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Environmental Scanning Systems: State Of The Art And First Instantiation

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ENVIRONMENTAL SCANNING SYSTEMS: STATE OF THE ART AND FIRST INSTANTIATION

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Abstract

The 2008/2009 economic crisis provided a sustainable impulse for improving environmental scanning systems (ESS). Although a rich body of knowledge exists, concepts are not often used in practice. This article contributes a literature review addressing six findings for ESS design to become more applicable than the state of the art. They are structured by the elements of information systems (IS) design theories. Addressing the lack of a sound requirements analysis, our first finding proposes a 360-degree ESS for executives' "managing a company" task and presents how to select just the most important scanning areas to keep focus. Three other findings cover the IS model perspective focusing on a better "grasp" of weak signals: define concrete indicators and use IT to identify relevant cause-effective-chains, leverage IT to automate day-to-day routines and monitor the variety of indicators' movements, and leverage expert experience and translate indicators' impact into a balanced opportunity-and-threat portfolio. From the methods perspective on ESS, we fifth propose to incorporate scanning results into executives' decision-making process more closely by generating scenarios from a set of assumptions and the development of indicators. Retrospective controls to update the ESS continuously and collaboration to share the scanning findings in day-to-day operation is our sixth finding. Finally, an instantiation at a large international company helped us validate our findings and to highlight how current developments in IS contribute to successful design, implementation, and day-to-day operation of new-generation ESS.

Keywords: Corporate management, balanced chance and risk management, business intelligence information systems (IS) design.

1 INTRODUCTION

The increasing volatility of a company's environment is a growing concern for today's executives. In particular, they worry about not being prepared for *environmental shifts* or—even worse—not being able to parry them. The 2008/2009 economic crisis gave a sustainable impulse for focusing earlier on emerging threats and opportunities (Hopwood 2009; Makridakis et al. 2010). *Environmental scanning*—ideally, IT-based within a corporate business intelligence[1] (BI) architecture (Wixom & Watson 2010)—can help to manage this challenge.

A company's environment could be defined as the relevant physical and social factors within and beyond the organization's boundary (Duncan 1972). While operational analysis focuses on internal difficulties in the implementation of strategic programs with the aim of fully leveraging identified potential, *strategic* environmental scanning, in turn, aims at anticipating (long-term) environmental shifts and analyzing their potential impact. This research concentrates on the latter referred to as "*environmental scanning*". Its main function is to gather, interpret, and use pertinent information about events, trends, and relationships in an organization's environment that would assist management in planning the future course of action (Aguilar 1967).

With Ansoff's (1975) article "Managing Strategic Surprise by Response to Weak Signals" as an example, a surprisingly rich body of knowledge exists, but it often goes unused in practice. Practitioners experience *difficulties* in designing, implementing, and operating environmental scanning systems (Albright 2004). Two information collection modes are distinguished (Choudhury & Sampler 1997): In contrast to the *reactive mode* in which information is acquired to resolve a problem, we follow the *proactive mode* in which the environment is scanned for upcoming changes that represent opportunities and threats (Fahey & King 1977). As a result, this article aims at ESS, which are conceived as structured, reticulated IT-based IS to allow executives to scan their environment from an overall perspective for a proactive corporate management.

The research presented here is twofold: we start with a review of related work for big picture thinking and then we demonstrate applicability of our findings. To do so, we follow v. Brocke et al.'s (2009) *five step model* with one modification: we arrive not only at future research questions, but apply our findings at a large international company.

Definition of review scope: We were motivated to pursue this topic by the identified gap between the rich body of knowledge on environmental scanning systems and survey results suggesting that these concepts are often not used in practice. *Conceptualization of the topic*: After revisiting foundations we derive a framework for categorizing the literature (Sec. 2). *Literature search and analysis*: We then lay open our literature search process (Sec. 3.1). Hereafter we describe the most important publications and the need for ESS, and we derive six findings (Sec. 3.2). *Demonstration:* The application of our findings from the literature research at a large international company provides direct feedback (Sec. 4). *Outlook and future research:* We close with an assessment of the research method presented here, its limitations, and an outlook for future research efforts (Sec. 5).

2 ELEMENTS OF IS DESIGN THEORIES

As an IS label to support *managerial* decision making, management support systems[2] (MSS) are proposed in the literature. They cover decision support systems (DSS), management information

[1] BI is a broad category of technologies, applications, and processes for gathering, storing, accessing, and analyzing data to help its users make better decision (Wixom & Watson 2010).

[2] Both, MSS (Clark Jr. et al. 2007) and DSS (Arnott & Pervan 2008) have been proposed as labels for IS intended to provide IT support for managerial decision making. Since DSS evolved from a specific concept that originated as a complement to MIS and was overlapped in the late 1980s with EIS, we refer to MSS on hand (Power 2008).

systems (MIS), executive information systems (EIS), more recently knowledge management systems (KMS), and business intelligence systems (BI, Clark Jr. et al. 2007)). *ESS*, in turn, have their roots in management literature focusing on the executives' task to be aware of environmental trends (Aguilar 1967). They specify the sectors to-be scanned and monitor the most important indicators that may create opportunities or threats for the organization Furthermore ESS cover the IT-based tools to be used (Narchal et al. 1987; Yasai-Ardenaki & Nystrom 1996), incorporate the findings of such analyses into executives' decision making, and often assign responsibilities to support environmental scanning (not covered in this article, but in Lenz and Engledow 1986).

Framework for literature systematization

Following Webster and Watson (2002) a literature review is concept-centric. Incorporating elements of IS design theories in combination with the research method offer a framework for structuring the literature (Figure 1).

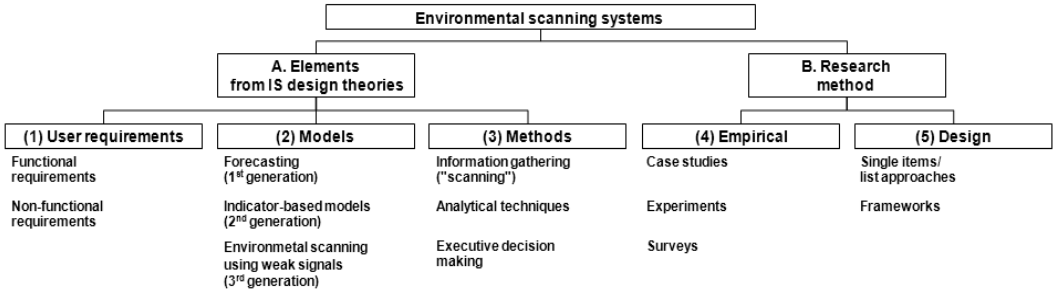

Figure 1. Framework for literature systematization.

Elements of IS design theories: According to Walls et al. (1992), IS design theories consist of three elements: (1) *Requirements* can be defined as prerequisites, conditions, or capabilities needed by users of software systems to solve a problem or achieve an objective (IEEE 1990). They delineate what IS should do, both from the functional and non-functional perspective (Dietz 2007; Kotonya & Sommerville 1998). Functional requirements address "what" IS should or must do (purpose of the IS). Non-functional requirements, in contrast, reflect "how well" IS perform within the given environment as it fulfills its function, e.g. response time and reliability (Paech & Kerkow 2004).

Designing ESS is not a Greenfield approach. For that reason, IS design theories cover guidelines for bringing the system to life. They contribute to methods and models. (2) *Models* outline concrete systems, features, or combinations of these (Gregor 2006). We distinguish between forecasting as the first generation of ESS, indicator-based systems as the second one, and environmental scanning using weak signals as the third generation. (3) *Methods* cover the process of environmental scanning. We differentiate between information gathering ("scanning"), analytical techniques to identify latent or pending changes; and the incorporation of the scanning results into executives' decision-making process.

Research methods: The type of research method is another dimension in our framework for systematizing the literature. Their distinction is important as it influences the granularity of requirements and design principles: from abstract findings by a survey regarding "appropriate technology" to detailed IS features from an in-depth case study such as "drill-down functionality to an upstream ERP" (Urbach et al. 2009).

(4) Papers are regarded as *empirical approaches* if they rely on observation and apply some type of empirical method. We differentiate between case studies to learn from single design, experiments, and surveys (Urbach et al. 2009). (5) *Design approaches* involve ideas and frameworks for creating a better world and provide more direct recommendations for IS (Walls et al. 1992). We go on differentiating between single items and broader "list" approaches that specify sets of requirements, design principles and frameworks that focus on the relationship between requirements and design principles.

3 LITERATURE ANALYSIS

Generally based on the Webster and Watson (2002) approach to literature review, we introduce our search strategy (Sec. 3.1). Then, we systematize the results of our literature analysis to discuss the most important publications allowing us to generate findings in order to improve the applicability of ESS (Sec. 3.2, in detail see Mayer et al. 2011)

3.1 Search Strategy

Following vom Brocke et al. (2009), we first perform a journal search. We focus on leading IS research outlets and select six of the most relevant IS journals[3] reflecting their ranking[4] and impact factor[5] (Webster & Watson 2002). Furthermore, we expand our list with proceedings from the two A-ranked international conferences listed by WKWI (2008): the International and European Conferences on IS (ICIS, ECIS). Second, we use EBSCO host, Google scholar, Science Direct, and Wiley Inter Science to access the journals. Third, the keywords "environmental scanning system" and "early warning system, weak signal, leading indicator" produce 14 relevant hits in total. Fourth, in our backward and forward search, we add the keywords "management support systems" and "business intelligence", leading to additional 13 IS articles. Finally, we did the same search on strategic management literature[6] coming up with another 53 hits. So, we end up with 80 relevant publications in total (Figure 2).

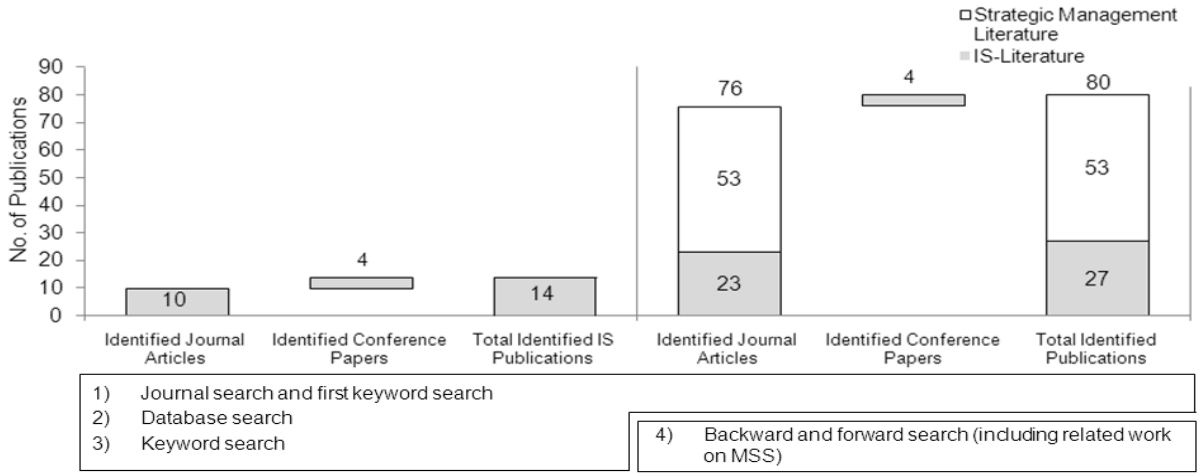

Figure 2. Selection of the relevant publications.

3.2 Results

Figure 3 presents the 80 publications identified as relevant within the framework we derived before. Along with our findings the most revealing publications are discussed below (For the full list of researched publications see Mayer et al. 2011).

[3] MIS Quarterly, Decision Support Systems, Information & Management, Journal of Management Information Systems, European Journal of Information Systems, and Information System Management.
[4] Based on journal rankings of AIS (2010); VHB (2008); WKWI (2008).
[5] We considered impact factors from http://www.elsevier.com.
[6] Strategic Management Journal (SMJ), Long Range Planning (LRP), Journal of Management Studies (JMS), Technology Analysis and Strategic Management (TASM), Academy of Management Review (AMR), Harvard Business Review (HBR).

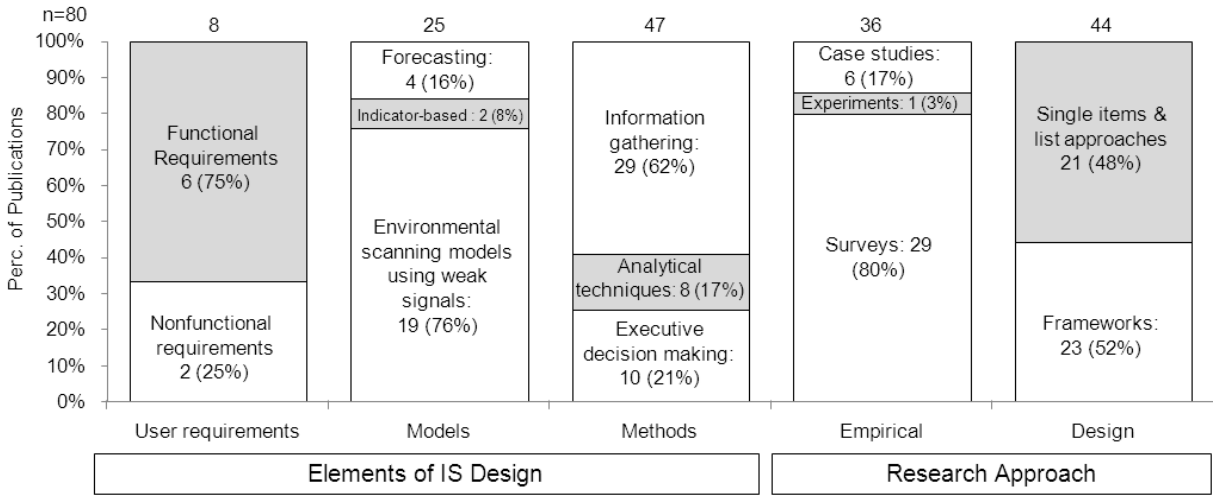

Figure 3. Classification of the publications.

User requirements

The first apparent issue is that just eight of 80 publications focus on requirements. The analysis of publications focusing on functional and non-functional requirements led to our first finding.

First finding: Because executives have the task of managing the company overall, a "360 degree" radar is suggested. Xu et al. (2003) conducted a cross-industry study and found that *task-related environmental areas* are perceived most important. The radar should reflect the organization's vision and *strategic program* (Yasai-Ardenaki & Nystrom 1996) and then follow the *value chain* for their scanning areas of procurement, production and sales (Fink et al. 2005). The most important *supporting areas* are capital supply, research and development, and human resources. Especially in volatile industries, the "*periphery*"—a metaphor, describing latent changes that can come e.g. from political movements—should be considered for environmental scanning (Day & Schoemaker 2004). Regarding Daft et al. (1988) the periphery should cover at least science, politics, law and justice and international relationships. Also, El Sawy (1985) should be considered who suggests focusing on just the most important areas.

Models

Out of our 80 articles, 25 publications cover models for environmental scanning. They can be distinguished into three generations: Early warning systems were first mentioned in the late sixties by Cohen & Zinsbarg (1967). These key-figure-oriented approaches are based on thresholds that define the range of tolerance. If a critical value is exceeded, an alert is triggered. Forecasting advances this technique using time series, not only for planned and actual data, but also planned and *extrapolated as-is data*.

Second generation ESS identify latent risks and chances. Such an indicator-based model is described by Davies et al. (2006). Their *key risk indicators* (KRI) are standardized indicators that focus on potential problems, e.g., staff turnover could signal inadequate human resources performance. Since random or natural fluctuations occur, they *recommend reference values and ranges of tolerance* to avoid overreactions.

After companies failed to act proactively on the oil-crisis, Ansoff introduced the concept of *weak signals* in 1975. An example of a weak signal is the spread of carbon fibre. Its usage has increased steadily in recent years and its potential to serve as a substitute for steel now represents a strategic issue for steelmakers. Weak signals often lack "grasp" for direct interactions (Rossel 2009). But Ansoff's concept is still topical in recent literature. In fact, 76% of publications about models use his approach. Therefore we stick to that concept with the aim to improve their missing "grasp".

Second finding: Define concrete indicators and use IT to identify relevant cause-effective-chains. Based on our literature review, we see two levers to improve weak signals "grasp": first, distinguishing relevant indicators foreseeing changes from the mass of available data (Narchal et al. 1987) and give guidelines on how to identify patterns attaining their strategic advantages for the organization (Aguilar 1967). Following Davies (2006), we propose as evaluation criteria indicators' lead time, clarity, and their appropriate cost-/impact ratio (Sec. 4.2). Second, the barriers preventing people from identifying and processing weak signals can be circumvented with IT (Frolick et al. 1997; Hand 2009). Structuring data, artificial neural networks, data mining, and semantic search should receive greater attention as ways to extract cause-effective-chains (Elofson & Konsynski 1991). So, IS researchers should therefore focus on exploring techniques to extract non-trivial, implicit, previously unknown and potentially useful patterns.

Third finding: Leverage IT to automate day-to-day routines and to follow the variety of indicators' movements. In a third step, data sources and the frequency of data collection must be determined. We particularly emphasize the Internet (Chen et al. 2011) as well as capital markets (Plambeck & Weber 2010) as data sources, because they have an inherent good cost/benefit ratio at least for basic information generation. The use of supportive, predefined and easy-to-handle user interfaces for data access or common IT languages, such as XBRL (eXtensible Business Reporting Language), facilitate accessing relevant information sources by automated routines to systematically monitor the movements of the most important indicators.

Methods

Aguilar (1967) was the first to examine four different modes of scanning, namely undirected viewing, conditional viewing, informal search and formal search. *Attaining strategic advantages* by *information gathering* have been of high interest and therefore 62% of articles on methods refine the concept.

Several *analytical techniques* can be distinguished: mathematical methods facilitate a systematic integration of quantifiable figures into ESS. But the 2008/2009 economic crisis showed that such models have significant shortcomings for ordinary users. Often premises were too complicated (Makridakis et al. 2010) or the use of confidence intervals in value-at-risk models excluded improbable, high-impact events (Fuld 2003). Taleb et al. (2009) also criticize these models because even small errors in the assumptions underlying the distributions can be devastating. Heuristic approaches, e.g. the Delphi method (Dalkey 1969), influence diagrams (Narchal et al. 1987) or cross-impact matrices (Fontela 1976) are alternatives.

Fourth finding: Leverage expert experience with an impact matrix and translate indicators' impact into a balanced opportunity-and-threat portfolio. Instead of using complex mathematical models, we propose a heuristic approach based on the delphi method and cross impact analysis (Mayer & Wurl 2011). A basic understanding of risks and their implications on organizations' performance is more important than pseudo-exact calculations.

For *executive decision making*, one dimensional performance measurement systems often do not suffice to meet the complete information need. Furthermore, Fuld (2003) showed that companies often fail to act on generated environmental scanning information.

Fifth finding: Incorporate scanning results more closely into executives' decision-making process by generating scenarios from a set of assumptions. To ensure that executives receive scanning findings in an amount and form that facilitates effective decision making, their reporting should cover critical opportunities and threats (Ansoff 1980). Large deviations in the values of single indicators or in assumptions should be reported ad hoc as "breaking news" or "turning points". We propose linking the identified opportunities and threats with a companies' management control (Frolick et al. 1997).

Sixth finding: Use retrospective controls to continuously update the IS and collaborate to share the scanning findings in day-to-day work. In addition to ad hoc reporting, a periodical presentation of findings helps to identify the most probable scenario and critical assumptions for the next planning period. Since scenario-technique is a laborious task, scenarios are not set up every month as it would

not meet the efficiency criterion. Instead the scenarios are further developed by the planning. The indicators give hints about the future state of assumptions. Assumptions should be verified and methods applied should be checked for modifications due to new findings. In day-to-day work, group-ware allows e-mailing and other forms of collaboration (Salmeron 2002).

Research Approach

Empirical evidence: Fuld (2003) showed the lack of an early warning system in 97% of the U.S. companies he surveyed. Interviews with 140 corporate strategists found that two-thirds had been surprised by as many as three high-impact competitive events in the past five years. Following Krystek & Herzhoff (2006), 30% of European chemicals companies do not have strategic ESS in place. 15% said that the instruments available are not sufficiently accepted to be used in practice. Day & Schoemaker's (2005) survey of global managers found that 81% perceived their future need for peripheral vision to be greater than their current capacity. Similar findings are reported from companies within the Financial Times "Europe 500" report (Mayer 2010): most of the executives consider environmental-scanning concepts to be too complex and even too difficult to implement. Therefore, results are not a substantial part of executive decision-making process.

Design approach: We classified 44 design approaches. 21 frameworks balance the 23 single items and list approaches. To install early warning capabilities, e.g. Gleißner & Füser (2000) propose to employ *Artificial Neural Networks* to support early warning capabilities in corporations. In contrast to humans, they are not limited by psychological barriers. Moreover they can deal with many different variables coincidentally—as needed to handle the potential span of indicators. They are self-learning and they can cope with contradicting information. Due to the limited human information processing capabilities, Frolick et al. (1997) show how to *embed environmental scanning systems* into executive information systems. EIS can enhance identifying issues, establishing means of scanning, and incorporating anticipated changes in the planning and reporting.

MSS and environmental scanning

To complement our results, we also consider findings from contemporary related MSS work. Understanding BI in a broader sense, Goul and Corral (2007) ask for *data warehouses* (DWH) to include information about external issues such as competitors or regulations and to provide measurability of the strategic advantages. Lönnqvist and Pirttimäki (2006) performed a literature review to evaluate existing methods for measuring the *value of BI* within the organization. For example user satisfaction gives an insight. Those measurement approaches should be checked for applicability to evaluate ESS.

Using value at risk (VaR, Chen et al. 2011) and unstructured data from BI can predict financial market risk and thus should contribute to environmental scanning. Recent developments in the www, namely web 2.0, and incorporated social networking, provide useful information on customers and competitors. For example, customers that judge their goods bought offer useful strategic information on products quality and future offers (Chen et al. 2011). Besides the internet, also capital markets provide useful information on customers, suppliers, competitors, and the economic development (Plambeck & Weber 2010). They can deliver future perspectives, e.g. on growth rates of economies or net sales of organizations.

4 DEMONSTRATION

The literature systematization in Sec. 3.2 reveals major gaps in research to overcome for more applicable ESS. The "corporate radar" (Mayer 2011) alludes to the findings from our literature analysis. We incorporate it at a large, international company to make the findings more concrete and provide feedback on them (Sec. 4.2).

4.1 Company description

During the 2008/2009 economic crisis, both, the business side and IT department recognized that they could contribute significantly more to executives' decision making with information about potential opportunities and threats. The company from the basic materials sector (Europe, sales: USD 56 bn; employees: 174,000) required a 360-degree environmental scanning system. The CIO was charged with two main objectives: Enhanced analysis should provide more information on their company's environment—going beyond standard business parameters to analyze the events, trends and forces that could radically alter the future of the company. To incorporate the findings into executives' decision making, a rigorous integration of the environmental scanning findings into group reporting was mandatory.

For a long time value-based management has been the basis for making decisions in this organization. It uses an Economic Value Added (EVA) concept, drawing on Earnings Before Interest and Tax (EBIT) which had already been an accepted KPI when value-based management was introduced (Figure 4).

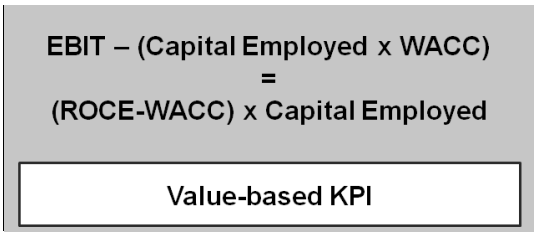

Figure 4. The steering logic is based on value-based KPI.

The corporate risk management is part of corporate controlling, which coordinates the value management system at strategic and operating levels and optimizes the control processes. Through top-down system defaults and bottom-up risk-responsibilities, the company complies with regulatory requirements. Basic agreements are relevant across the group. Corporate controlling is responsible for further development of the risk management system. In this context required tools and processes are developed and provided by corporate risk management. Thus the integration of the environmental scanning system is driven in corporate controlling.

4.2 Instantiation

Applying the findings from our literature review had the following outcome:

First, scanning areas differed according to the strategic business unit. While there were regional differences, area importance was also perceived differently according to the business segment.

Second, when selecting and working with indicators, the following aspects turned out to be applicable guidelines (Figure 5).

Figure 5. Guidelines to determine the relevance of indicators.

Clarity: The cause-and-effect chain should be unambiguous. *Lead time*: The more the lead time the easier indicators can be used for proactively steering a company. *Availability*: Critical indicators that cannot be monitored on time cannot help in the decision making process. *Cost effectiveness*: Ideally, indicators and the associated costs are low. *Completeness*: Threats and opportunities from scanning

areas should be described without any gaps. *Reliability*: If indicators alert for no reason, the integrity of the whole environmental scanning system will be at risk. An example for an indicator meeting all these requirements is the Baltic Dry Index: it measures the rates charged for dry-bulk vessels, indicating overall economic development, which influences the scanning area "sales".

Third, a trade-off is necessary between the cost of data collection, such as license fees of data sources, costs of additional employees, or the reporting system itself and its ability to indicate potential opportunities and threats. Often indicators from internal data sources are already used in a different context. But it turned out to be critical, to not overcharge local units. Currently a kind of newsletter is developed to regularly inform local units about most important global indicators to support their scanning activities.

Fourth, the balanced opportunity-and-threat portfolio draws on the results of the analysis quantifying the impact of each individual indicator on the most important threats and opportunities (Fontela 1976). On the left hand side in Figure 6 the indicators, their scoring according to threats and opportunities (x-axis) and their estimated lead time (y-axis), are shown. The bundling is used to derive the associated opportunities and threats for the organization (right hand side): We chose this visualization because it is comprehensive in terms of content and it represents a condensed overview about the most important opportunities and threats for the organization.

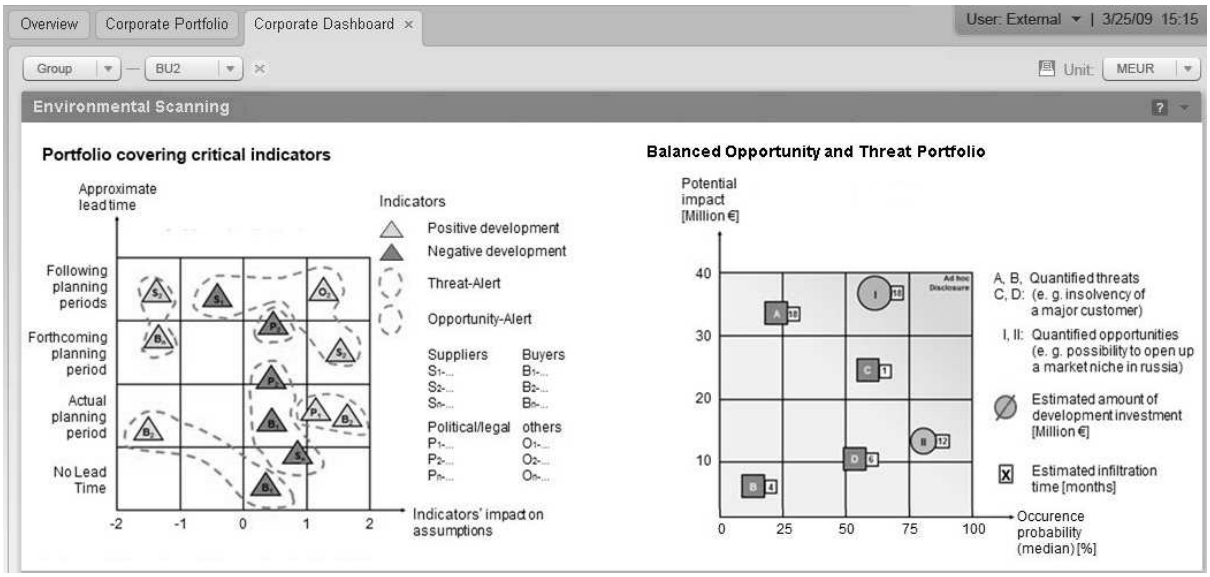

Figure 6: Deriving and quantifying opportunities and threats in a balanced opportunity-and-threat portfolio.

Fifth, to provide executives with environmental scanning results, we linked them with the management control logic, which took the form of an economic value added at risk tree. Once the indicators and the associated opportunities and threats have been identified, they should define three scenarios (Fontela 1976)—optimistic, most probable and pessimistic—covering the set of opportunities and threats that the organization faces due to environmental changes (Narchal et al. 1987). It is easier to define a range of tolerance for a development than to define the whole distribution function, as necessary in mathematical approaches.

A user-friendly interface ("frontend") should provide the scenario visualization that allows switching between the best, worst and most probable scenarios (Figure 7, left hand side). The best and worst case scenarios define the range of the most important value drivers such as net sales and costs. Because of the mathematical connections between them, also ranges for the financial performance indicators EBIT, ROCE and EVA (Figure 7, right hand side) are defined as well. The slider position shown here represents the most probable scenario. All drivers can be moved to the right or to the left to simulate changes no matter which scenario is selected. Furthermore, on an ad-hoc basis, "breaking news" and "turning points" that refute prior assumptions can be helpful.

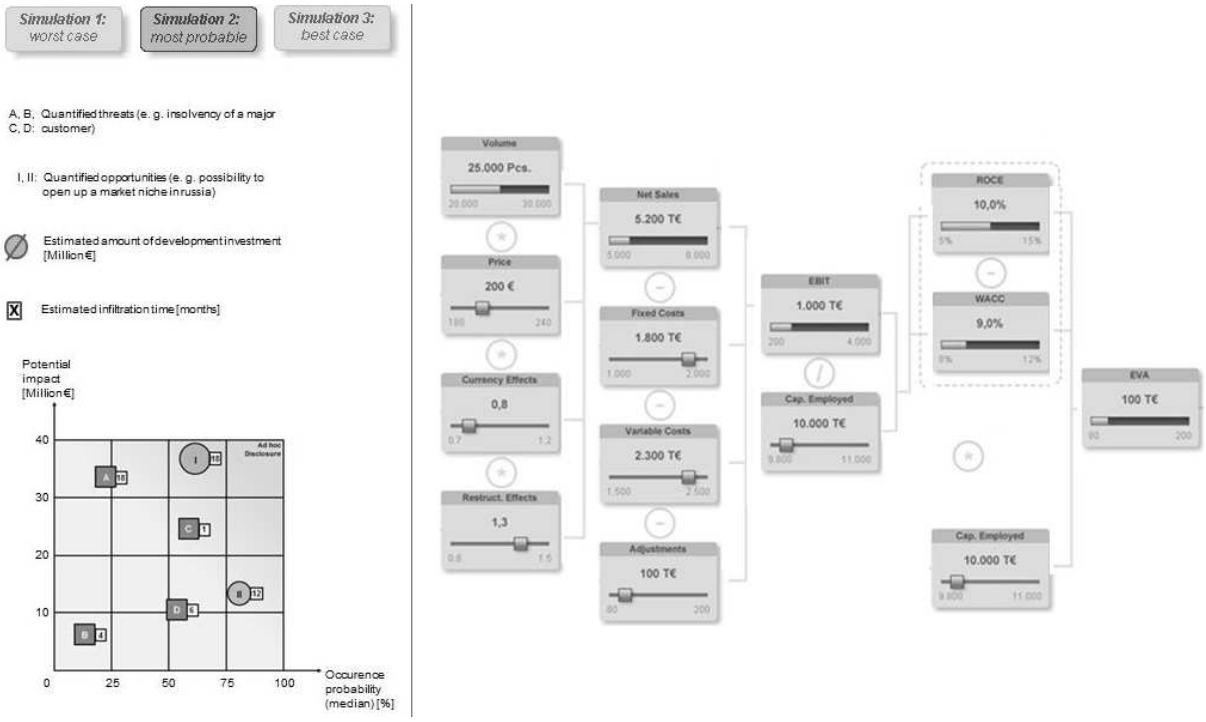

Figure 7: Incorporating the results of ESS into executives' decision making by scenario technique (first instantiation).

Sixth, for day-to-day operations another two ideas are discussed concerning new IT capabilities for ESS: First, today paper-based reports still define how decisions are made in executive boardrooms. In addition to high-performing frontends (software perspective), interactive screens (hardware perspective) will turn future company boardrooms into "management centers", helping executives stay up to date, get the big picture, and focus on what's important in interactive discussions (Figure 8, right hand side). Second, new end-user devices for mobile computing will make the information available to executives not only working in their individual office, but moving among several offices, and "on the road" (Figure 8, left hand side).

Figure 8. New-generation end-user devices.

Since it was an interdisciplinary project, project managers can establish their role in new-generation ESS systems if they can act as mediators between business requirements and IT capabilities. The most important analyses were useful in achieving a second type of alignment: one between business requirements and increasing IS capabilities. By connecting the right parties across the company, the CIO as the project manager brought in an interdisciplinary business/IT perspective that made him the ideal mediator in the course of the design.

5 OUTLOOK AND FUTURE RESEARCH

The objective of this article was to contribute to develop ESS that are more applicable than the state of the art. To do so, we conducted a *literature analysis* structured by the elements of IS design theories.

We came up with six findings to overcome this gap and demonstrated improvements in an instantiation at a large international company.

Comparing the findings with the state of the art reveals some points worthy of discussion. On the one hand, literature based findings offer greater rigor than action research does. Another limitation is that the synthesis entails *subjectivity*. In short, the validity of the derived findings could have been increased if more researchers had been involved. Furthermore the number of case studies needs to be increased. It is not possible to derive guidelines that are universally valid from a single instantiation. In our future research agenda, we are going to expand our research to a few more case studies to evaluate our findings.

Regarding *IS* in environmental scanning, we expect *ongoing innovations*. Today's executives grew up with IT and have a more natural attitude toward IS. New technologies have been established in the field of corporate BI, such as EIS, which have evolved from a single-system approach to an integrated module in powerful data warehouse environments. Moreover, new user interfaces and end-user devices, especially for mobile computing, should simplify IS handling. Hence, ESS should claim a position in the domain of MSS (Sec. 2) as it focuses on forward looking information for executives to manage their organizations.

For future research it is important to specify the findings on hand with further "build" and "evaluate" activities. A valuable contribution could be a *survey* to get a direct perspective on executives' requirements and to evaluate the findings in a broad sample. If someone may come to the conclusion that the body of knowledge from literature research is more wishful thinking than a sound basis for applicable design principles, it would be interesting to define a set of evaluation criteria, take successful implementations from practice, evaluate them, ascertain what they have in common and compare these findings with the first design principles presented on hand. Our own research will use additional instantiations to determine the generalizability of the findings on hand and, hopefully, the forthcoming extensions.

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