Six Principles for Redesigning Executive Information Systems—Findings of a Survey and Evaluation of a Prototype

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Information Systems (IS) meant to help senior managers are known as Executive Information Systems (EIS). Despite a five-decade tradition of such IS, many executives still complain that they bear little relevance to managing a company and, even more, fail to accommodate their working style. The increasing acceptance of IS among today's executives and technological advances of the Internet era make the present moment favorable for redesigning EIS. Following the design science paradigm in IS research, this article provides six principles for such a redesign. To do so, we survey executives regarding their requirements and the IS they currently use. We then derive principles for a redesign to fill the gaps. They address diverse areas: a comprehensive information model, functions to better analyze and process information, easy-to-use IS handling, a more flexible IS architecture and data model, a proper information management, and fast prototype implementation. Finally a field test demonstrates and evaluates the utility of our proposal by means of a prototype.

Categories and Subject Descriptors: H.4.2 [**Decision support**]: Information Systems (IS) Analysis and Design

General Terms: Design, Management, Performance

Additional Key Words and Phrases: Corporate business intelligence, executive information system (EIS), working style, design requirements, design principles

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1. INTRODUCTION

Companies must operate in an increasingly dynamic environment. Due to their overall responsibility for companies' success, *executives* are particularly affected by this situation. Executive Information Systems (EIS) help such senior managers perform their jobs more productively and efficiently by serving as their central, hands-on, day-to-day source of information [Walters et al. 2003; Nord and Nord 1995].

Managers and the Information Systems (IS) to support them have been a topic of interest to researchers over the last five decades [Ackoff 1967; Mintzberg 1972; Rockart and Treacy 1989; Elam and Leidner 1995; Wixom and Watson 2010]. Despite this tradition, many executives still complain that their current EIS bear little relevance to managing a company and fail even more to accommodate their working style [Eckerson 2010]. Their points of criticism are information overload, inadequate technology, complex IT handling, and a lack of evolution planning [Dreiling 2007].

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The present moment seems favorable for redesigning EIS. More and more of today's executives grew up with information and communication technology and have an increasingly positive attitude towards IS [Vodanovich et al. 2010], along with higher expectations for how IS should accommodate their user preferences. Furthermore, significant technical progress has been made in the Internet era, during which EIS evolved from individual IS to integrated applications on top of a corporate Business Intelligence (BI) architecture [Cheung and Babin 2006].

In the light of these considerations, this article proposes six principles for redesigning EIS in the Internet era. We start with a survey of executives about their EIS requirements and how well the IS they currently use meet them. Then we derive design principles to address the identified gaps. Finally, we use a prototype to demonstrate and evaluate the utility of these principles.

This article adheres to the design science approach in IS research, which aims to create useful artifacts that solve relevant design problems in organizations [March and Smith 1995; Hevner et al. 2004]. We follow Walls et al. [1992] and Gregor [2006] who regard requirements, principles in form and function, and implementation principles as essential parts of an IS Design Theory (ISDT). *Requirements* are the prerequisites, conditions, or capabilities needed by users [IEEE 1990]. They specify the functional or "black box" view of EIS. *Principles*, in contrast, define how the EIS is brought to life and thus provide the constructional or "white box" view [Hoogervorst 2009].

In terms of methodology, we follow the IS design research process proposed by Peffers et al. [2007]. Starting with identify a problem and motivate the research, in our case the changes mentioned before challenge existing EIS designs. The next phase is define objectives for an (IS) solution. Based on a literature review, we identify existing EIS requirements (Section 2.1). As their scientific rigor increases, they become less relevant for direct use in practice. In contrast, practitioner publications demonstrate relevance, but do not evidence strong rigor. We therefore develop a new, more business-driven set of requirements based on the principle of economic efficiency (Section 2.2). We then conduct a survey with executives from companies listed in the Financial Times "Europe 500" report (Section 3.1). The findings reveal gaps between their requirements and existing IS that indicate six areas for research (Section 3.2). Phase 3 is design and develop. A second literature review identifies existing design principles. Based on a metamodel, we structure these principles and add new ones to bridge the gaps our survey brought to light (Section 4). To accomplish Phase 4, demonstrate, we apply the principles in a prototype (Section 5.1). Phase 5 is evaluate: we gave executives the opportunity to work with and evaluate the prototype (Section 5.2). Comparing their assessments to our survey findings allows us to quantify our research progress. The sixth and final phase is communicate: we discuss our set of six design principles as a building block of an ISDT for redesigning EIS.

2. EIS – HISTORY AND CURRENT DEVELOPMENTS

Researchers have proposed the terms "management support systems" (MSS) [Clark, Jr. et al. 2007] and "decision support systems" (DSS) [Arnott and Pervan 2008] as labels for IS intended to support managerial work. MSS, the more general term, was first used by Scott Morton [1967] and covers Management Information Systems (MIS), Decision Support Systems (DSS), and EIS [Hartano et al. 2007].

This article focuses on EIS, a specific type of IS distinguished by three characteristics [Paller and Laska 1990; Walters et al. 2003]. First, EIS help organizations carefully monitor their current business processes and progress toward strategic goals, often using the Critical Success Factor (CSF) method [Rockart 1979]. Second, they should enable users to navigate through information culled from both internal and external

databases [Nord and Nord 1995]. And, third, even senior executives should be able to operate such IS themselves [Houdeshel and Watson 1987].

To a large extent, dashboards [Eckerson 2006] and scorecards [Kaplan and Norton 1992] fulfill the role of EIS today [Watson 2011]. We nevertheless maintain the term "EIS," arguing that one key distinction exists. The main purpose of dashboards/scorecards is to synthesize and present comprehensive information in a concise format. They are good at hitting the decision support "sweet spot" in that they are easy to use and meet the information needs of a large number of users [Eckerson 2002]. EIS, in turn, represent a more comprehensive approach with additional analytical capabilities, such as dimensional reporting (OLAP), exception reporting, simulations, trend/sensitivity analyses, and drill-downs/drill-throughs. They also support comments and communication capabilities, including email and collaboration [Papageorgiou and de Bruyn 2010].

Today's Data WareHouses (DWH) make data sourcing much less of an issue than it was in the 1980s/1990s [Wixom and Watson 2010]. EIS on top of a corporate BI architecture benefit from this development in two ways. First, DWH ensure consistent, integrated data handling and, when combined with OLAP, they also improve information analysis in various dimensions, such as products, countries, and customers.

Not only executives use EIS, but their support staff does as well. New frontends, which often apply Web technology, make it easier to provide up close and more personalized access to required information. Finally, efforts are underway to make EIS results more readily available on mobile devices. Advances in both new end-user devices and user-interface software components should significantly simplify EIS handling, even for technology-averse users [Li et al. 2009].

2.1. State-of-the-Art

To compile a list of EIS requirements, we searched several databases covering the most important journals for EIS. The search string ["executive information systems" or "EIS" and (requirements or antecedents or determinates)] resulted in the following hits per database: 1,043 in Science Direct, 272 in Proquest, 95 in EBSCOhost, 3 in ACM, 254 in Wiley Inter Science, and 128 in Google Scholar. After identifying the relevant articles, we added a backward search to find further relevant articles and frequently cited books on designing EIS, balanced scorecards, and dashboards, such as Paller and Laska [1990], Kaplan and Norton [1997], and Eckerson [2006]. This process produced a diverse group of requirements we analyzed by their research approach.

It influences both the number of requirements provided by a study and their level of granularity, for example, abstract variables like "appropriate technology" versus specific IS features like "drill-down." We reveal not only *single requirements characterization* (e.g., Volonino et al. [1995]), but list approaches of requirements (e.g., Poon and Wagner [2001]), frameworks, and Structural Equation Models (SEM) as well. *Frameworks* take a deductive approach to examining requirements (e.g., Byun and Suh [1994]), while *SEM* provide an independent, external method for empirically testing the impact of variables and surrogates on EIS. Frequently cited SEM are DeLone and McLean's [2003] IS success model and Davis and Venkatesh's et al. [2003] technology acceptance model. Both provide a rigorous understanding of EIS requirements, but no direct guidance for design as they miss hands-on EIS variables [Urbach et al. 2009]. Some extensions have tackled this issue, but rarely in terms of EIS [Wixom and Todd 2005]. *List approaches*, in contrast, provide more direct guidance, as they outline IS features and hands-on variables [Mayer and Marx 2010]. However, they do not evidence strong rigor as they often bear no connection to proven relationships within the more rigorous frameworks and SEMs.

Table I. Overview of the Most-Cited EIS Requirements from Literature Review

Scope of information	Functions	User interface	Information management
• Compliance and controls [Eckerson, 2010]	• Email integration [Papageorgiou and de Bruyn, 2010]	• Browse functions as navigation web provides [Cano Giner et al., 2009]	• Appropriate IS-technology: corporate data warehouse [Wixom and Watson, 2010]
• Financial vs non-financial data [Kaplan and Norton, 1997]	• Comprehensive information format [Kelly, 1988]	• Ease of use, even for senior executives: information accessability, language, number of features etc. [Houdeshel and Watson, 1987]	• Support consistent taxonomy across businesses [Walia and Carver, 2009]
• Internal data vs external data [Nord and Nord, 1995]	• Multidimensional reporting (OLAP) [Eckerson, 2011]	• Extensive graphics [Nord and Nord, 1995]	• Correctness of data [Jiang et al., 2000]
• Additional soft, human data [Rockart, 1979]	• Drillable charts: drill down/ drill through [Mayer and Krönke, 2010]		• Cost considerations [Rainer and Watson, 1995]
• Task-related vs individual data [Houdeshel and Watson, 1987]	• Exception reporting [Rainer and Watson, 1995]		• EIS in mobile situations [Gebauer et al., 2010]
• Information clusters for "managing a company" [Mayer and Marx, 2010]	• Hierarchical information aggregation [Mayer and Marx, 2010]		• Flexibility [Mayer and Krönke, 2010]
	• Mobile access [Li et al., 2009]		• Timeliness/fast response time [Rainer and Watson, 1995]
	• Print function, help function, and calendar integration [Walstrom and Wilson, 1997]		
	• Simulations, trend, and sensitivity analyses [Bergeron et al., 1995]		

Publications thus differ significantly regarding the scope of EIS requirements. Following Warmouth and Yen [1992], we categorize our findings in terms of scope of information, (IS) functions, and user interface. We also add a new category, information management, to cover how EIS handle relevant information flows. Table I shows the most-cited EIS requirements we identified.

The literature review reveals that the field of study regarding EIS requirements is mature, but still has three shortcomings. First, list approaches are practical, but most often incomplete; second, the identified requirements need to be prioritized in terms of their importance for future EIS design; and third, more current studies are needed, since many articles are from 1990–2003.

2.2. Requirements Criteria for Redesigning EIS

To bridge the divide between the "truth" provided by SEM and the practicality of less rigorous hands-on list approaches of EIS requirements, we propose a more balanced approach. In a three-step deductive process [Popper 1982], we first derive evaluation criteria from the *principle of economic efficiency*. This generally accepted paradigm in business research [Samuelson 1983] addresses the ratio between benefit and cost. In

Principle of economic efficiency	Design criteria		Evaluation criteria	Description
Solution capabilities (system output)	Scope of information	Information completeness	1. Coverage of objective information need	Does your current EIS take your task-related (objective) information needs into account?
			2. Coverage of subjective information need	Does your current EIS take your personal (subjective) information needs into account?
		Information structure	3. Coverage of "strategy" (non-financial) information	Does your current EIS consider "strategy" information, (e.g. non-financial, qualitative information)?
			4. Coverage of "regulatory compliance" information	Does your current EIS consider information on regulatory compliance?
	Functions		5. Aggregation level	How extensively does your current EIS aggregate information?
			6. Verifiability	Can your current EIS break down aggregated information into its original components?
			7. Functional scope	To what extent does your current EIS provide advanced functions for data analysis, simulation, and communication?
	User interface		8. Quality of presentation	To what extent can your current EIS tool present information graphically?
			9. User-interface design and dialoque control	To what extent is the user interface design and dialogue control of your current EIS comfortable and user-friendly?
	Information management		10. Flexibility	How flexible (agile) is your current EIS to meet changing business and IS requirements?
			11. Timeliness	How frequently is the data basis of your current EIS updated?
			12. Accuracy	How important is it that your current EIS provides information that cover reality in terms of the "decimal places" used?
			13. Consistency	How important is the accuracy of your EIS in terms of avoiding manipulation, disruptions, and mechanical failures?
Resources required (system input)	Effort		14. Cost adequacy	What was the amount of money so far your current EIS costed (including IS redesign and maintenance)?
			15. Time adequacy	How much time has been invested so far in developing your current EIS (including IS redesign and maintenance)?

Fig. 1. Set of requirements criteria for redesigning EIS following the principle of economic efficiency.

our case, it means that the evaluation criteria for EIS must be oriented towards what is economically feasible, not just technically possible.

The principle of economic efficiency can be expressed in terms of basic criteria, which can be broken down into solution capabilities (system output, Figure 1) that deliver the benefits of EIS to executives and the resources required to generate this output (system input [Matek et al. 1987]).

In the IS success model (Section 2.1), information and IS characteristics relevant to users determine system output [Wixom and Todd 2005]. We make these criteria more EIS-specific. Following this classification and using our findings from literature research (Table I), we structure the requirements for redesigning EIS on a second level in terms of scope of information, functions, user interface, information management, and effort. A third step based on Mayer and Marx [2010] leads to measurable evaluation criteria (Figure 1).

3. IDENTIFYING EIS DESIGN GAPS WITH A SURVEY

3.1. Survey Design and Sample Characteristics

A cross-section analysis in the field served as our research method. It allowed us to cover various perspectives on EIS and ensures that our results contain findings from multiple companies. Since corporate management without IS is impossible at large international companies in particular, we define this organization type as the population for the survey. To reach this group, we sent a paper-based questionnaire to the CEOs and CFOs of the 250 largest companies listed in the Financial Times "Europe 500" report on April 1, 2008.

Table II. Sample Characteristics

Criteria		Sample						Sum
Market capitalization. in bn. EUR	Category	< 30	< 60	< 90	< 120	> 120		
	No.	25	18	7	5	4		59
	Share	43.01%	31.03%	12.07%	8.62%	10.34%		100%
Industry	Category	Financial Institution	Basic Resources, Construction & Utilities	Automobile & Industrial Goods	New Industries	Chemical, Pharmaceutical & Health Care	Retail	
	No.	17	13	11	7	5	6	59
	Share	29.31%	22.41%	18.97%	12.07%	8.62 %	10.34%	100%

The survey consisted of 58 questions in four categories: the company's profile, functional requirements of EIS, design requirements (to-be profile), and the IS currently used by the company (as-is profile). The last two sections helped to answer the research questions relevant to this article:

—What requirements do executives have for EIS in the Internet era (to-be profile)?
—How do executives rate the way their current IS meet these requirements (as-is profile)?

The evaluation criteria derived before (Figure 1) specify these questions for both the to-be and as-is profile. Of the 250 executives surveyed, 59 responded (23.6%). Under the chi-squared test of homogeneity (v = number of clusters – 1), the sample is *representative* in terms of market capitalization ($X^2 = 3.8 < X^2 = 9.5_{(v=4,\alpha=0.05)}$) and industry ($X^2 = 6.1 < X^2 = 11_{(v=5,\alpha=0.05)}$). Table II provides an overview of the sample characteristics.[1]

3.2. Results

We asked the executives how important it is for EIS to fulfill the characteristics of each of the criteria and how they rate the IS currently used at their company. In both cases, they answered using a five-point ordinal scale (Figure 2). To more clearly show the differentiation among their responses, we expanded the area between the values "3" (somewhat) and "4" (high). The difference between the as-is and to-be profiles ("design gap" column, Figure 3) indicates the relevance of each issue. To check the statistical significance of the mean difference between the profiles for each criterion, we performed a *two-sided t-test*.

In doing so, we first consider a confidence interval of 5% (0.05) to be significant for our null hypothesis that the arithmetic mean for the as-is value will be equal to the mean for the to-be value for each of our 15 EIS requirements (column "t-values"). The results are presented in Figure 3. With the sample size varying between n = 54–56, this assumption produces student's t-distribution of 2.00-2.01 (degree of freedom (df) = sample size n −1).[2] Second, we go on with the *p-values* for each of the evaluation criteria in terms of the significance levels: ***: 0.01 (1%); **: 0.05 (5%); *: 0.1 (10%, "p-values," Figure 3).

Two implications emerge from the results. On the one hand, if we take publications from the 1990s as a starting point, we see that several EIS design issues have been resolved over time. Today's EIS provide the information that executives think they need

[1]While our sample is small, its size is comparable to those in other executive-focused articles: Seeley und Targett [1999] is based on 85 datasets, Rainer und Watson [1995] on 48, Nord and Nord [1995] on 47, Walstrom and Wilson [1997] on 43, and Watson et al. [1991] on 43.

[2]For any of the criteria, the difference between the as-is and to-be means is significant if the upper t-value is larger than the positive reference value or the lower t-value is smaller than the negative reference value.

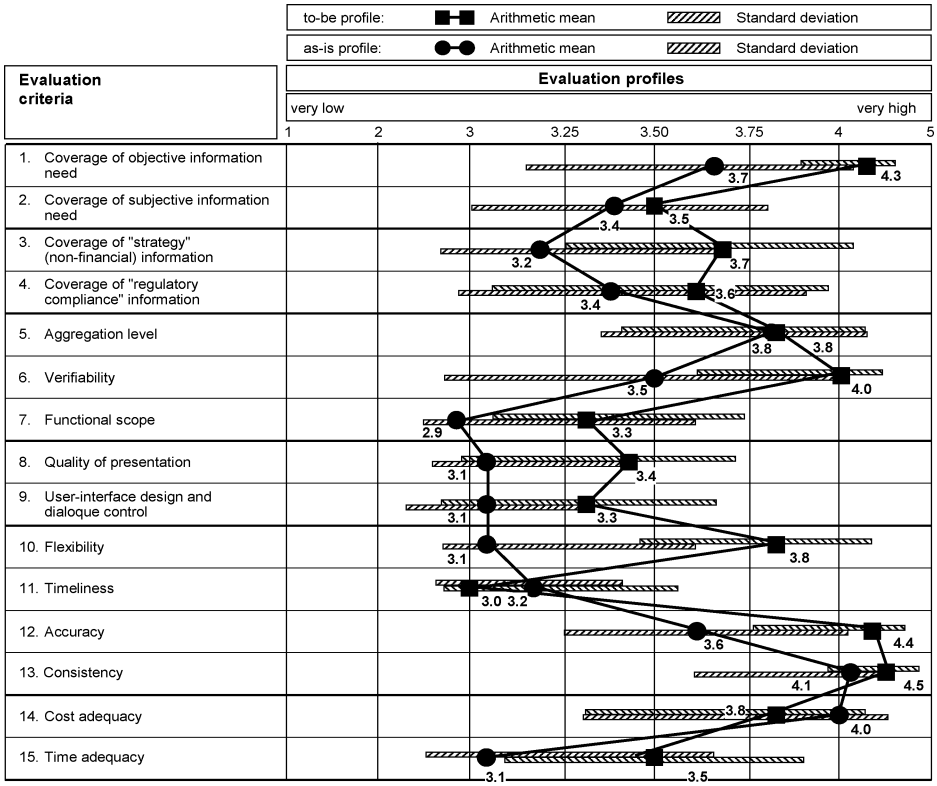

Fig. 2. Analysis of EIS design from the survey: as-is and to-be profiles.

(subjective information need, evaluation criterion 2, Figures 2 and 3), information to cover regulatory compliance (criterion 4) and deliver them at the desired level of aggregation (criterion 5). Furthermore, delivering information on time (criterion 11) and designing EIS on budget (criterion 14) are no longer issues. On the other hand, six design gaps are still evident between as-is and to-be profiles as follows.

Gap 1: Incomplete Information. Executives rate the fulfillment of their objective information needs at an arithmetic mean of 4.3, the third-highest to-be score overall (criterion 1, Figures 2 and 3). They also point out an increasing need for "strategy" information (criterion 3). In other words, in addition to financial data, they need more nonfinancial information (arithmetic mean of 3.7). Comparing the to-be and as-is profiles proves executives desire more objective information (design gap: 0.6; p-value: ***) and "strategy" information (design gap: 0.5, p-value: **) than their existing IS provide. Even though EIS design is a mature research topic, the question of the "right" information for such IS to cover has not been fully resolved.

Gap 2: Insufficient Verifiability and Processing Functionality. Furthermore, executives need key insights to be synthesized at an aggregated level (arithmetic mean of criterion 5: 3.8). Comparing as-is and to-be values shows that executives are satisfied with how their information is aggregated, evidenced by the fact that the arithmetic mean of the as-is value equals the mean of the to-be value, but that they also want to be able to access the underlying details (criterion 6, "*verifiability*," arithmetic mean: 4.0; design gap: 0.5; p-value: **). In other words, a design gap exists in terms of capabilities

Evaluation criteria	Statistical significance of the mean difference: Design gap (to-be ./. as-is)	t-value >=< t-value (significance level: 5%)	p-value *** < 0.01 ** < 0.05 * < 0.1 - no difference	Gap description and proposed design principle
1. Coverage of objective information need	0.6	4.18 >> 2.00	*** (0.02%)	1. Incomplete information: design a comprehensive information model
2. Coverage of subjective information need	0.1	0.72 << 2.00	-	
3. Coverage of "strategy" (non-financial) information	0.5	2.71 > 2.00	** (1.76%)	
4. Coverage of "regulatory compliance" information	0.2	0.57 << 2.00	-	
5. Aggregation level	0.0	0.00 << 2.00	-	2. Insufficient verifiability and processing functionality: tailor EIS functions to better analyze and process information
6. Verifiability	0.5	2.53 > 2.00	** (2.84%)	
7. Functional scope	0.4	5.14 >> 2.00	*** (0.00%)	
8. Quality of presentation	0.3	2.25 > 2.00	* (5.62%)	3. Overly complex IS handling: improve easy-to-use IS handling
9. User-interface design and dialoque control	0.2	2.26 > 2.01	* (5.61%)	
10. Flexibility	0.7	5.27 >> 2.00	*** (0.00%)	4. Inflexibility: set up a more flexible IS architecture and data model
11. Timeliness	- 0.2	-1.62 > -2.00	-	
12. Accuracy	0.8	5.83 >> 2.00	*** (0.00%)	5. Inaccuracy and inconsistency : design for more reliable information with a proper information management
13. Consistency	0.4	3.20 >> 2.00	*** (0.45%)	
14. Cost adequacy	- 0.2	-0.14 > -2.01	-	6. High design, implementation, and maintenance effort needed: implement prototypes faster
15. Time adequacy	0.4	2.42 > 2.01	** (3.78%)	

Fig. 3. Analysis of EIS design from the survey: statistical significance of the mean difference, gap description, and proposed design principles.

to analyze the (aggregated) information presented. A related gap exists regarding functional scope (criterion 7, design gap: 0.4; p-value: ***). Executives demand not only functions to better analyze and process information, but also filtering and synthesizing capabilities to avoid "information overload."

Gap 3: Overly Complex IS Handling. Furthermore, the survey suggests that IS solutions are often difficult for executives to handle (user orientation, criteria 8 and 9). Design gaps exist in terms of the quality of information presentation (design gap: 0.3), user-interface design, and dialog control (gap: 0.2). Both p-values are rated "*," indicating that the differences between executives' requirements and the capabilities of their current EIS are still significant.

Gap 4: Inflexibility. Executives expressed a need for EIS that can easily adapt to changing information requirements (arithmetic mean of criterion 10 "flexibility:" 3.8). Such changes, for example, due to new regulations or company restructuring, currently require time-consuming adjustments, which are certain to represent a serious issue in practice (design gap: 0.7; p-value: ***).

Gap 5: Inaccuracy and Inconsistency. The requirements of accuracy and consistency received the highest scores in the survey, revealing the importance executives place on trustworthy information. The arithmetic mean for accuracy, defined here in terms of

the number of decimal places used in calculations to cover reality (criterion 12), was 4.4; for consistency, which indicates the extent to which the system protects information from manipulation, disruptions, and mechanical failures (criterion 13), this value was 4.5. Furthermore, executives not only view these criteria as very important, but also see a problem with how existing EIS perform in terms of information accuracy (at 0.8, the largest design gap in the study; p-value: ***) and information consistency (design gap of 0.4; p-value: ***).

Gap 6: High Design, Implementation, and Maintenance Effort Needed. Cost and time adequacy served as the final requirement criteria. The score for the first was above average (3.8), while that for the latter was average (3.5). The design gap of 0.4 for time adequacy (p-value: **) suggests that delivering EIS projects on time is a greater issue than keeping to budget; the "gap" for cost adequacy is actually an inverse one (−0.2).

To summarize, executives' ratings of the importance of various EIS requirements and the performance of their current IS reveal six distinct design gaps. Taken together, these gaps produce a *design paradox*: on the one hand, executives want the comprehensive content required to manage a company; on the other, they want simple information presentation and IS handling.

4. DESIGN PRINCIPLES

4.1. State-of-the-Art

In addition to considering requirements that EIS should meet, the body of knowledge includes design principles for achieving this end. The search string ["executive information systems" or "EIS" and (method or model)] resulted in the following hits per database: 548 in Science Direct, 166 in Proquest, 91 in EBSCOhost, 26 in ACM, 126 in Wiley Inter Science, and 1,800 in Google Scholar. We restricted the results to articles with either "executive information systems" or "EIS" in the title, abstract, or keywords and to articles developing EIS design methods and models, and ended up with a total of 46 articles. The fact that existing EIS do not fulfill all the demands executives make indicates that current design principles are not sufficient, at least not fully applied. Thus, our next step is to address the gaps between existing methods and models on the one hand and the design principles needed to meet all the requirements we identified on the other.

4.2. Managing the Design Paradox

We start by invoking the idea of design principles threefold [Hoogervorst 2009]. First, *statements* express the principle's main idea. Second, *rationales* explain why this idea is important. Third, *implications* describe how the principle could be applied using models and methods (Figure 4). Based on this metamodel, we structure the following six principles to fill the gaps in EIS design as currently practiced. While they do not collectively form a comprehensive list of guidelines for EIS redesign, they can guide the development of such a list.

Principle 1: Design a Comprehensive Information Model. Executives demand comprehensive information (Section 3.2). Not surprisingly, EIS literature provides several methods for analyzing information needs along with corresponding reference models. A trend towards more elaborate information analysis methods is evident. As a starting point, Rockart's [1982] Critical Success Factors (CSF)[3] method focuses on single executives and interviews. Shank et al.'s [1985] ten-step method involves consultants

[3]CSFs are "the limited areas in which results, if they are satisfactory, will ensure the successful competitive performance for the organization. They are the few key areas where 'things must go right' for the business to flourish" [Rockart 1982].

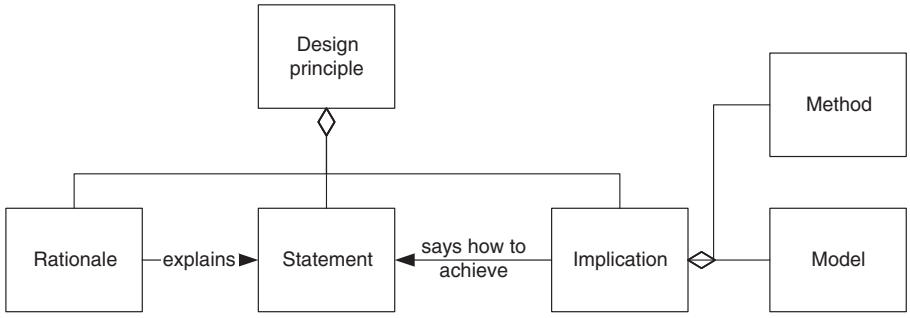

Fig. 4. Metamodel of design principles according to Hoogervorst [2009].

to profit from external EIS experiences. The Strategic Business Objects (SBO) approach by Volonino and Watson [1991] determines information needs by identifying business objectives, processes, and task-specific information. Stein [1995] tries to combine the organizational and individual perspective by deriving Information Success Factors (ISF) for individual executives from an agreed-upon set. In addition, Watson and Frolick [1993] provide an overview of 16 techniques for determining executives' information needs, such as participation in planning sessions, analyzing existing reporting, and conducting executive interviews. In conclusion, agreement exists that the choice of which information an EIS has to present should based on a systematic method for information need analysis. Furthermore, a balance is needed between information for top management overall (objective information needs) and for individual needs of executive users (subjective information needs).

The changing view on which information EIS should deliver reflect a strategic shift in corporate management. Palvia et al. [1996] focus on external information: competitors, markets, economics, finance, etc. Singh et al. [2002] derive recommendations along the strategic management process, including external information in the scanning phase, scenario information in the planning phase, information about strategic initiatives in the implementation phase, and actual performance against budgets and benchmarks in the control phase. Mayer and Marx [2010] call for five clusters to balance information: financial accounting, management accounting, program management, compliance management, and cash flow and liquidity management.

In summary, the literature provides a sound base of reference content for EIS, with recommendations regarding information structure and scope that enhance the EIS beyond standard financial corporate reporting. Table III outlines the first principle for redesigning EIS that results.

Principle 2: Tailor EIS Functions to Better Analyze and Process Information. Information overload is a problem in the Internet era. In response, executives need comprehensive information support (design principle 1), but presented in a *concise format* (criterion "aggregation level" of information: 3.8, Figures 2 and 3). To address this issue, executives would like to be able to analyze and process information on their own. However, our literature review shows that only a few researchers integrate this functional specification into their EIS development method. Crockett [1992] shifts from an approach based purely on determining CSFs towards one involving the use of *Key Performance Indicators* (KPIs) and the definition of reporting and analysis formats. Adam and Pomerol [2002] do the same, adding a step to their method that defines how identified KPIs can be broken down into meaningful levels of detail.

The functions the design model should cover differ depending on whether EIS include core functionalities only or modeling and communication capabilities as well (Table I).

Table III. Comprehensive Information Model

Statement	Design a comprehensive information model
Rationale	Overcome incomplete information, in particular missing objective information needs and "strategy" (non-financial) information (design gap 1)
Methodical implications	• Use existing structured development method (e.g. SBO or ISF method) • Be aware of objective and subjectiveinformation needs • Use a plurality of techniques in order to determine the full scope of information needs • Use existing reference information
Model implications	Provide balanced information in five clusters: • Financial accounting(balance sheet, profit & loss statement) • Management accounting(additional internal information(e.g. quality, personal) and external information (e.g. customers, competitors)) • Program management (tracking of strategic initiatives) • Compliance management (major risks) • Cash flow and liquidity management

Table IV. Functions to Better Analyze and Process Information

Statement	Tailor EIS functions to better analyze and process information
Rationale	Overcome insufficient verifiability and processing functionality (design gap 2)
Methodical implications	• Integrate functional requirement analysis into EIS development method • Specify output for predefined analysis • Use existing EIS functional reference models
Model implications	• Provide analytical functions: drill down along organizational and managerial hierarchies, break down analysis to highlight computation rules and components, sensitivity (what-if) analysis, temporal and comparison analysis for trends • Provide alerts and comments to guide executives • Provide access to information processing capabilities: e-mail, print, and copy of EIS information

Hierarchical drill-downs, alerts, and traffic-light coding are accepted core functionalities [Walls et al. 1992]. At the other extreme, the inclusion of advanced modeling, for example, for scenario building and simulation, is questionable as such functionalities are often too complex for executives to use on their own.

However, drill-downs and alerts alone do not seem to provide sufficient analytical capabilities. They would be enhanced by the ability to break down KPIs into their computational components and represent the result as a value-driver tree or strategy map. Such breakdowns can also support easy-to-use sensitivity analysis. Singh et al. [2002] recommend providing temporal analyses and comparisons of measures so that executives can explore trends. At the same time, better information filtering and synthesis is crucial to combat information overload. As each type of analysis involves different information, the output format should be predefined according to the presented information, for example, timelines, pie charts, or waterfalls.

Furthermore, several authors discuss communication functionalities such as integrated email, collaboration, and comments [Haley and Watson 1996]. Within groupware communication infrastructure, EIS do not need to provide their own email functionality, but should allow qualitative comments [Singh et al. 2002]. In summary, effectively redesigning EIS requires better tailoring IS functions. Table IV outlines this design principle.

Principle 3: Improve Easy-to-Use IS Handling. EIS are often difficult for executives to use (Figures 2 and 3). One the on hand, the interface must allow them to access the information and functions outlined in principles 1 and 2. At the same time, it

Table V. Easy-to-Use IS Handling

Statement	Improve easy-to-use system handling
Rationale	Overcome overly complex IS handling (design gap 3)
Methodical implications	• Integrate the user-interface design into EIS development method • Use experienced IS designers for user-interface design
Model implications	• Use a dashboard as central concept • Use colour-coding to indicate relevant information • Use report hierarchy with increasing details for example, entry screen with few KPIs and main events, dashboard with more KPIs and detailed analysis reports • Use graphical navigation within the information presentationfor example, using breadcrumbs, predefined buttons for analysis, click-on KPIs to drill down • Use predefined inputs and outputs for high recognition • Provide semantic searches for fast information access

must accommodate executives' time restrictions, limited IS skills, and individual expectations as nontechnical users.

While they do not supply explicit recommendations, Watson and Satzinger [1994] specify guidelines for involving executives in the interface design. In terms of the model, Adam and Pomerol [2002] favor *dashboards* as a concise EIS interface. Such an approach makes relevant information available in a single screen, supported by graphical depictions of KPIs. Diagrams, screen layout, format, and colors should be conservative and easy to read, focusing the user on important facts. Overly "fancy" EIS dashboards have not been successful [Eckerson 2010].

A one-page format alone cannot cover the broad range of information and analyses outlined in design principles 1 and 2. EIS should therefore incorporate a hierarchical concept to structure reports and analysis at increasing levels of detail [Eckerson 2006]. To navigate between the different reports, Chen [1995] recommends graphical browsing, while Watson and Satzingers [1994] focus on "designing the main menu as a gateway to all computer use." Warmouth and Yen [1992] propose scheduled reports, query functionalities, menus (step-by-step procedures), and command languages with predefined short cuts. Looking at user's requirements, graphical browsing within interactive reports seems adequate, and can be accompanied by semantic searches using a natural language (Table V).

Principle 4: Set Up a More Flexible IS Architecture and Data Model. EIS need to be flexible to adapt to increasingly rapid changes in executives' information and functional requirements [Watson and Satzinger 1994]. Several design methods emphasize the need to not only plan the development and initial implementation of the EIS, but anticipate its evolution as well [Frolick and Robichaux 1995].

From the model perspective, accommodating change is the leading topic in EIS architecture. EIS today are based on a central data warehouse and integrated modules on top of a corporate BI architecture (Section 2). This structure makes it possible to integrate even data from transactional and other analytical sources [Koutsoukis et al. 1999]. OLAP provides flexible data analysis [Salmeron 2002].

To leverage this flexibility, Mayer and Krönke [2010] argue for ad hoc reporting capabilities and direct links *to* transactional systems for deep-dive analyses, such as risk portfolios or cash-flow statements. For ad hoc reporting, Cheung and Babin [2006] favor relational ROLAP using in-memory technology to perform direct analysis of transactional data. When providing direct links, DWH architecture and corresponding BI platforms allow the reuse of functions and access rights, as well as standard graphical user interfaces. Such a modular design supports a uniform "look and feel."

Table VI. More Flexible IS Architecture

Statement	Set up a more flexibel IS architecture and data model
Rationale	Overcome EIS inflexibility(design gap 4)
Methodical implications	• Be aware of changes in the EIS on all levels: information, function, and user interface • Plan the evolution of EIS
Model implications	• Provide a data warehouse-centric architecture for flexible integration of heterogeneous data sources • Provide ad hoc and drill-through capabilities to access nonroutine information and to access transactional systems for detailed analysis • Provide a flexible data model for reflecting new and restructured information, e.g. use a temporal data model • Provide graphical administrative editors for reports and queries in order to enable fast new EIS content

Table VII. Proper Information Management

Statement	Design for more accurate and consistent information with a proper information management
Rationale	Overcome inaccuracy and inconsistencyof EIS (design gap 5)
Methodical implications	• Define EIS data quality management • Define EIS information management concept
Model implications	• Use corporate metadata and master data repository • Use defined information workflows

Li [2009] addresses another aspect of flexibility by proposing graphical editors to allow fast, easy IS modification ("power user concept") as well as a shift in IS responsibility from the IT department to the business side. Summarizing the need for a more flexible architecture and data model to cope with change, Table VI outlines the resulting fourth design principle. Modifications should be handled by the business side itself.

Principle 5: Design for More Accurate and Consistent Information with a Proper Information Management. Executives currently see a need for more accurate and consistent EIS information. To address this issue, Koh and Watson [1998] focus on data planning and management, emphasizing the use of corporate-wide data standards and data stewards. Other researchers propose integrating ongoing quality management practices (guidelines, measurement, and improvement) to ensure data quality over time.

Cheung and Babin [2006] propose a central repository for master data and metadata. *Master data* ensures that IS data is presented and stored in a proper format, while *metadata* ensures that the data content is correct. Both need to be defined on corporate level, and decentralized data must be defined and mapped within a corporate standard. Therefore, Mayer and Marx [2010] focus on the entire process of "information management" as a way to define and schedule information flows. This includes workflow validations, calculations, and sign-offs before data is made available to the EIS in the first place.

In summary, an EIS data quality and information management concept should be part of any EIS redesign. Table VII outlines the fifth design principle.

Principle 6: Implement Prototypes Faster. Cost and time adequacy is a final challenge in EIS design. Guimares and Saraph [1991] and Byun and Suh [1994] advocate *prototyping* as a central development technique. Standardized dashboard applications should help to reduce implementation effort. Since they are now available in most vendor portfolios, they can be easily integrated into the EIS architecture. Table VIII outlines the sixth and final design principle.

Table VIII. Fast Prototype Implementation

Statement	Implement prototypes faster
Rationale	Overcome high design, implementation, and maintenance effort needed (design gap 6)
Methodical implications	• Use prototyping for an early sense of "look and feel" • Stimulate demand and feedback for the EIS development
Model implications	• Use dashboard applications of a standard BI platform

Table IX. Specifications of the Prototype and Addressed EIS Design Guidelines

EIS component	Specification "Corporate Navigator"	Addressed design principles
Scope of information	Five information clusters: financial accounting, management accounting, compliance management, program management, cash flow- and liquidity management	1
Functions	Analysis functions such as drill-down, trends, sensitivity analysis, drill-through to the upstream systems Processing functions: comments, prints, and e-mail	2
User interface	Breadcrumbs, buttons instead of pull-down menues, and "three layer design of analysis:" (A) Corporate Portfolio with three KPIs (B) Corporate Dashboard with about 20 KPIs (C) Corporate Analyses with several detailed analyses	3
Information management: data base and architecture	Central BI architecture with group data warehouse and documented information management for most important KPIs and their analysis	4, 5

5. EVALUATION

5.1. Prototype

To develop a prototype, we set up a project with a large, international chemicals group, with SAP as the software provider and a BI company as the implementation partner. Applying the design principles (Section 4.2), we built a prototype we call the Corporate Navigator. In a first step, we analyzed the SBOs, processes, and organizational structures of the chemicals group. In a second step, we determined information and functional IS requirements. We began by analyzing the company's existing management reporting and conducted structured interviews with six executives. We then challenged the business requirements we identified with our design principles to produce an applicable specification. In a third step, we derived the data model and IS architecture to support information management as well as the user interface of the Corporate Navigator.

To implement the EIS, we customized SAP's Business Objects (BO) dashboards software (former BO Xcelsius) and used SAP business warehouse (BW) as our central database. Table IX outlines the prototype specifications. Figure 5, in turn, shows the three-step reporting hierarchy and gives an impression of the Corporate Navigators' user-interface design.

5.2. Evaluation

The prototype was presented to six executives of large, international companies. With one exception, the companies had participated in our survey (Section 3.1). After trying

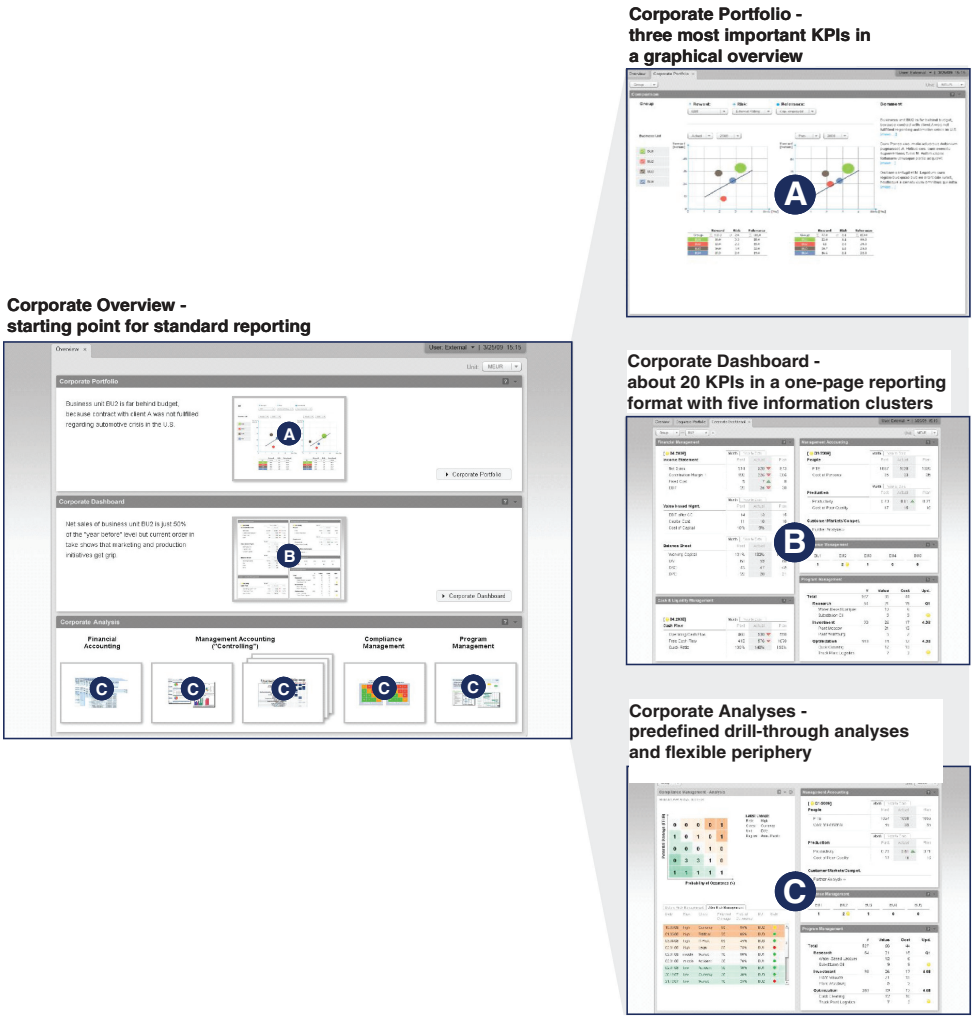

Fig. 5. Corporate Navigator prototype – three-step reporting hierarchy of a redesigned EIS.

out the prototype, the executives evaluated the Corporate Navigator using the same criteria as the survey (Figure 1). Their responses provide an indication of how well our principles support EIS design addressing the six gaps we identified in current EIS design.

All executives appreciate the comprehensive information model. Using accepted development methods and reference content makes information delivered by EIS more complete. Two executives mentioned that it is difficult to fully predefine the objective information need regarding a company's business model. As examples, they named different hierarchies, for example, for products, or country-focused versus central group steering logic.

Four executives mentioned that the prototype on hand is a clear improvement over both their paper-based reports and their intranet-based standard reporting without communication functionality. In doing so, they confirm that a more detailed functional

model with predefined analyses significantly improves information aggregation and verifiability.

Involving executives not only in analyzing their information needs but in designing the user interface and iteratively implementing the EIS leads to concise information presentation and easy-to-use IS handling. In our prototype, color coding is used exclusively to focus attention on new information and on important deviations. All the executives responded well to the three-step reporting hierarchy (Figure 5), intuitive mouse-click navigation, and self-explanatory symbols.

Because they could not really assess the prototype's flexibility, three executives gave a rating of "somewhat" for this criterion. However, the data warehouse approach we used allows new data sources to be integrated. Furthermore, all reports are self-contained and elements our modular approach can be exchanged without affecting the IS architecture. At the same time, the fact that every EIS requires an individual "fit" within the corporate BI architecture means no general template is fully adequate to this task.

Four executives stated that accuracy and consistency could only be assessed by using the IS "live" within their landscape, but all executives confirmed that a proper information management is very important to handle growing information load today. Finally, all executives appreciated the low costs for EIS redesign, implementation, and maintenance. The prototype also received high marks for time adequacy. As we have seen, delivering EIS projects on time is more complicated than staying within budget; a predefined model, design, and implementation approach should make staying on schedule easier.

Overall, the Corporate Navigator represents progress towards redesigning EIS and should help to improve the utility of these systems. As this approach is now SAP's reference model for "new-generation" EIS (www.sap.com/germany/campaign/2010_04_cross_corporate_navigator), we expect more feedback in the coming months.

6. CONCLUSION AND FUTURE RESEARCH

The objective of this article was to set out principles for redesigning EIS. The rich body of knowledge seems to suggest that requirements for them are known in detail and the resulting design principles are well established. However, our survey reveals gaps that demand an EIS redesign, especially in light of the increasingly positive attitude of today's executives toward IS and technological advances in the Internet era.

To close these gaps, we match existing EIS knowledge with new insights from our survey. Six design principles emerge: a comprehensive information model, functions to better analyze and process information, easy-to-use IS handling, a more flexible IS architecture and data model, a proper information management, and fast prototype implementation. Using a metamodel, we specify the design principles with a problem statement, a rationale, and implications in terms of method and model.

A prototype incorporates our findings. It differs from existing EIS by providing more complete information and functional capabilities via reference content for corporate management. A three-step reporting hierarchy ensures the required concise information presentation, while easy-to-use IS handling allows navigation through the different analysis levels. Finally, a flexible periphery provides ad hoc analysis, nonroutine information, and direct links to upstream IS in addition to this standard reporting.

The small number of instantiations so far makes it impossible to definitively determine whether our design principles will meet executives' objectives of being more business-driven and applicable in practice than the state-of-the-art. At a minimum, the results should contribute to an ISDT for redesigning EIS.

The small sample size of the survey represents another limitation. Furthermore, the design and evaluation entail some subjectivity. Insights from the long-term use of the

prototype will guide our future research. Additional instantiations should determine the generalizability of our design principles. Moreover, another survey is underway to identify different executive working styles, EIS use cases, and EIS access modes. This is to develop an IS approach that better meets executives' individual needs. Another research avenue is the question of whether the Web 2.0, with its more interactive and collaborative features, will influence a next EIS redesign. At the moment, blogging and twittering seem far away even for today's more tech-savvy executives.

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