement contains not only regular reviews of the ISMS with the management to align the ISMS with the governing stakeholder needs and expectations which is realized with the information security governance process. Improvement also contains regular improvements of efficiency, effectiveness, suitability and adequateness of the ISMS processes and of the information security controls which is realized with the information security improvement process.

Taking into account that the improvement process requires a continuous scanning and monitoring of the internal and external environment, emerging technology and innovations as well as a regular processing of improvement suggestions the process must be repeated on a regular basis.

Inputs like suggestions for improvement and nonconformities are transformed into request for changes to realize the improvement or to eliminate root causes of non-conformities.

The information security officer is owner of this process, as he or she is responsible for an effective and efficient ISMS. This process is carried out while operating the ISMS.

Results of this process like request for changes to improve the ISMS represent direct value for the top management (stakeholders) as they ensure that the ISMS is operated effectively and efficiently.

This process is also part of the service management system. While planning the integration of an ISMS with a service management system this enables synergy effects by planning an integrated instead of two separate processes.

4.16 Information security customer relationship management

On the basis of [35, pp. 19–20] the information security customer relationship management process consists of the following:

- Identification and documentation of the customers, users and interested parties;
- Establishment of a communication mechanism with the customer;
- Establishment a method for measuring and demonstrating the value of information security and the efficient resource usage [40, p. 53];
- Track outcomes of information security initiatives and compare to expectations to ensure value delivery against business goals;
- Measurement of the customer satisfaction at planned intervals;
- Establishment and documented procedure to manage information security complaints from the customer;
- Initiation of changes to improve the customer satisfaction;
- Communicate information security performance and added value to the customers.

According to the COBIT process EDM02 [40, p. 73] – ensure benefits delivery –, it is also necessary for information security to ensure an appropriate balance between benefits, and costs of information security investments as well as risks. This is especially necessary as most costs for information security controls are funded by or charged to the demanding customers. Financial and non-financial measures are used to describe the added value of information security management.

The information security customer relationship management process transforms inputs from the customers – like requirements and complaints – into changes in the ISMS or information security controls. This process needs to be performed at a regular interval and at an operational level, because complaints and changes need to be considered in the operation of the ISMS.

To continuously demonstrate the added value of the ISMS or information security controls, is the responsibility of the information security officer, who should therefore be the owner of this process. Of course the business relationship management process is value generating as it ensures an appropriate customer satisfaction.

4.17 Configuration management process

The configuration management process ensures that every configuration item (CI) including their relationships to other CIs and service components is uniquely recorded in the configuration management database [35, pp. 22–23] which is used as input for most operational ISMS and SMS processes. Changes to CIs are also recorded. This requires a regular execution of the process. The process of the configuration management transforms single information about CIs, changes or problems into a structured, actual and reliable information basis for most ISMS and SMS-processes. So, this process is not of a direct value for the customers and other stakeholders of the ISMS and SMS, but it supports the value generation of other processes. As this process is part of the service management system and it is not mentioned in the ISMS, the accountability lies within manager of the service management system.

5. Evaluation

To verify or dismiss the identified ISMS core processes or add missing ISMS core processes, the authors of this article conducted a study [48]. In this study, 90 experts were asked to name ISMS core processes in form of a questionnaire. A panel of 90 German experts in the field of information security was selected, from which 75 experts answered the questionnaire. Roles of the experts were: 53 Information security officers/managers (23 working for private companies; 30 working for public administration); 8 consultants for information security (8 working for private companies); 14 auditors for information security (3 working for public administration; 8 working for private companies).

The set of possible ISMS core processes was given as shown in Table 2. Results of the study to identify ISMS core processes.

Table 2. Results of the study to identify ISMS core processes

Named process
ISMS planning process
Information security risk assessment process
Information security risk treatment process
Resource management process
Process to assure necessary awareness and competence
Communication process
Documentation control process
Requirements management process
Information security change management process
Process to control outsourced processes
Performance evaluation process
Internal audit process
Information security improvement process
Information security governance process
Information security incident management process
Service level management process
Service reporting process
Service continuity and availability management process
Budgeting and accounting for services process
Capacity management process
Business relationship management process
Supplier management process
Incident and service request management process
Problem management process
Configuration management process
Change management process
Release and deployment management process
Information security customer relationship management process

The detailed results of the study are described in Haufe et al. [48] and mainly confirmed the set of ISMS core processes proposed in this work.

The ISMS core process framework have been implemented and are operational in a medium-sized government organization as a pilot project. The first results of the pilot application are:

- An unmodified application of the ISMS process framework is not suitable. ISMS processes need to be tailored to the specific needs of the organization, but are of great value as a starting point. Starting with a holistic ISMS process framework results in focusing on a process perspective rather than a measure perspective. This is especially helpful because risks of a measurement driven approach like the understanding of information security as a one-time project are avoided and replaced by a process oriented view which better fulfills the requirement of operating an ISMS. A holistic ISMS process framework as a starting point also prevents the implementing organization from researching the standards regarding ISMS processes, as they are already provided;
- Beside the modification of the ISMS processes, processes differ in the implemented maturity level. Especially the process to control outsourced services and the information security incident management process need to be implemented at a high maturity level in the piloting organization due to a significant dependability on the provided services;

- Some processes are not necessary at maturity levels of “defined” or lower. Examples are internal audit process, performance evaluation process, information security improvement processes;
- The process "Documents and records control process" should be divided in "Security policy management process" (ISMS core process) from Veiga and Eloff [50] and "Records control process" (Support process).

To sum up the initial evaluation results, implementing the proposed ISMS process framework has the following advantages compared to the traditional measurement or control-objective-driven approach:

- Efficiency – the implementing organization does not need to research possible ISMS processes in the ISO standards, as they are provided with the framework;
- Operational focus – by implementing the ISMS process framework the focus is shifted from control objectives to a process oriented view, which better enables and supports an operation of an ISMS.

6. Conclusions and future work

The pilot implementation of the proposed ISMS process framework proved that a process-oriented view of the ISMS can help focusing on the operation of an ISMS and improve the efficiency while planning such processes. By this, as a main finding, the systemic character of the ISMS consisting of processes and the perception of relevant roles of the ISMS is strengthened.

The pilot implementation also showed that some improvements of the framework need to be done and that an unadjusted implementation of the framework will not be sufficient. Given that the future work will consist of three steps:

Step 1: Improvement of the framework

In the future, the first and further results of the evaluation of the proposed ISMS process framework should be analyzed and used to improve the framework. Especially already available results of the pilot implementation will be used and the process "Documents and records control process" will be divided in "Security policy management process" (ISMS core process) from Veiga and Eloff [50] and "Records control process" (Support process). Those processes will be integrated in the framework.

Step 2: Development of a method to adjust and make costs for operating the ISMS core processes transparent.

Transparency of information security costs could be further improved by tailoring the maturity level of ISMS processes to the requirements of the organization. Considering limited resources as well as ensuring an efficient use of those resources, not every ISMS process should be established and operated at the same level of maturity [25, p. 8]. By considering a maturity level model for ISMS processes combined with an approach for the determination of the necessary maturity level, the appropriateness of an ISMS can be made transparent as well as unnecessary costs of information governance can be avoided.

Step 3: Derive a basic process framework for lower maturity levels

The pilot implementation of the proposed ISMS process framework showed that, especially in the case of organizations were the overall maturity level of the ISMS is not higher than “defined”, the proposed process framework is too complicated and too big. For those organizations, a modified basic ISMS core process framework should be derived. This framework could also be a milestone for organizations which want to establish a higher maturity by an iterative approach.

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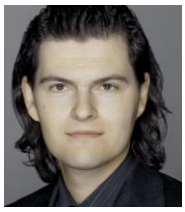

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IJISPM

International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at www.sciencesphere.org/ijispm

Thematic grouping for messages in major events

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International Journal of
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Available online at www.sciencesphere.org/ijispm

W. Pinheiro, R. Fernandes and L. Souza, "Thematic grouping for messages in major events," *International Journal of Information Systems and Project Management*, vol. 4, no. 4, pp. 51-65, 2016.

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Abstract:
The process of information evaluation may compete with the decision making process by requiring the limited cognitive resources. In the case of Major Events, such as the Football World Cup or the Olympic Games, the thematic grouping of every information may be overwhelming. The theme switching caused by information associated with a different thematic group may be modelled as an interruption in multitasking set-ups. Thus, automating the thematic grouping of information may facilitate the decision making process by reducing the theme switching for a decision maker when he reads a set of messages. In this paper were used clustering techniques with multi-criteria to group the messages in themes. These criteria were implemented as configurable operators. To achieve a better comprehension of those parameters, we introduced the concepts of Thematic Strength (TS) and Thematic Density (TD). The evaluation of the strategy was made over a set of operational messages available in the Pacificador system during the 2014 FIFA World Cup.

Keywords:
decision-making; thematic grouping; multi-criteria clustering; major events; messages.

DOI: 10.12821/ijispm040403

Manuscript received: 20 April 2016
Manuscript accepted: 8 September 2016

1. Introduction

The human decision making process is a cognitive process of choice among alternatives [1],[2]. It means the decision making process is bounded by the human cognition constraints. Considering this and the higher demands for information processing and agile decision, the human brain becomes a bottleneck for the decision flow. We can conclude that the human cognition is the main asset to be preserved for critical decision operations.

For that reason, it is mandatory to avoid unnecessary cognition overload in order to preserve agility. The process of information evaluation, for example, may compete with the decision making process by requiring the limited cognitive resources. In the case of Major Events, such as the Football World Cup or the Olympic Games, the thematic grouping of all information may be overwhelming. Under this scenario, the communication among the operational people is made through message-enabled devices, such as cell phone and tablets. But the messages presentation order is not based on thematic association. It means that the decision maker may use much of the cognitive resources only to organize the information on the proper theme.

The theme switching caused by information associated with a different thematic group may be modelled as an interruption in multitasking set-ups [3].

We propose a solution for the cognitive overload caused by high information processing demands in Major Events based on the automation of the thematic grouping process. The thematic grouping process can be understood as the process of clustering information related to a same theme in a same group using one or more features of the information. In this paper, the information is materialized as one or more message and a set of features extracted from the messages.

Automating the thematic grouping of information may facilitate the decision making process by reducing the theme switching for the decision maker when he reads a set of messages. To group the messages in themes, we used some clustering techniques with multi-criteria. These criteria were implemented as configurable operators. To achieve a better comprehension of those parameters, we introduced the concepts of Thematic Strength (TS) and Thematic Density (TD). The evaluation of the strategy was made over a set of operational messages available in the Pacificador system during the 2014 FIFA World Cup. The information processing from different sources must deal with information duplication and correlation. The information correlation is understood as the relation among information that refers to the same object, event or theme. In our case, we propose a way to group information according to their themes.

From Peng et al. [4], it is possible to remark the importance of the grouping process for supporting the analysis of large amount of data. It points out that the grouping contributes by reducing the number of alternatives as it offers some representative elements to be used in the process of alternative choices.

The application of multi-criteria may contribute to the effectiveness of message recovery as reported by Schuff et al. [5]. In this work, the themes are approximated by groups built by a computer program, using multi-criteria.

These groups need to contain at least two messages to be considered a theme. Those groups aim at facilitating the message association recovery as a good way to reduce the complexity of message analysis [4],[5]. Therefore, we denote those groups as thematic groups or themes because they should provide a set of messages related to a similar topic.

We remark that theme recovery, in the comprehension cognitive level, based on the thematic grouping, might demand human evaluation, however it is out the scope of this work. Moreover, it is important to

observe that, according to Roussinov and Chen [6], the computer grouping resembles the human grouping made by specialists.

We also remark that the number of messages in each theme depends on operational factors. We put those factors aside of our approach, allowing the number of messages in each theme be variable. The statistical analysis of each theme is also excluded from the present article.

The thematic grouping proposed in this work evolves some concepts from Souza and Pinheiro [7],[8] for multi-criteria clustering of data from different sources. Specifically, we propose new ideas for the architecture, the multi-criteria clustering, the sequential filtering based on attributes and the configuration techniques for the operators. Furthermore, we apply the proposed methodology as an experiment over operational messages from the 2014 FIFA World Cup, obtained from the Pacificador system.

The remainder of this work is organized as follows: Section 2 describes the related works; Section 3 presents the proposed methodology; Section 4 shows the experiments results; and Section 5 presents the conclusion and future works.

2. Background and Related Works

2.1 Techniques for Analyzing and Grouping Information

One way of connecting pieces of information with correlation is using a strategy known as record linkage [9]. The demands presented by the growing amount of information impose scalability and performance requirements over the record linkage process. And that imposition leads to the development of many indexing techniques to reduce the number of comparison among the set of information. It is done by the identification of sets of information with explicit no correlation. It effectively reduces the number of comparisons, maintaining the high quality of record linkage and reducing the complexity of the algorithms [10].

The Traditional Blocking indexing technique is used since 1960 [9]. It is done assigning each piece of information to a given block according to some criteria. These criteria are given to increase the potential relation among the information inside the blocks. The comparison reduction is achieved by restricting the search among the information in the same block. The sensitive part of this strategy is the definition of the criteria, which may separate the information correlated in different blocks. To solve these issues, many different approaches were proposed [9],[10]: Sorted Neighborhood Indexing; Q-Gram Based Indexing; Suffix Array-based Indexing; String-Map-based Indexing; Canopy Clustering; and Hierarchical Clustering. This last one received a special attention in this work and it is used to cluster elements composed by texts. On the Hierarchical Clustering, the algorithms may change the number of groups after each iteration. The proximity or similarity measure of that kind of grouping method is known a linkage metric. Dendograms may be built by agglomeration (bottom-up) or division (top-down), being the latter more computationally complex. Therefore, this work implements the agglomerative clustering strategy.

Others frequent techniques used to group information involve partitioning clustering algorithms, such as K-means and K-medoids [11]. However K-means and K-medoids demand the user provides, a priory, the number of clusters, which makes this strategy unsuitable for the scenario discussed in this paper. The hierarchical clustering is relevant for this work because it uses tree of groups, denoted as dendograms, that allows choosing the number of final groups according the chosen similarity level for the groups. Similarity out of these limits means explicit no possible correlation among groups, being quite intuitive to users. The definition of the limits may depend on expert knowledge and can be done by parameters and attributes in a multi-criteria way, as proposed in this work.

Multi-criteria decision methods are also important in the context of this work, because they allow comparing different attributes (or critters) based on people judgment. As this work uses different attributes to group messages from different sources (people), these methods enable the valuation of these attributes using pair-wise comparisons between the attributes. In this scenario, Analytic Hierarchy Process (AHP) [12],[13] is one of the most used multi-criteria decision, because it is simple and effective in many scenarios. In this method, people indicate the relative significance between pair of attributes. The attributes correspond to features extracted from alternatives to be ordered. For example, alternatives can be represented by cars and attributes can be represented by price, category, boot space, etc. The responsible by the decision can specify their preferences using comparisons (to pair of attributes and alternatives) using values that can range from 1/9 to 9 (1 represents attributes with the same value). These values are used to populate a matrix that is used to calculate the weight of attributes and alternatives.

2.2 Pacificador System

The Pacificador system, developed by the Centro de Desenvolvimento de Sistemas (CDS), is the Brazilian Army Command and Control system employed by the Brazilian Defence Ministry. It was used in the 2012 Rio+20 United Nations Conference, the 2013 Confederations Football Cup, the 28th World Youth Day (2013) and the 2014 FIFA World Cup.

The operations of support and security of Major Events involve people that must work in harmony. The coordination of the operational staff requires communications to serve different possible media. The text messages are of great value because they are relatively cheap and because they tend to be efficient on information codification, synthesizing the ideas and lowering the communication infrastructure.

The operational messages carry some relevant attributes, for instance: description in natural language; time stamp; and position of the author of the message. These attributes were used for the information grouping. In order to achieve this goal, this paper proposes an architecture for correlation data from distinct sources, in a Command and Control environment (C2), whose data follow the "Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM)" specification that aims for the international interoperability between C2 Systems. Therefore, messages provided by the Pacificador system were exported to the JC3IEDM format (http://mipsite.lsec.dnd.ca/).

3. Thematic grouping

3.1 Overview

In this article, the grouping of information is divided in two major phases: information normalization and information grouping. The decision diagram of the proposed strategy is given in Fig. 1 using BPM (http://www.bpmn.org/) notation through Bizage Modeler (http://www.bizagi.com/).

The first phase is responsible for preparing information incoming from different sources. It deals with the aspects of natural languages that may interfere on the grouping algorithms. It also understands different information formats in order to extract the attributes to be used in the next phase. Among the tasks of this process, it can be cited [14],[15]: tokenization; filtering normalization; discarding of stopwords; lemmatization; and stemming. These tasks are important to correlate data from different sources, but the user can choose which of them should be executed. For this reason, in Fig. 1, each one of the tasks can or cannot be executed, according to the analyses of the input data.

The second phase is responsible for identifying the information with higher similarity under multi-criteria building groups of similar messages. This grouping is meant to recover the theme of every information piece, for that reason we denoted it as thematic grouping. Under the Major Events scenario, the information relation should not only consider the descriptions, which are related to the semantic dimension. This

approach can be seen in the information relation processes as in Christen [9]. We propose that other attributes must be considered. We base our approach in the 5W2H approach where: WHAT corresponds to the description of the message; WHERE corresponds to the location from the message is sent; WHEN corresponds to the data-hour of the message creation; WHO corresponds to the author of the message; WHY corresponds the reason of the message sending; HOW corresponds to the context of the message (type of object or event being described and the environment where is located the object or event being described); and HOW MUCH corresponds to the relevance of the message. These attributes offer a better explanation of the message to leverage the quality of the thematic grouping.

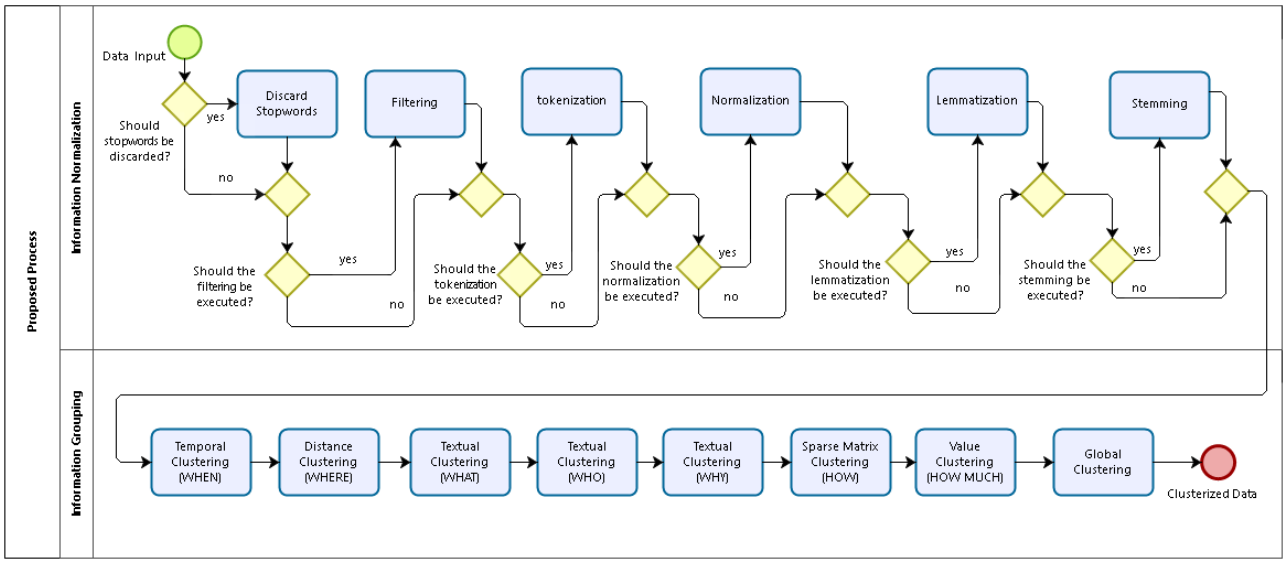

Fig. 1. Proposed Strategy

The attributes classified according to the 5W2H action plan are related to the JC3IEDM entities that provide the pattern for the messages obtained from the Pacificador system. In this process, this paper follows the idea detailed in Souza and Pinheiro [8]: the OBJECT-ITEM entity is associated to the WHAT attribute, indicating the textual description of the object or event. The attribute WHERE is related to the LOCATION entity and their connected classes: GEOGRAPHIC-POINT and OBJECT-ITEM-LOCATION, which provide the object position (latitude and longitude) and velocity. The REPORTING-DATA-ABSOLUTE-TIMING entity provides the date/hour of a report that is resulted from object or event visualization. It is associated to the attribute WHEN. The attribute HOW is associated to the OBJECT-TYPE entity and provides a combination of information related to the type of the objects (for instance: aircraft, ship, etc.) and the environment where objects were found (for instance: air, water, etc.). The attribute WHO provides information about the source of the message and it is related to the entity REPORTING-DATA. At this point, this paper extends this idea using the entity REPORTING-DATA from JC3IEDM to provide information about the source of the message (WHO sends the message) as well information about the message, such as: accuracy (accuracy-code), credibility (credibility-code) and reliability (reliability-code). Thus, these parameters can be used to infer the value of the message (HOW MUCH) through a correspondence between the string values used in the JC3IEDM for each parameter and numeric that can be set to them. For instance, the parameter accuracy could receive the following values: Confirmed = 100; Probable = 80; and Doubtful = 40. Finally, the attribute WHY is associated to the entity ACTION that can describe the goal of the message.

In this work, an operator that combines pair of messages implements each attribute. Similarity functions present in each operators link messages and this link is established when the similarity between two messages is higher than a minimum pre-established level of similarity. Groups of messages are composed of messages that have some relation of similarity with at least one member of a group. Members of different groups do not have any relation with any member of other group. In other words, the groups do not have overlap.

Operators are used in sequence and only pairs of messages that are related by the previous operator need to be processed by the next operator, allowing that each operator acts as a filter for the next. Thus the first operator analyzes all possible pair combinations of messages. The following operators just need to analyze the pair related by the previous operator.

The operators consider five types of similarities functions to link messages: based on temporal difference (attribute WHEN); based on distance (attribute WHERE); based on textual similarity (attributes WHAT, WHO, WHY); based on value difference (attribute HOW MUCH); and based on a sparse matrix similarity (attribute HOW). This last attribute, differently from the others, has to deal with two parameters: type of object and environment. The textual similarity (attributes WHAT, WHO, WHY) is implemented by the Hierarchical clustering approach, discussed in Section 2.

The parameters follow a pattern provided by the JC3IEDM specification. For instance, the types of the objects can be described by: aircraft, ship, car, troop, among others; and the environment of the object can be described by: air, water, road, trail, etc. When the user sends a message, he can choose the type and environment related to the object or event being described in the message. Thus, we proposed for this last attribute the use of a sparse matrix to obtain the similarity level between two messages. An example of a sparse matrix, based on Souza and Pinheiro [8], to calculate similarities related to the HOW attribute is showed in Table 1.

Table 1. Sparse Matrix

	Type: Aircraft Environment: Air	Type: Aircraft Environment: Land	Type: Vehicle Environment: Road	Type: Vehicle Environment: Field	Type: Troop Environment: Road	Type: Troop Environment: Field
Type: Aircraft Environment: Air	1	0.4				
Type: Aircraft Environment: Land	0.4	1				
Type: Vehicle Environment: Road			1	0.6		
Type: Vehicle Environment: Field			0.6	1		
Type: Troop Environment: Road					1	0.7
Type: Troop Environment: Field					0.7	1

As the final stage, results of the operations are combined to produce a global similarity between each pair of messages. The decision maker can set a minimum global similarity value that relates two messages. If the similarity between a pair of message is higher than the global similarity, then the messages of this pair belongs to a same group. To calculate the global similarity, it is used the formula showed in (1), where: *w(ATTRIBUTE)* corresponds to the weight of an attribute of the 5W2H approach and *w*o(ATTRIBUTE)* corresponds to the weight multiplied by the similarity between two messages using an attribute.

$$GlogalSimilarity = (w*o(what)+w*o(where)+w*o(when)+w*o(who)+w*o(why)+w*o(how)+w*o(howmuch))/ (w(what)+w(where)+w(when)+w(who)+w(why)+w(how)+w(howmuch)) \quad (1)$$

To estimate the weights of the other operators, it can be used a multi-criteria decision making method, such as Analytic Hierarchy Process (AHP) [12],[13]. In this case, AHP should be used just to calculate the weight of each attribute (critter) using pair-wise comparisons between the attributes. Thus, we have a way to calculate the importance of each attribute considering the opinions of several users. The approach proposed in this paper considers that new message can be processed on demand. It allows the creation of new groups or the inclusion of new messages in the existent groups, without having to process all combinations of messages again.

The analysis of complexity is important because it allows knowing the cost of each operator. Thus, the less expensive operators can be applied first, considering that the operators have the commutative property. The correct ordering of the operators may reduce the total time of the clustering process. The first operator generally processes a higher number of messages combinations than any other operator. It happens because it discards some combinations of messages according to its similarity levels. These combinations do not need to be evaluated by the next operator. Following this idea, the second operator processes a higher number of messages combinations than the third operator and so on.

The complexity operator analysis studies the time and the space used by the algorithms. The asymptotic complexity analysis considers the relation between time and space used by algorithm depending on a large number of input information [16]. That analysis is directly linked to the operator cost.

Other perspective that could be considered to apply operators sequentially is the selectivity analysis. However, this analysis is not considered in this work.

3.2 Operators configuration

The use of acceptable levels of similarity brings advantages, because they can be interpreted as maximum errors admitted to correlate each attribute of a message. However, it is not easy to define suitable error values. In certain cases, it is easier to define the characteristics of the message groups that should be created. Because of that, it is proposed two new concepts that are related to the features of the clusters:

Thematic Strength (TS) and Thematic Density (TD). These concepts are represented by the expressions (2) and (3), where: the variable numClusters corresponds to the number of clusters with two or more messages and the variable numMsgs indicates the total number of messages grouped in the clusters with two or more messages, being considered themes the clusters composed of two or more messages. Clusters composed of just one message are not considered in these expressions.

$$TS(numClusters, numMsgs) = numClusters * numMsgs \quad (2)$$

$$TD(numClusters, numMsgs) = numMsgs/numClusters \quad (3)$$

In order to adjust the right values according to these concepts considering a set of messages, it is necessary to calibrate them through a small subset of the messages considered as a training set (it is proposed a training set composed of approximately 10% of the total messages number). Thus, each operator needs to be applied to this subset using different configuration values. The results will provide the suitable values for the operators' parameters. Thus, from this process, it is possible to define the acceptable levels of similarity.

It can be noticed that TS increases when the number of clusters and the number of messages in the clusters increases. The maximum theoretical value of this measure is reached when the clusters are composed of just two messages and the total of messages is equal to the number of processed messages. It follows that higher values of this measure may produce higher number of clusters with few messages in each one. This situation makes difficult to analyze the themes for a big number of messages. Otherwise, lower values of TS may produce lower number of cluster with few messages, which is not appropriate to evaluate the themes.

On the other hand, TD increases when the average size of the cluster increases. The maximum theoretical value of this message is reached when all processed messages belongs to the same cluster. It follows that

higher values of this measure are produced by a small number of cluster with many messages, which does not facilitate the processing to be executed by the decision maker. Otherwise, lower values of TD indicate cluster with few messages, which is also not interesting for the user. In a way, TD gives a counterpoint to TS.

Therefore, it is proposed to combine these two measures trying to find a balance between them. It is proposed to use the maximum value given by the weighted arithmetic mean of TS and TD. If correctly set, this measure may reduce the number of cluster composed of just one message and may increase the size and number of clusters accordingly. This measure, named maximum Thematic Clustering (maxTC), is given by the expression (4), where the terms alpha and beta represent weights and allow adjusting this measure to different scenarios. The terms maxTS and maxTD correspond to the maximum values of TS and TD.

$$maxTC = ((alpha * (TS/maxTS) + beta * (TD/maxTD))/(alpha + beta)) \quad (4)$$

It is possible, from the maxTC, to find the number of clusters and the total number of messages in the clusters and, consequently, the parameters of each operator.

4. Experiments

It is important to highlight that the number of themes depends on clusterization process based on attributes extracted from the messages. As seen previously, this process was based on messages temporal difference, distance of senders, similarity among objects or events descriptions, messages from the same sender (grouping), similarity of messages goals, similarity of the object types and environments where the objects were found, and similarity of the items: accuracy, credibility and reliability from the messages.

To evaluate the strategy proposed, it is used a subset of the attributes related to the 5W2H approach. They are: time (data-hour of sending); position (latitude-longitude of the data sender); and description (detailed of observed object or event). These attributes are considered sufficient for this analysis because when they are used in a combined way they provide suitable results in a scenario of operations in major events, as demonstrated in the experiments. In future works, all 5W2H attributes will be analyzed together what should improve still more the results.

The three chosen attributes are implemented by operators working with: temporal distance (based on time); spatial distance (based on distance); and textual similarity (based on description). The operators used the agglomerative hierarchical clustering that has at least quadratic order. However, each operator uses a different number of parameters, what implies they have different costs.

In the case of the text operator, the similarity functions, like Jaccard or TF-IDF functions [14], need to compare all terms (words) from the data items. Thus, the cost of this operator is related to the average number of words. According to this idea, the texts related to descriptions are more expensive than the texts that identify authors (normally shorter).

In the case of the distance operator, the function used to calculate the distance receives two parameters: latitude and longitude. To calculate the distance, it is necessary to compare these two values for each data pair. As it just compares these two values, in most part of the cases, this function is less expensive than textual similarity functions.

In the case of the operator based of temporal difference, the function used to calculate the difference receives one parameter: the message timestamp. To calculate the time difference, it is necessary to compare this value for each item data pair. As it just compares this value, function is less expensive than the others analyzed until now.

Consequently, the optimized ordering of the operators is: 1) Temporal Clustering; 2) Distance Clustering; and 3) Textual clustering.

Additionally, after applying the operators sequentially, it was applied the global similarity to obtain the final results. This operation is set to consider the same weight for the three criteria (temporal difference, distance, textual similarity) and the minimum global similarity equal to 1%. This value represents the minimum acceptable similarity in this experiment. In other scenarios, it is suggested to use AHP to set the weights and the minimum global similarity.

In this paper, it was executed experiments using data from real operations that happened in the 2014 FIFA World Cup. The messages representing the data were registered using the Pacificador system.

The methodology proposed in this paper was implemented through components developed in java. These components were encapsulated as plugins of the Apatar Tool, an open source application that aims to provide connectivity to several databases and applications [17].

Field agents wrote most messages used in the experiments, but all people involved in the military operations could write messages. The messages normally described potential and real incidents, orders and monitoring of planned activities.

The methodology of evaluation considered, firstly, each operator isolated using 500 messages and, after, all operators combined using 2000 messages. The first experiment is used to set the parameters of the operators and the second experiment evaluated the behavior of the operators using these parameters. Therefore, the first experiment considered several level of similarities and the second experiment considered one level of similarity to each operator.

Fig. 2 and Fig. 3 describe the results obtained by the operator based on textual similarity.

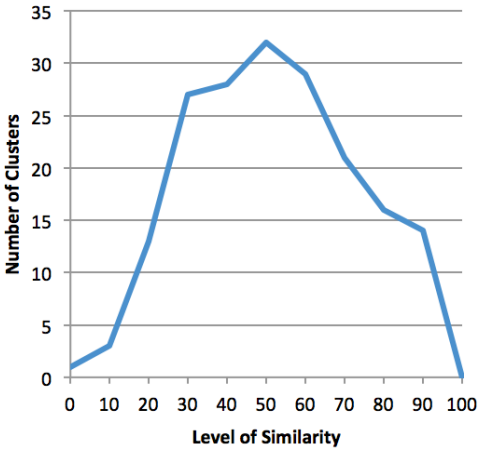

Fig. 2. No. of Cluster versus Level of Similarity

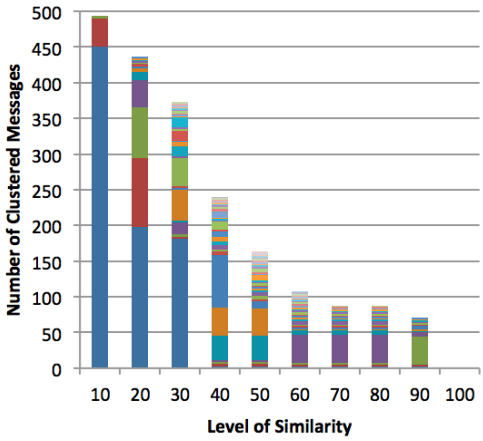

Fig. 3. No. of Clustered Messages versus Level of Similarity

Fig. 2 shows number of cluster (composed of two or more messages) versus level of textual similarity. It can be noticed that the number of cluster increases up to the similarity level reaches approximately 50%. After that, the number of cluster starts reducing. This happens because the clusters are fragmented in smaller pieces when the similarity level increases. When this value reaches approximately 50%, the clusters start splitting in clusters with one element that were not considered as themes.

Fig. 3 shows total number of clustered messages (composed of two or more messages) versus textual similarity level, completing the analysis of this operator. Thus, messages not grouped with other messages are not considered. It can be seen that the total number of messages in groups of two or more messages reduces when the similarity level increases. Besides, the number of clusters (represented by the colored bars) starts with a small number of clusters, reaches their maximum value approximately on 50% and, after, reduces this value when the similarity level increases.

Fig. 4 and Fig. 5 describe the results obtained by the operator based on temporal difference.

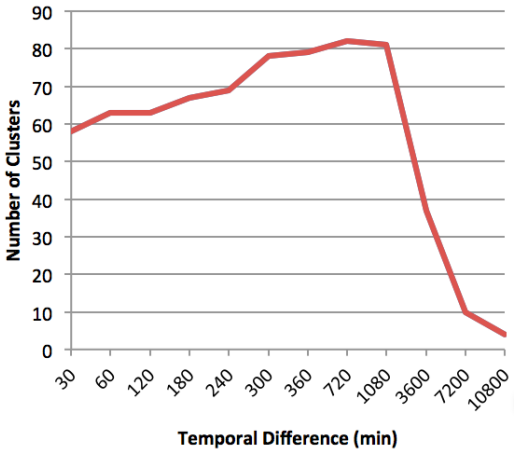

Fig. 4. No. of Cluster versus Temporal Difference

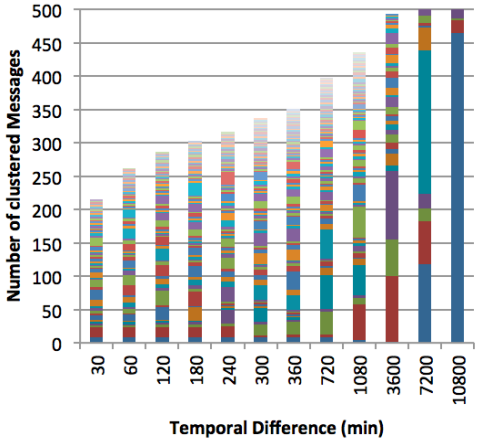

Fig. 5. No. of Clustered Messages versus Temporal Difference

Fig. 4 shows number of clusters (composed of two or more messages) versus temporal difference. It can be observed that the number of clusters increases up to the temporal difference reaches approximately 720 minutes. After that, the number of clusters starts reducing. This happens because the clusters are combined in bigger clusters when the temporal difference increases. Initially, clusters with two elements are produced more frequently. When the temporal difference reaches approximately 720 minutes, the clusters start combining more frequently in clusters with more than two elements, reducing the total number of clusters and, consequently, themes.

Fig. 5 shows total number of clustered messages (composed of two or more messages) versus temporal difference. It can be observed that the total number of messages in groups of two or more messages increases when the temporal difference increases. This behavior is the inverse of the operator based on textual similarity. The maximum number of clusters is reached when the temporal difference is about 720 minutes.

Fig. 6 and Fig. 7 describe the results obtained by the operator based on distance.

Fig. 6 shows number of cluster (composed of two or more messages) versus distance among the points of messages sending. It can be seen that the number of clusters increases up to the maximum near 50 meters. After, it reduces and increases twice: near 5 kilometers and 50 kilometers. After that, it reduces continuously. It can be inferred those three maximum points represent limits of cluster (and sub-clusters) of messages considering distance. 50 meters limit small groups, such as: people that provided security around stadiums, displacements. 5 kilometers limit the people that took care of major event places, such as: places of games, training, resting, etc. 50 kilometers correspond to the combination of groups in different cities

where the events happened. Thus, these different sizes of clusters represent the groups of entities existent in the operations.

Fig. 7 shows total number of clustered messages (composed of two or more messages) versus distance.

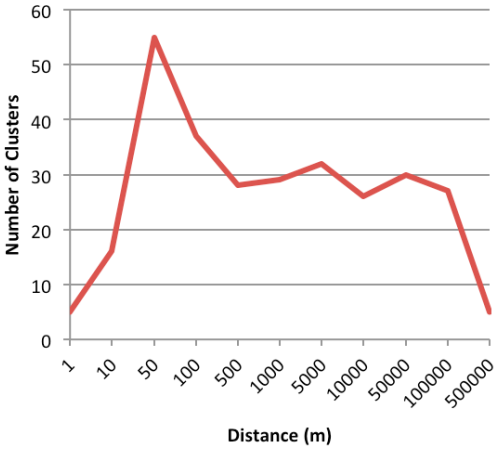

Fig. 6: No. of Cluster versus Distance

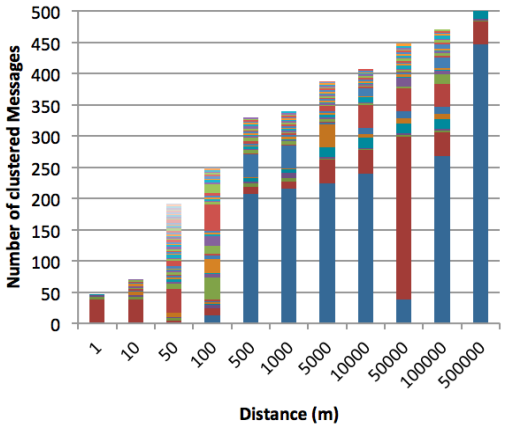

Fig. 7: No. of Clustered Messages versus Distance

It can be seen that the total number of messages in groups of two or more messages increases when the distance increases. As discussed previously the number of cluster (represented by the colored bars) varies according to the distance. The maximum number of cluster is reached when the distance is about 50 meters.

To set parameters of the operators used previously, it was used the concepts of Thematic Strength, Thematic Density and Maximum Thematic Clustering, given by the expressions (1), (2) and (3). We recommend that a calibration of the parameters values be done using a small subset of the messages to be grouped. In this paper the set of 500 messages initially used in the experiments were considered as a set of calibration for the operators. The parameters obtained were: 30% for textual similarity; 1080 minutes for temporal difference; and 50 kilometers for distance.

To set parameters of the operators used previously, it was used the concepts of Thematic Strength, Thematic Density and Maximum Thematic Clustering, given by the expressions (1), (2) and (3) applied to a small subset of the messages to be processed (set of calibration). In this paper, the set of 500 messages, used in the previous experiments, were considered as a set of calibration for the operators. The better values for the parameters, as demonstrated previously, were: 30% for textual similarity, 1080 minutes for temporal difference and 50 kilometers for distance. These values can be reused in different scenarios. However, to better calibrate the parameters values, it is recommended to use a small subset of the messages to be processed.

Fig. 8 shows the result of three operators combined using the parameters. Four sets of messages were used with: 500, 1000, 1500 and 2000 messages. The percentages of grouped messages were: 23% to 500 messages; 35% to 1000 messages; 42% to 1500 messages; and 47% to 2000 messages. Independently of the processed messages quantity, the number of clusters corresponded to approximately 10% of grouped messages. It is important to highlight that not all messages will form groups with other messages, remaining isolated. In our experiment, using 2000 messages, approximately 53% remained isolated. For these messages, the decision maker still needs to do a traditional evaluation, having to analyze these messages and correlate them manually. However, if it is possible to observe that increasing the number of messages, the percentage

of grouped messages (composed of two or more messages) is increased while the percentage of created clusters is kept, reducing the number of isolated messages. It happens because more and more messages under the same theme are inserted in the clusters that have already been created or are grouped with the isolated messages. This fact is very interesting, because it indicates that, increasing the number of processed messages, in a certain point, the creation of new clusters (themes) becomes less frequent and new messages are normally included in the existent clusters that will provide the themes for the decision maker. It is important to point out that the themes are built according to the parameters of the operators that can be defined by the decision maker.

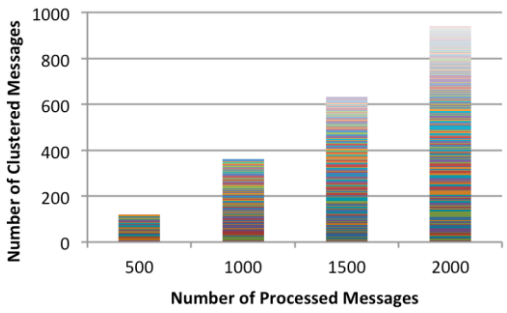

Fig. 8: No. of Clustered Messages versus No. of Processed Messages

Based on the experimental results, it is possible to see that instead of dealing with messages related to similar themes scrambled in a big bag of messages, the user can deal with groups containing related or similar messages. As demonstrated in the experiments, considering 2000 messages, the users have almost 50% of messages grouped in approximately 100 clusters. Thus, the theme switching caused by information associated with a different thematic group was reduced, facilitating the decision making process.

5. Conclusion and Future Works

This paper discusses a strategy for clustering textual messages using multi-criteria in a scenario of major events. The goal is to facilitate the decision making process once these messages would be grouped according to some criteria that may provide a proper contextualization for the messages. These message clusters, named themes, offer a better situational awareness for people involved in the operations that are executed in events. This way, a decision-maker can read the all messages related to a subject sequentially without having to change to another subject every time he read a different message. This strategy makes easier the decision process.

The proposed strategy uses an approach of multi-criteria clustering inspired in the 5W2H approach. To evaluate the strategy, it was used three features of the messages: temporal difference among the messages sending, distance among the messages senders and textual similarity. Each one of these attributes is used as a different operator. One operator acts as a filter for the next, therefore the order of the operators is also analyzed to optimize the global application of them.

Additionally, to set the parameters of the proposed operators, it is proposed two news concepts: Thematic Strength and Thematic Density that are applied in a combined way to calibrate a set of messages. This approach allows calibrating the parameters of the operators through the required features desirable for the cluster, customizing the operators in different scenarios.

The Strategy is applied to messages obtained from real operations executed in the 2014 FIFA World Cup. The results show the approach is very promising. The clusters of messages that can be produced may facilitate the decision-making process in future events, as well as analysis of past events that may help the organization of forthcoming events.

In future works, the parameters configuration should also consider the multi-criteria decision making method AHP to calibrate the weight of the concepts that are used in a combined way. Besides, we intend to apply the operators considering selectivity analysis.

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IJISPM

International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at www.sciencesphere.org/ijispm

Formal approach to modeling of modern information systems

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International Journal of
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ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
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B. Molnár, A. Benczúr and A. Béleczki, "Formal approach to modeling of modern information systems," *International Journal of Information Systems and Project Management*, vol. 4, no. 4, pp. 69-89, 2016.

International Journal of
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Abstract:
Most recently, the concept of business documents has started to play double role. On one hand, a business document (word processing text or calculation sheet) can be used as specification tool, on the other hand the business document is an immanent constituent of business processes, thereby essential component of business information systems. The recent tendency is that the majority of documents and their contents within business information systems remain in semi-structured format and a lesser part of documents is transformed into schemas of structured databases. In order to keep the emerging situation in hand, we suggest the creation (1) a *theoretical framework* for modeling business Information Systems and (2) a *design method* for practical application based on the theoretical model that provides the structuring principles. The modeling approach that focuses on *documents* and their interrelationships with business *processes* assists in perceiving the activities of modern information systems.

Keywords:
formal modeling; document centric process and data modeling; information system architecture; information systems modeling.

DOI: 10.12821/ijispm040404

Manuscript received: 20 January 2016
Manuscript accepted: 28 November 2017

1. Introduction

The current Business Information Systems shows new behavioral properties. Namely, the documents, unstructured and semi-structured data, have high relevance beside the structured data. One of the directions within management sciences is the service-orientation. Being the business processes of companies organized by the service-orientation pattern, consequently, the structure of functions within Information Systems follows the model of IT (Information Technology) services, independently from the applied technologies as either Web, REST, Micro Services or other appropriate technology that are based on Services.

These two trends – document and service centric approaches – are slowly modifying the requirements against the modeling methods that are intended to describe the behavior of IS [1], [3]. The documents, interactive documents and the emphasis on Web interfaces led to the concept of modern Information Systems.

In the core of IS there is a set of data that delivers the required information either to the business activities or to the information processes. During analysis, the question that is investigated is as to whether what information should be kept in the system. The data and their collections exist independently from business documents that may or may not related to decision processes. The modeling of Information Systems focused on document should adhere to established practices of data and information modeling. The model should be perceivable by users at high level. The approach for modeling and analysis should be semantically powerful in order to serve as a basic model and be understandable by users. The document-centric model is unlike data models but they are interdependent on each other. The document model tries to gather the results of business activities and the transformations in order to extend information within documents with new facts (Fig. 1).

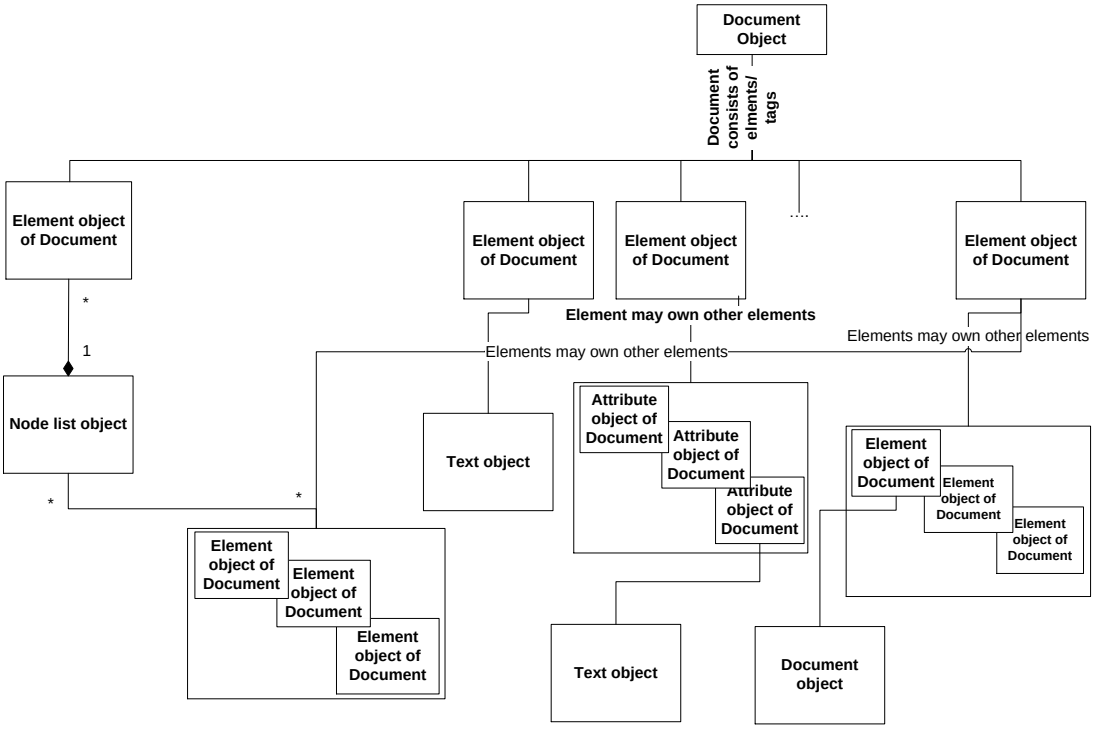

Fig. 1. Levels of collections related to documents.

The manipulation of documents happens through business processes; moreover, the document model mirrors the structure of organization and events (Fig. 2).

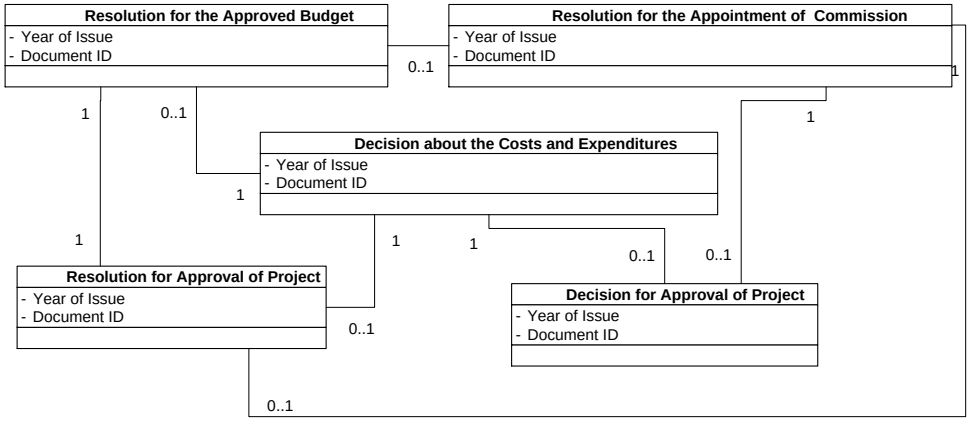

Fig. 2. Example of Class Diagram for Documents at "Document Conceptual Level" within a Case Study.

Within the data model, those alterations that change elements that are significant for business should be tracked, i.e. create new ones, transform existing ones, set up new dependencies or adjust existing relationships. The actor or role that performs the data conversion should be distinguishable during transformation processes; furthermore, the collection of data that are linked to documents and roles should be identifiable as well. In an E-government environment, a case study is planned and designed to verify and validate the results of proposed modeling approach with theoretical background.

In section 2 we present previous research reported in the literature. In section 3 we outline our method, making use of the previous approaches in a document centric approach. In section 4 it is presented the formal mathematical background. Section 5 presents the formalized document centric approach. Section 6 discusses the information architecture and documents. Finally, section 7 provides the summary and the conclusions.

2. Literature Review

Joeris [1] proposed a document based approach for modeling control and data flow for business activities and data interchange among them. Wewers et al. [4] presented a system that supports a framework for inter-organizational, document oriented workflow.

To help the perception of the complex behavior of IS the enterprise architecture approaches offer support, namely the Zachman ontology and TOGAF, both was developed for IS [5], [6], [7].

The artifact-centric business process model uses three basic concepts [8], [9]: artifact classes; tasks; and business rules. The tasks handle the artifacts, the business rules govern which tasks should be triggered and which artifacts will be manipulated [10], [11]. SOA (Service Oriented Architecture) and the related technologies as XML (Extensible Markup Language), SOAP (Simple Object Access Protocol), WSDL (Web Service Description Language) and UDDI (Universal Description, Discovery, and Integration,) permits that services to be available through the Web [12]. The Web documents typically in XML format can be considered the central notion of Information Systems on the Web. There are analysis and design problems that should be improved. Emphasizing the problems with IT rather than business processes hinders the modeling and abstraction of stable and reliable IS [32]. The approaches as *Service Oriented*

Computing (SOC), and *Cloud Computing* concentrates on services as a standardized and general information exchange interface towards users. There are different input data format for interchange between services [13], [14], [15]: (1) HTML pages; (2) SOAP messages (XML); (3) unstructured documents (XML). Unstructured documents may contain text, images, and other binary data, only the metadata may have formalized in XML using tags. Set of documents without uniform XLST (Extensible Stylesheet Language Transformations), DTD (Document Type Definition) or any other "style-sheets", we consider them as set of unstructured files since there is no general principle that can be enforced on each single document. Unstructured documents are the typical office documents without pre-defined style-sheets for tagging as the meta-data of documents may be tagged but the textual information is not. SOAP messages as XML tagged data can be regarded as structured but it may transport unstructured data.

XML documents can be considered as application-relevant "things", i.e. they can be perceived as new data objects to be stored and managed by a DBMS. This type of XML documents, in this sense, is document-centric, since their meaning depends on the document as a whole. The XML structure is more irregular in contrast to structured data, and data contained in them are heterogeneous. Chidlovskii [14], [16] provides a formal grammatical description of XML.

The alignment and fitting between business processes and organization can be analyzed on the base of ontologies and semantic approaches [17], [18]. The e-commerce, e-banking, e-tourism, Web-based Enterprise Resource Systems can be considered as typical Information Systems on the WEB.

To combine the previously referred approaches to model modern Information Systems, there are various proposals [2], [3], [19]. Blokdijk's assembly of Information System Models [20] offers structuring principles; moreover, the axiomatic design approach [21] can be employed for the Information Systems provides clues for both theoretic and practical modeling point of view. The concept of generalized hypergraph [22] seems to be a proper mathematical formalism that fits to unifying all viewpoints, perspectives, artifacts and modeling elements.

3. Document centric approach

On modeling IS, the data model plays a central role traditionally (Fig. 3). To harmonize the traditional data model with document model, we generalize the concept of data models.

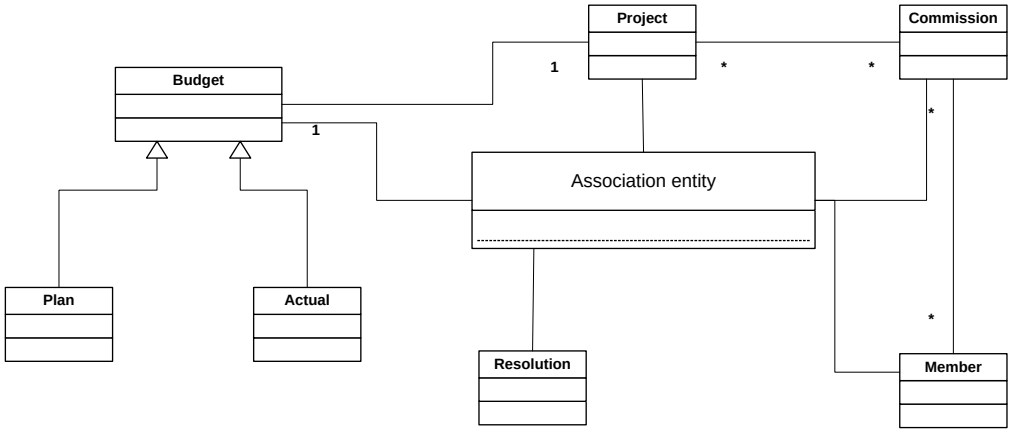

Fig. 3. Class Diagram for Documents Class Diagram for Documents at "Data Model Conceptual Level" within a Case Study.

In this representation, data models consist of **collections** (of data) so that each collection has a designation. The collections are *sets of data* or multi-set (bag) of data or *data types* with well-defined properties and structure; the most

typical representation of *data model* is either relational data model or object-relational data model (However, there are several concurrent representation and implementation technology). The extension of data types as occurrences compose subsets of dataset that can be deduced from document structures. The *collections* include identified data that are significant as their modifications over time are linked to documents (but that is not the same as the logging of database activities, in opposite it depicts the impact of activities related to document manipulation).

3.1 The Document-centric Modeling

The proposed approach is unlike to the traditional database modeling methods and the recent fashionable artifact-centered approaches. The document-centric modeling should exist with a strong *correspondence* to the Enterprise Architecture of the given organization, with a definite emphasis on the business processes. The structure of documents within an organization can be mapped onto the organigram and structure of business processes through homomorphism (Fig. 4).

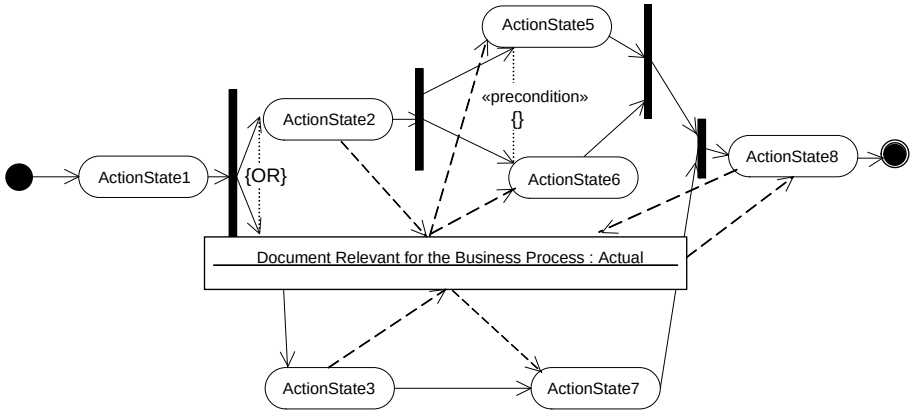

Fig. 4. Business Process Model - A Case.

The representation of both business processes and organization structures appear within Business Process Owner/Manager perspective of Enterprise Architecture [7]. The needs for flexible IS lead to tendencies that can be formulated as a *customer-centric* paradigm. The customer-centric paradigm can be partly captured by a highly flexible document structure at the User Interface level. The documents should be adaptable to changes both in their structure and in their related content. There is correlation between the software architecture and the project structure of the software development [23]. The document model should mirror the life cycle of documents, the manipulation, the events, and effects by business processes. The *modifications* that affect the data included in *documents* should be traced, i.e. creating, modifying data items, establishing new relationship; the *precedence* analyses are an available option for tracking the impacts [20].

The chain of events and processes can be monitored through *roles*/*actors* and their *handling* of identifiable data items within documents. The human roles stimulate data processing activities that affects documents, consequently the data items as well that are included in the documents. The *document-subdocument* structure (Fig. 1, Fig. 2, Fig. 3) is able to represent both the organization and the information model at the same time. Whilst the data model is not structured as set of *sub-data models* instead it displays rather uniform configuration [20] (Fig. 5).

Blokdijk's model offers a structuring approach for perceiving Information Systems. The model's major components are (Fig. 5): (1) **organizational model**; (2) **information model**; (3) **data model**; (4) **process model**. The process model provides the composition of business *activities* and it is strongly coupled to the *control structure*. However, the data

model is not an exact representation of the organization structure. For the reason that *patterns of data model* reflect the relevant facts about the organization but it does not map the *organization structures*. The document and data model requires a common representational method in which the services, and functions of documents, the coupled business activities can be depicted in a uniform manner. Furthermore, the interrelationships between the data and document model can be shown as much the same way as possible. There is logic of inheritance to identify data items within documents. Within the document chain, data elements are inherited from the previous element of documents.

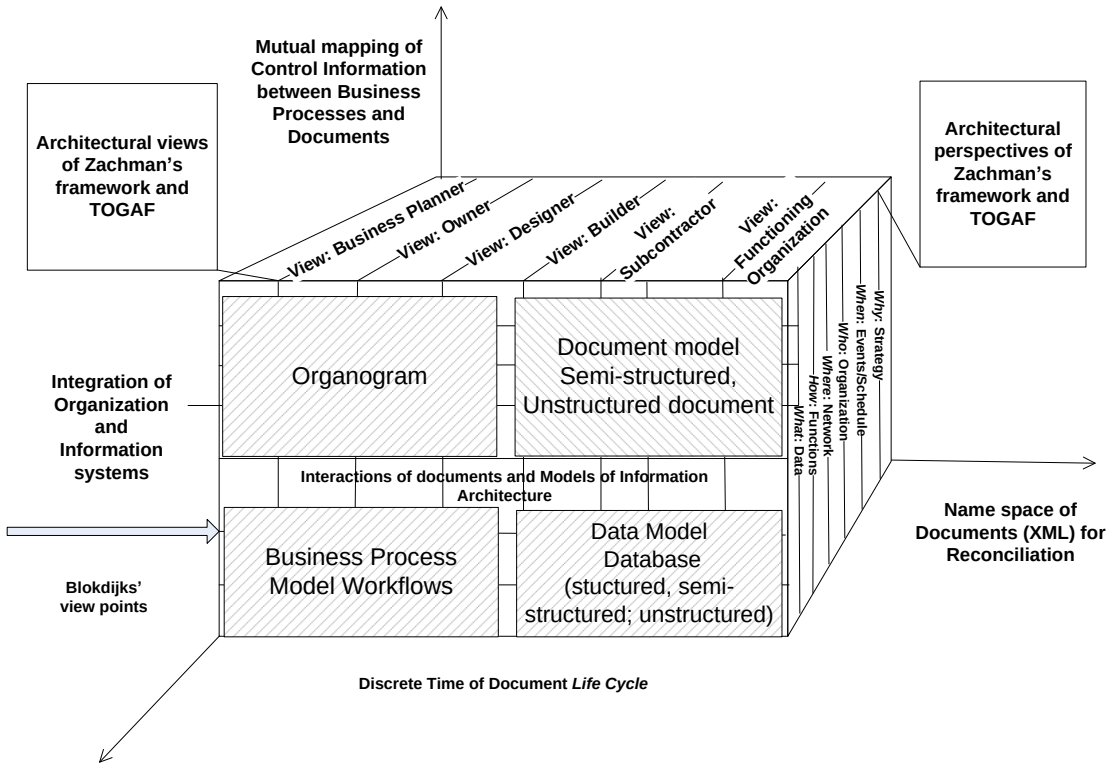

Fig. 5. A Multi-dimensional model for interaction of Information Systems and Documents.

3.2 Types of Documents

The document model is composed of **document types**. The types of documents designate the state of their variables. We define the concept of ***binding*** by this way: a free field within a document; or a free variable is set for a value, i.e. valuated. The status and the type of documents can be inferred from the bindings; i.e. how many variables are already set to specific values. A **generic document** is a hierarchy of classes of documents. Finalizing or finishing a document instance within a hierarchy of a generic documents leads to that all free variables/fields are set to a certain value step-by-step. The finalization of documents ensues from overarching business processes that can be linked to the flow of documents. The documents flow can be represented by data flow, Event Process Chain or Business Process Modeling Notation.

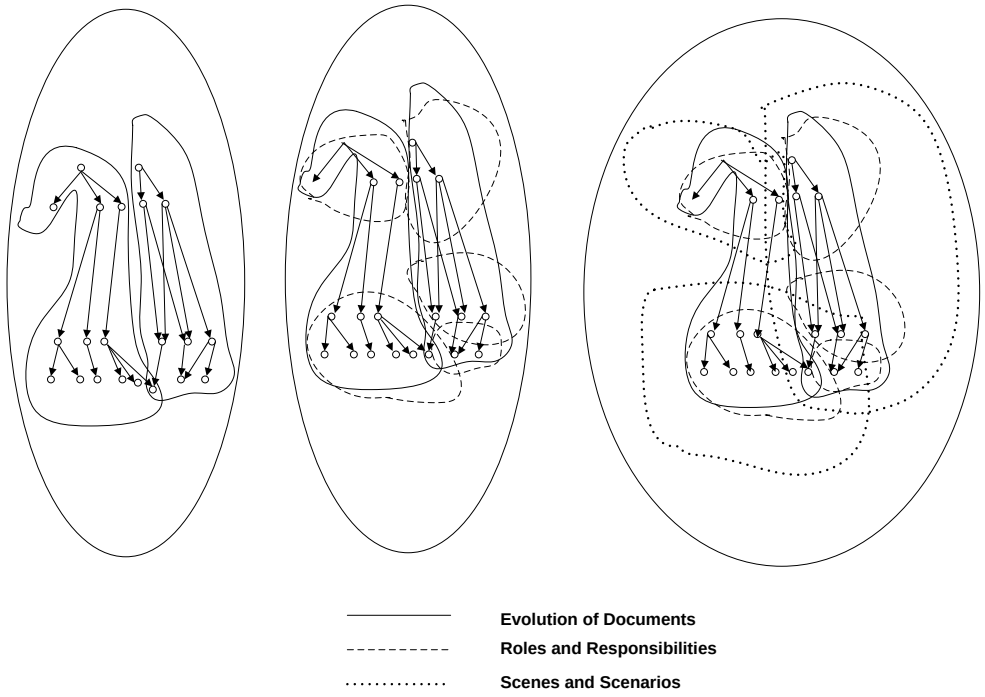

Fig. 6. Representation the Life of Documents by Hypergraph.

The **free-documents** – like free tuples from tableau queries – can be perceived as documents that contain unbounded variables. As the document evolves more and more variables valuated, finally the documents achieve a state in that the documents cannot contain any unbounded variables. We can call documents in this state as ground-documents. The parts of documents can be regarded a finalized one from the viewpoint of one of the system roles; however, the parts of the documents may still contain some free variables that require further processing by some other system roles. The external information is supplied by system roles out of the organization. i.e. outside of IS, the steps of the fulfillment process and their sequences are defined by business rules of the organization Valuation of a free variable needs external information what is supplied by system roles out of the organization, i.e. outside of Information Systems, the steps of the fulfillment process and their sequences are defined by business rules of the organization. For that reason, we make differences between the states of *finalized* and *ground-document*. However, the responsibility for recognizing the proper data items relates to the currently valid *system role* (human or business process). The previously published figure (see [2]) (Fig. 5) has been extended to designate the *name space* of document's DBMS, emphasize the mutual mapping between the information related to *control* and *business processes*, and to pinpoint to set of models that play a crucial role in integration of *enterprises* and *Information Systems*.

A finalized document may contain free-variables and/or error signaling variables /fields that designate the necessity for further processing by some certain roles. The defect resolution of documents happens typically by organizational roles, i.e. outside of the automated Information Systems. In the case of algorithmic approach for error handling, the further document processing requires an intensional treatment, and usage of intensional documents, i.e. generate document instances based on business rules that are fulfilled by the automated Information Systems to create extensional occurrences. A stable state of an instance of an overarching business process within an IS can be achieved in the case if all documents that were involved in it are already ground-documents. The document handling finally results in ground-documents, ground sub-documents and assembled documents through several stages of development of to-be-finalized documents. The initial state is an uppermost documents and derived (intensional) documents. The intensional

documents may contain free variables at meta-data and data level at the same time. On finishing their processing, the ground-documents build up a network (Fig. 6). To establish interdependencies among ground-documents may require some extra information. The supplemental information may assist to finish building-up the network of documents.

3.3 Representation of Documents

The current standards for describing the structure of documents are the XML, DOM (Document Object Model), JSON [15], [31]. The conceptual data model is either represented by entity-relationship or object-oriented modeling methods. The interdependency between document model and data model can be represented by RDF.

To support enterprise architecture, the recent IT architectures (SOA, REST, etc.) offer procedures as orchestration and choreography to create complex services along with documents. The documents may belong to various categories as generic, intensional, to-be-finalized, and ground-document type. The architectures provide the opportunity to create protective, security and safety mechanisms [5], [24].

The document handling finally results in ground-documents, ground sub-documents and assembled documents through several stages of development of to-be-finalized documents. The initial state is an uppermost documents and derived (intensional) documents. The intensional documents may contain free variables at meta-data and data level at the same time. On finishing their processing, the ground-documents build up a network. To establish interdependencies among ground-documents may require some extra information. The supplemental information may assist to finish building-up the network of documents.

3.4 The proposed document model

A database-centric IS model that is based on an information theory approach [25] outlines a framework that describes the input, output and query processing. Fig. 7 contains the IS model indicated by the dashed line; the previously published version [2] was enhanced to express that the source code data outside of the system and the code generated by the information system towards destination are communicated through a *crust consisting of documents*. In computerized systems, interactive documents and Web services become visible on the source and the output side. Free documents appear at the *interface/façade* level. The system roles (either human or automated system) perform variable valuation, or binding at each single variable through simple tasks. The business activities consist of tasks; a task can be composed of elementary tasks. An elementary task can be coupled to specific variables and its manipulation. The end-users who typically use information can retrieve data through documents, e.g. querying and fetching data from database and then processing the obtained responses.

The two sides of the model, the input and potential output data are separated by the document model in the Fig. 7. Although the various possible states and instances of document types integrates both sides at the same time. The two sides show the same behavior but provide different services. The twofold behavior is actually either querying or alteration like.

In front of data model and its manifestation in the form of a database system, a new, document model should be placed in. Beside the logical formulation of data retrieval and modification, the model should contain the description for sequences of interaction among documents; moreover, they should deal with collection of documents.

We can make difference between documents as being static or dynamic. The structure of a dynamic document may change as the response that is triggered by the system or system roles indicate it. The response may create instances of a general dynamic document that results in a sequence of free documents. The free documents are gradually converted into ground-documents starting from generic ones through intensional ones to be finalized and ground-documents. The ground-documents do not include any free variables thereby the names of variables in the ground-documents can be placed into the name-space of database.

The system of documents – generic, intensional, free-documents, to-be-finalized and ground-documents – can be perceived as a meta-database. This meta-database encloses not only static structures, but it includes active component as well that can be realized by web services. The *active component* incorporates the potential *program code* for interactions among the system roles, documents etc. The active components encapsulate the codes for database management too. The above-mentioned techniques can be integrated into a unified framework (Fig. 3, Fig. 4). Although, there is a lack for a comprehensive and not too complex scheme that combines all elements required for modeling Information Systems from a document-centric viewpoint and it is computable. Our proposal takes a step into the direction that both theoretic modeling and engineering viewpoint can be vindicated in a unified approach. The hypergraph as an appropriate mathematical tool may serve as a unifying approach to reconcile the before-mentioned heterogeneous model into a unified schema.

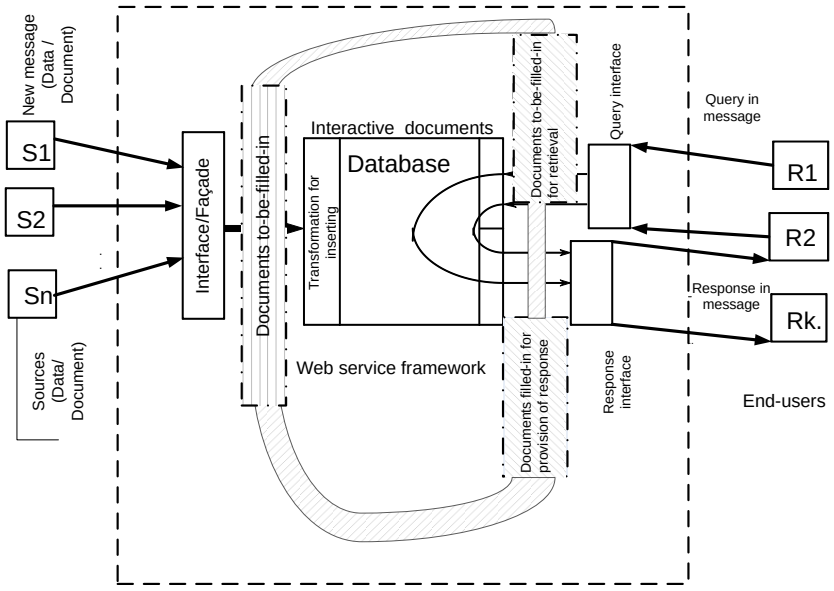

Fig. 7. Information Systems' model in a document-centric approach.

4. Formal mathematical background

Hypergraphs. As we have outlined previously, the problem to be solved can be described as a set of complex, heterogeneous relationships. The basic components that appear as constituent participate sometimes in hierarchical, sometimes rather network-like relationships that are different to each other. The hypergraphs as mathematical structure seems to be apt to representing the interrelationships among the models, views, viewpoints, perspectives, and the overarching documents and business processes [7].
We start with the basic definitions of hypergraphs in order to employ for depicting the before-mentioned complex relationships.

Definition 1. A *hypergraph H* is a pair *(V, E)* of a finite set $V = \{v_1,..., v_n\}$ and a set *E* of nonempty subsets of *V*. The elements of *V* are called vertices; the elements of *E* are called edges [22].

Definition 2. *Generalized* or extended hypergraph. The notion of hypergraph may be extended so that the hyperedges can be represented – in certain cases – as vertices, i.e. a hyperedge *e* may consist of both vertices and hyperedges as well. The hyperedges that are contained within the hyperedge *e* should be different from *e* [22].

The hypergraphs as a tool for describing Information Systems from various viewpoints yields a formal method to analyze the system, and to check the conformance, compliance and consistency of the set of models. The representation created by the above-mentioned way can be leveraged for design and operational purposes as well. Considering a document model, a particular document type hierarchy can be perceived as a "hierarchy" of hyperedges. The free variables or placeholders to be filled-in may occur as ultimate vertices within hyperedges that represents the instance of extension of particular document type. In a document subpart hierarchy, a specific subpart of document may be denoted by a vertex within a particular hyperedge that describes this document that contains the subpart, although that subpart as a vertex may include a document type hierarchy that can be depicted by a hyperedge.

Definition 3. A *directed hypergraph* is an ordered pair

$$\vec{H} = \left(V; \vec{E} = \{\vec{e}_i : i \in I\}\right) \quad (1)$$

Where V is a finite *set of vertices* end $\vec{E}$ is a set of *hyperarcs (directed hyperedge)* with finite index set I. Every *hyperarc* $\vec{\mathbf{e}}_\mathbf{i}$ can be perceived as an ordered pair

$$\vec{e}_i = \left(\vec{e}_i^{+} = \left(e_i^{+}, i\right); \vec{e}_i^{-} = \left(i, e_i^{-}\right)\right) \quad (2)$$

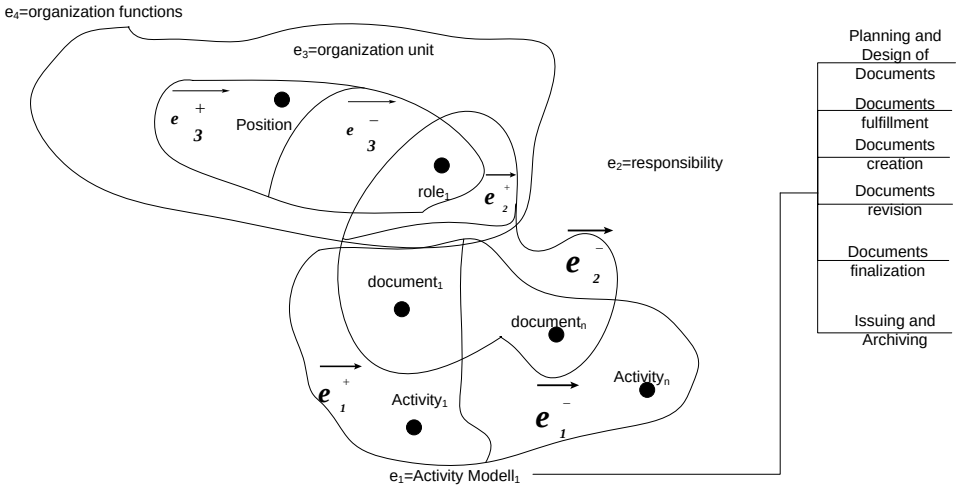

Fig. 8. Example for Directed Hypergraph Representing a Sample of Essential Relationships.

Where $e_i^{+} \subseteq V$ is the set of vertices of $\vec{e}_i^{+}$ and $e_i^{-} \subseteq V$ is the set of vertices $\vec{e}_i^{-}$. The elements of $\vec{e}_i^{+}$ (hyperedges and/or vertices) are called *tail* of $\vec{\mathbf{e}}_\mathbf{i}$, while elements of $\vec{e}_i^{-}$ are called *head* [22]. We may use as shorthand notation for ordered pairs, e.g. a vertex and a directed hyperedge as ordered pair $<v_i, e_j>$.

The underlying graph representation is based on the hypergraphs and directed hypergraphs. The potential implementations of hypergraphs in a hypergraph database make allowance for linking attributes to vertices, even more to hyperedges. The target domain, namely documents and model of Information Systems within organizations, contains complex n-ary relationships. The hypergraph provides the opportunity to depict recursive construction, to describe

logical relations, to store compound structures along with their values [26], [27], [28]. As an illustration of the basic concepts of directed hypergraph, an example can be seen in Fig. 8. that makes sense of the representation for the domain by hypergraph. The essential characteristics is that vertices contain composite constituents that are themselves may be graphs; generalized hyperedge may contain other hyperedges but not itself and vertices.

Definition 4. *Architecture Describing Hypergraph* is a generalized hypergraph with undirected and directed hyperedges. It can be designated as a tuple $\langle V, A, E, E_U, E_D, Attr \rangle$:

- $\boldsymbol{V}$ is the set of *vertices*;
- $\boldsymbol{A}$ is the set of arcs, i.e. directed edges, an arc is an ordered pair $\langle i, j \rangle$, where $i, j \in V$;
- $\boldsymbol{E}$ is the set of hyperedges;
- $\boldsymbol{E}_U$ is the set of the *undirected* hyperedges, because of the properties of generalized hypergraphs, a hyperedge *e* is
  - either $e \neq \varnothing, e \subseteq V$, (*basic hyperedge*),
  - or a *bag* of hyperedges;
- $\boldsymbol{E}_U$ is divided up at a meta-level into partitions:
  - $\boldsymbol{E}_C$ consists of the *configuration hyperedges*. Each $h_i \in \boldsymbol{E}_C$ is a simple hyperedge, i.e. containing only vertices, not complex structures and other hyperedges. All $h_i \in \boldsymbol{E}_C$ can be labeled unambiguously. The configuration hyperedges manifests the structure of "things", the vertices within a hyperedge are the properties of the specific "thing". The properties can be perceived as variables or attributes (depending on the context) that can be valuated thereby they linked to an individual value (vertex in *D* (see **Definition 6**.)) or a set of values, e.g. to a grouping hyperedge;
  - $\boldsymbol{E}_E$ is composed of the e*xtensional hyperedges*. The extensional hyperedges can represent collections of data, the instances of *generic documents*. For example, the collections of data can be built up by tuples of data items, the instances of documents can be composed of certain bags of free variables that are contained in the particular documents' object structure. In these examples, the distinct elements, the vertices of these hyperedges can be considered as constituents of extensional hyperedges;
  - $\boldsymbol{E}_I$ comprises the *intensional hyperedges*. The intensional hyperedges show the logical and rule-based interrelationships among the vertices (models within the architecture), moreover configuration hyperedges;
  - $\boldsymbol{E}_G$ is made up of *grouping hyperedges* that embody various structuring principles on components, as e.g. view, viewpoint and perspectives etc. in architecture describing approaches; they symbolize interrelationships between certain models and pieces or parts of documents as e.g. business activity models, documents and responsibilities of roles within an organization unit. The hyperedge $h \in \boldsymbol{E}_G$ can be utilized for sorting the vertices (representing either documents or models) into organizational-related, document-related and activity related relationships.
- $\boldsymbol{E}_D$ is a set of *hyperarcs*, i.e. *directed hyperedges;* the hyperarc $\vec{e}_i \in \boldsymbol{E}_D$ can be as it follows (see **Definition 3**):
  - $\vec{e}_i =< v_j, \vec{h} >= \left(\overrightarrow{e_i^+} = (e_i^+ = v_j, i); \overrightarrow{e_i^-} = (i, e_i^- = h) \right)$ where $v_j \in V$, and $\vec{h} \in \boldsymbol{E}_G$;
  - $\vec{e}_i =< v_j, \vec{h} >= \left(\overrightarrow{e_i^+} = (e_i^+ = v_j, i); \overrightarrow{e_i^-} = (i, e_i^- = h) \right)$ where $v_j \in V$, and $\vec{h} \in \boldsymbol{E}_C$;
  - $\vec{e}_i =< v_j, \vec{h} >= \left(\overrightarrow{e_i^+} = (e_i^+ = v_j, i); \overrightarrow{e_i^-} = (i, e_i^- = h) \right)$ where $v_j \in V$, and $\vec{h} \in \boldsymbol{E}_E$;

– there does not exist two hyperarcs $\vec{e_i} =< v_j, \vec{h} >$ and $\vec{e_k} =< v_l, \vec{h'} >$ that either $\vec{h}, \vec{h'} \in \boldsymbol{E}_C$ or $\vec{h}, \vec{h'} \in \boldsymbol{E}_E$, i.e. every vertex $v_j \in V$ is linked, at most, to one configuration hyperedge ($\boldsymbol{E}_C$) and at most to one extensional hyperedge ($\boldsymbol{E}_E$). These conditions can be interpreted the following way: a vertex may belong to a configuration structure (either document or model), or it may belong to an extension that represents the instantiation of either a document or a model.

Description Logics. One of the most common approaches of formalization is the use of some mathematical-logical language. The Description Logics belong to mathematical logics, and their purpose is formal knowledge representation [29]. Compared to propositional calculus (or propositional logic), the expressiveness of description logic is higher, and it has a more efficient algorithm for the decision problem than the first-order predicate logic. On the other hand, the network like knowledge representation - where the elements of the network are vertices and links are relationships as e.g. the semantic net- work - can be related to the theory of hypergraphs. In both case, vertices can be used to define concepts, and links can be used to characterize the relationships among them. Bearing this in mind, it is obvious to apply description logic on a system based on the mathematical background of hypergraphs.

The knowledge representation systems based on Description Logics contains two main components: the TBox, and the ABox. The TBox introduces the terminology, i.e., the basic concepts, which denote sets of individuals (atomic and complex), and roles, which define binary relations between individuals. These are forming the vocabulary of an application domain. The ABox contains assertions among named individuals and the vocabulary.

There are many variations of the Description Logics (originated from the varieties of description languages) and there is an informal convention, where their name indicates which operators are allowed. For example, a basic logical language is the Attributive Language – AL, which allows: atomic negation; concept intersection; limited existential quantification; and universal restriction. This can be extended with other operators, as e.g. concept union (U), full existential qualification (E), cardinality restriction (N), or complex concept negation (C). The description language lays the groundwork for the description logic [29].

To illustrate Description Logic in document centric environment, we show some examples below:

- With ***Parameter*** $\sqsubseteq$ (***Free Variable*** $\sqcup$ ***Bound Variable***) notation we describe, that a document parameter can be either free or bound variable.
- ***Parameter*** $\sqsubseteq \exists$ ***is_part_of.*** (***Document Fragment***) means, that a document fragment consists of parameters, and ***Document Fragment***. $\exists$ ***is_derived.*** (***Free Document***) means, that the document fragments are derived from unprocessed free documents.
- ***State.P*** $\sqsubseteq \exists$ ***has_successor.*** (***Action State.Q***) means, that *Q* action-state follows the *P* state.
- The following line describe, that an action-state needs free variables to work with: ***Action State*** $\sqsubseteq \exists$ ***has_free_variables*** (***Document***); ***has_free_variables*** $\equiv \geq 1$ ***is_free_variable*** $\sqcap$ ***is_free_parameter***.***Parameter***

The output of a well-designed formalization of an information system that is depicted by description logics and – at the same time – represented by a hypergraph exists in machine-readable format thereby this formalization has the opportunity to use various frameworks and tools to evaluate the model. With this it is possible to effectively optimize the information system even in the early model-development phase.

5. Formalized Document Centric Approach

In the case of a particular organization, we can imagine that there is a comprehensive document that is a representation, in conceptual sense, all potential documents. This overarching document is composed of generic document types. Generic document types are hierarchical structures that can be described by configuration hyperedges that reflect the composition of documents. There are hierarchical relations among the members of a generic document. The hierarchical

relationships can be described by configuration hyperedges; the instances of a generic document member can be perceived as extensions and can be represented by extensional hyperedges.
There is an approach that recognizes documents as "a unit of business information exchanged in a business transaction'', i.e. as a medium for message exchange between business partners [30]. Business can be perceived as a general notion in this context, namely the entirety of commercial and non-profit companies, public services and public administration as branches of economy and societal life use documents, and decisively electronic documents. Because of proliferation of computer literacy, the users' requirements stated more frequently in the form of documents as e.g. word processors, calculation tables, etc. There are several sectors of IT applications where documents in various conceptual forms play important roles. A document can be described technically by *XML* schema, and additional or contextual information may be supplied by *DTD*, *XLink*, *XInclude*, *XSL/XSLT*. The Document Object Model (*DOM*) yields an object-centric representation for documents [31].

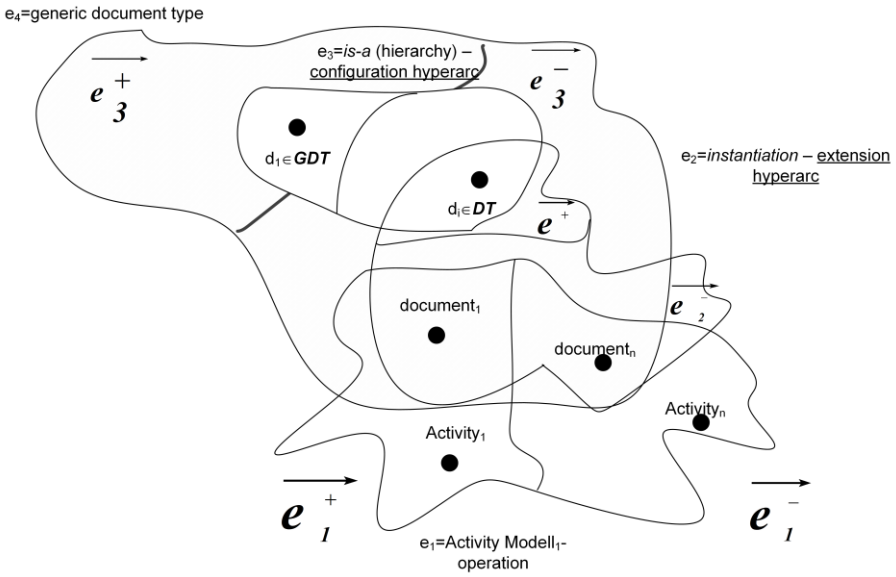

Fig. 9. Interrelationships of Documents Represented by Hyperedges.

In our approach, we emphasize the existence of overarching document as a projection of the embracing organization. The parts and subparts of documents and document hierarchies are the subject of operation that initiated by business processes, activities and tasks. The responsibilities for executing the operation linked to roles within the organization. The documents utilize the underlying collections of data and thereby the serve as media to facilitate the data flow within organization.

A generic document type ***GDT*** is a hierarchy of document types ***DTH***. The elements of ***DTH*** can belong to a configuration hyperedge e_{Ci} as vertices. The generalized hypergraphs allow that the vertices may appear as complex structures, as hyperedges. Therefore, a vertex can be a hyperedge that itself a configuration hyperedge that contains a hierarchy of document types. Thereby, the representation makes possible for a recursive definition of document types and gathering them into a generic document type.

The direction of the hyperarc shows whether a document plays the *input* or *output* role in a particular context (Fig. 9). The definition of the hyperarc is given above (see formula (2)) permits the differentiation between the *information*

represented by the *head* and *tail* of a hyperarc, and the *information* that are represented in the form of vertices that are contained within the heads and the tails [22].

Definition 5. The *Document Subhypergraph* consists of:

- A finite set of documents that are represented by vertices ***DOC***= {doc_1, ..., doc_n};
  - The documents contain variables, the variables belong to certain attribute type of Attr= {T_1, …, Tn} that consist of the attribute types;
  - The finite set of domains is ***DOMSET***= {D_1....D_k} that contains the domain of each single type, T_i;
- The relationship between a generic document type ***GDT*** hierarchy and its constituents document types belonging to a ***DTH*** can be described by hyperarcs representing *is-a* relationships; the hierarchy is a mapping of super type-subtype relationships between document types. The relationships can be deduced from the variables, their attributes and the types of attributes.
- The relationship between a document doc_i and a document type ***DT*** can be described by a hyperarc representing the *instance-of* relationship.

The instances of a document type can be linked to the particular document type through an extension hyperedge. The document instance contains typically free-variables; thus these document instances can be called as free-documents. Free documents as document instances and extensions of document types are the subject of manipulation by business processes. A value for a variable can be a new fact or a new free-document of appropriate types. The concept of generic document type offers possibilities for derivation of new document types from other document types that can be regarded as templates. The derivation rules can be formalized by logical statement that may create either a slightly different document type according to the structure of documents and then an instance of it or operate during the lifecycle of an instance of the document types. A document type may contain business rules in the form of predicates, data retrieving and calculation rules. Both cases demand operators that create documents through intension, i.e. logical inferences. To depict these relationships, the intensional hyperedges can be used. The common characteristics in both cases is that neither the creation of a new document type and its instance nor a document instance with more valuated variables require human interaction through business processes and activities, they should be fully automated. A fully automated business process may be described in BPEL (Business Process Execution Language), but the full automation raises several issues that should be handled if there is no direct human, external interaction at a certain point of time during the execution. During their lifecycles, the free variables of free-documents are valuated, i.e. a variable is set for a value. A document is modified during processing by business activities in the context of actual responsibilities (organization units, roles, actors). A document may achieve the finalized status but the policy and rules of organizations permits further processing in some cases. When a document is in such a status that it cannot be modified in any case then this document can be called ground document. This situation is typical in public administration as it manufactures document during the business process and ships a ground document to the customer. The time is important factor of life cycle of documents. The interplay between business activities and documents moves through the time dimension.

6. Information Architecture and Documents

As we have seen previously, the documents are strongly coupled to their embracing organization context, even defining the appropriate document types request referencing to the related activities. Beside the essential documents, IS can be described by various models that are ordered into a reasonable structure by Enterprise Architecture approach. To describe the document manipulation requires operators so that we can extend the definition:

Definition 6. *Architecture Describing Hypergraph* is a generalized hypergraph that can be extended by some functions and operations:

- $label_{node} : V \to L_{node}$; where L is a set of labels, it is a vertex labeling function;
- $label_{edge} : E \to L_{edge}$; where L is a set of labels, it is an edge labeling function;
- $source_E : E \to V;$
- $target_E : E \to V;$ these functions return the source and target vertices of an edge *E;*
- $attr : Attr \to V$; attribute assignment function;
- $source_{Attr} : Attr \to V;$ The vertex that owns the attribute is returned;
- $target_{Attr} : Attr \to D;$ The *data values* of attributes are yielded; *D* represents the set of data.
- *D* can be grasped (efficiency of the representation is left out of the investigation) again as vertices within the hypergraph and it can be interpreted as *variables*.
- Over *D* as a set of variables, set of operations (*OP*) can be defined that can be used to describe constraints and rules within formulas.

Table 1. Representation of Information Systems by Hypergraph.

Concept of Information System Theory	**Representation of concept in the domain of hypergraph theory**
Information System	A result of a system-development exercise that created a set of design artifacts. The set of elements and *relationships* among them can be represented as vertices and edges within the graph. We can map the model elements to a *hypergraph* that consists of vertices and hyperedges.
Node/vertex in a hypergraph	Each vertex corresponds to an element within an Information Systems, e.g. *documents*, elements of documents (constituting a tree structure), business processes, workflows, layers of workflows, web services, networks of web services, etc. The documents may represent one of the aspects for the information flow both inwards and outwards.
Edge in a hypergraph	*Edge* is a specific *hyperedge* with cardinality equal to two. Edge denotes binary relationships between two vertices, as e.g. free documents is processed by a certain Web service, a generic document is the ancestor of an intensional documents, a free-document resulted in a ground-document after binding, valuating of variables, etc.
Hyperedge	A hyperedge represents a relationship among a subset of vertices as e.g. Web services belonging to a specific workflow, business process containing workflows, etc.
System graph	A hypergraph that includes a disjoint vertex for modeling the environment of the system, plus all the vertices and hyperedges of the WIS.
Sub-system	A subset of vertices and their incident hyperedges. A vertex is *incident* to a hyperedge if the hyperedge contains the vertex. A sub-system may be composed of documents, Web services and related entities out of data model, etc.
Interconnecting sub-systems hyperedges graph of the generalized hypergraph	A graph consisting of all the vertices in a sub-system and all hyperedges connecting together subsystems.

Beside the documents, the various models that follow some architectural description and system design style are essential constituents of IS (Table 1). The hypergraph representation gives the chance to represent the complex interactions and interrelationships among models and documents that drives the behavior of systems. The object-oriented paradigm and UML visual language proliferated as specification language for models. For the uniform discussion, we presume that all of the models in line with the UML modeling and visual language standard, moreover their representations pursue the object-oriented, meta-data structure codified into standard. The models' descriptions appear usually in semi-structured document forms as XML and/or JSON that offers a chance for uniform treatment of documents and models of Information Systems. As structuring principal for models of IS, we can use Zachman ontology and/or TOGAF (Fig. 5) [6], [7]. A model is a description of specific properties of an IS and it represents an

artifact of views, viewpoints and perspectives [7]; or it can be perceived as an architectural building block of the system [6]. The set of relations among models and the internal structure of models plays essential role.

The models can be arranged into three meta-groups namely *organization*, *documents* and *activities* related models. For modeling, the relationships and interactions among these three meta-groups and the underlying collections of data are significant. The models, documents and concepts of IS and a vertex representing the external environment compose a hypergraph that embraces all important parts of the application domain that may be called as *System Hypergraph*. The specific models can be considered as complex structures, and at the first cut, they can be represented as vertices containing the information about the model, possibly in the form of a hypergraph, because of generalized hypergraph permits to set up a hierarchy. We may structure the overarching hypergraph several sub-hypergraphs as documents, organization and its units, underlying data collections, business processes and their constituents.

We can exploit the flexibility of hypergraphs to describe relationships. A hyperedge, and a hyperarc (directed hyperedge) can depict various relationships. In the case of documents, a hyperarc can express the input and output roles of documents that they may fulfil within activities of business processes. The document may be attached to organization units and actors through a *responsibility hyperedge* (labelled directed hyperedge). The variables of documents may be connected to data vertices of *D* that is organized into reasonable partitions that are represented by vertices contained in hyperedges that can be mutually mapped to specific data collections. These sub-hypergraphs may be called *Sub-system Hypergraph*s. Between the models, a refinement relation can be identified within an architectural perspective (Fig. 5) and represented by a hyperarc (directed hyperedge) *is-a-refinement*. The documents and their structures can be described by documents model.

Definition 7. *Models* of IS represented in the Architecture Describing Hypergraph are:

- The set of vertices is divided up into two basic subsets V_{Doc} and V_{Model};
- $V_{Doc} \supseteq \{OGDT\}$ where *OGDT* signifies the *overarching generic document*, that is the super type of all other document types and their instances;
- $V_{Model} \supseteq \{EA, \{external\_evironment\}\}$, where *EA* designates the overall *Enterprise Architecture* consisting of models, the *external_evironment* refers to the outside world that is typically the source of *stimulus* that is generated by either humans or any other systems;
- $V_{Configuration} = \cup\, h_i$ where $h_i \in \boldsymbol{E}_C$, and $\cap\, h_i = \varnothing$ where $h_i \in \boldsymbol{E}_C$.

The expressions articulate the fact that the configuration hyperedges represents the structure of artifacts of models and documents in the form of structural constituents as vertices.

- The set of arcs (directed edges of graphs) **A** is partitioned into subsets $\mathbf{A}_{\text{Doc\_Target}}$, $\mathbf{A}_{\text{Model\_Target}}$, $\mathbf{A}_{\text{Interaction}}$, where $\mathbf{A}_{\text{Doc\_Target}} \subseteq \text{V}_{\text{Configuration}} \times \text{V}_{\text{Doc}}$, $\mathbf{A}_{\text{Model\_Target}} \subseteq \text{V}_{\text{Configuration}} \times \text{V}_{\text{Model}}$.

The directed edges, the arcs map a complex structure, a configuration of elements (vertices) to a vertex that represents either a document or a model.

- $\mathbf{HA}_{\text{Interaction}} \subseteq \text{V}_{\text{Model}} \times \text{V}_{\text{Doc}}$, $\mathbf{HA}_{\text{Interaction}} \subseteq \mathbf{E}_{\text{D}}$;

The interaction between certain models and specific documents can be expressed by a hyperedge $h \in \boldsymbol{HA}_{Interaction}$.

- $\mathbf{E}_{\text{C}}$ can be partitioned into two subsets $\mathbf{E}_{\text{Configuration\_Document}}$ and $\mathbf{E}_{\text{Configuration\_Model}}$.

The hyperedges $h_{i,\ cd} \in \boldsymbol{E}_{Configuration\_Document}$, $h_{j,\ cd} \in \boldsymbol{E}_{Configuration\_Model}$ represent an inheritance structure. The inheritance structure conforms to the object-oriented paradigm, i.e. the configuration of documents and models inherit the attributes of super-classes, and may have extra attributes as well. Each attribute of a certain configuration can be represented by a vertex of the hyperedge. An attribute linked to a vertex either in V_{Model} or in V_{Doc}, its value represented by a link to a $d \in D$ when it is valuated. If the attribute is multi-valued, then the attribute is connected to hyperedge $h \in Power\ (D)$ (the power set of D).

- The set of extensional hyperedges $\boldsymbol{E}_E$ is split into two subsets $\boldsymbol{E}_{Superclass}$ and $\boldsymbol{E}_{Extension}$
  - The hyperarc $h \in \boldsymbol{E}_{Superclass}$, if $h \in \boldsymbol{E}_E$, (h set of vertices)
    - Either $h \subset V_{Doc}$ and $OGDT \in h$
    - or $h \subset V_{Model}$ and $EA \in h$.
    - Given a vertex $v_i \in h$ and $h' \in \boldsymbol{E}_{Superclass}$, then either valid that $< v_i, h' > \in \boldsymbol{E}_{Super\_doc}$, then $h' \subseteq h$
    - Or $< v_i, h' > \in \boldsymbol{E}_{Super\_model}$. then $h' \subseteq h$
      - Notation: $\boldsymbol{E}_{Super\_doc} = V_{Doc} \setminus \{OGDT\}) \times \boldsymbol{E}_{Superclass} \subset \boldsymbol{E}_D$;
      - Notation: $\boldsymbol{E}_{Super\_model} = ((V_{Model} \setminus \{EA, \{external\_evironment\}\}) \times \boldsymbol{E}_{Superclass} \subset \boldsymbol{E}_D)$.

The hyperedges $h \in \boldsymbol{E}_{Superclass}$ provide the association between a class of objects (models or documents) and its super-classes in compliance to the object-oriented paradigm. For the reason for our modeling approach, we make distinction between the two top super-classes, namely *OGDT*, the *overarching generic document*, *EA* the overall *Enterprise Architecture*. The conditions above specify the transitivity of *is-a* relationship for the relation between class and its super-classes.

- The instances of models can be represented by $\boldsymbol{E}_{Instance\_model} \subset V_{Model} \times \boldsymbol{E}_E$ (extensional);
- The instances of documents can be represented by $\boldsymbol{E}_{Instance\_doc} \subset V_{Doc} \times \boldsymbol{E}_E$;
- $h \in \boldsymbol{E}_E$, (h set of vertices) is $h \in \boldsymbol{E}_{Attribute\_Set}$ if $h \subset D$. The following statement is valid as well: $\cup\ h_i = D$, $h_i \in \boldsymbol{E}_{Attribute\_Set}$. The hyperarcs $h \in \boldsymbol{E}_{Attribute\_Set}$ are used to represent the attributes domains, and the associated values;
- The hyperarc $h \in \boldsymbol{E}_{Extension}$, if $h \in \boldsymbol{E}_E$, (h set of vertices) and
  - Given a vertex $v_i \in h \subset V_{Doc}$ and $h \in \boldsymbol{E}_{Extension}$, then $< v_i, h > \in \boldsymbol{E}_{Instance\_doc}$, $< v_i, h' > \in \boldsymbol{E}_{Super\_doc}$, then for each $n \in h$ and each $d_t \in h' \exists\ ha \in \boldsymbol{E}_E$ (hyperarc) where $< d_t, ha > \in \boldsymbol{E}_{Instance\_doc}$;
  - Or
  - Given a vertex $v_i \in h \subset V_{Model}$ and $h \in \boldsymbol{E}_{Extension}$, then $< v_i, h > \in \boldsymbol{E}_{Instance\_model}$, $< v_i, h' > \in \boldsymbol{E}_{Super\_model}$, then for each $n \in h$ and each $d_t \in h' \exists\ ha \in \boldsymbol{E}_E$ (hyperarc) where $< d_t\ , ha > \in \boldsymbol{E}_{Instance\_model}$.

A hyperedge $h \in \boldsymbol{E}_{Extension}$ represents an extension for models and documents respectively as well. The above described statement formalizes the transitivity of *instance-of* relationship.

- The intensional hyperarc $h \in \boldsymbol{E}_I$, $< d, h > \in \boldsymbol{E}_{Intension}$ if $\boldsymbol{E}_{Intension} \subset V_{Doc} \times \boldsymbol{E}_I$, $d \in V_{Doc}$, $h \in \boldsymbol{E}_{Configuration\_Document}$, $h \subset V_{Doc}$; the intensional hyperarc defines the hierarchical relationship between templates, rule-based document types and extensional document types that are instantiated.
- The set of hyperarcs (directed hyperedges) in $\boldsymbol{E}_D$ can be arranged into several subsets according to the notion of Enterprise Architecture:
  - The hyperarc $h \in \boldsymbol{E}_{View} \subseteq \boldsymbol{E}_G$, $h \subseteq V_{Model}$, represents a stakeholder's view that puts together models that describe the specific viewpoint of a role within organization. The hyperarc may be defined as $<r_i, m_j = (e_i^-; j \in \mathrm{I})>$, where r_i represents a vertex within an organizational model and it is mapped to a role of organization; $m_j \subset \boldsymbol{E}_{Instance\_model,}$ or $m_j \subset \boldsymbol{E}_{Configuration\_Model}$ before instantiation of models;

- The hyperarc $h \in \boldsymbol{E}_{Perspective} \subseteq \boldsymbol{E}_G$, $h \subseteq Powerset\ (V_{Model}\ )$, embodies a hierarchy of models according to a refinement hierarchy;
- The hyperarc $h \in \boldsymbol{E}_{Doc\_Life\_cycle} \subseteq \boldsymbol{E}_G$, $<d, h> \in \boldsymbol{E}_{Instance\_doc} \times \boldsymbol{E}_{Instance\_model}$, $d \in V_{Doc}$, that depicts the life cycle of document through the interactions with models.

7. Conclusion

We have described issues and problems of modeling IS. The recent evolution of technologies at user interface level and database handling raised questions that can be solved through new modeling approaches taking into account of ubiquitous documents as data holder.

Using of successful methods for single particular views, viewpoints and models, a framework for unifying the various approaches is outlined. To provide a theoretically sound but reasonable complex and comprehensive approach for description and research of IS a hypergraph based method is proposed (Table 1). The direction of future research is to exploit the hypergraph as mathematical model to formalize the IS' model from a document centric view.

In this paper we proposed an Architecture Describing Hypergraph as representation for Enterprise Architectures and related Documents. The suggested descriptive method takes advantages from the basic properties of generalized hypergraphs, i.e. unequivocal representation of complex relationships; moreover, there are some distinguished features:

- Uniform treatment of both intensional and extensional aspects of documents and models within Enterprise Architecture;
- Direct depiction of hierarchical relationships through instance-of, sub-class-of, super-class-of relationships.

The outlined approach can also be considered as a formal background to analyze and design IS. The documents play important roles in Information Systems in the time of analysis, design, specification and operation with strong coupling to roles of organizations. The unified framework provides an opportunity for uniform handling of models and documents on a formal foundation.

The hypergraph–based approach offers the chance to apply further mathematical tools for assistance in the design, verification and validation to maintain the integrity and consistency of IS.

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International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
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Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
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Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
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