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ORIGINAL ARTICLE

More applicable environmental scanning systems leveraging "modern" information systems

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Abstract With Ansoff's article about weak signals as a flagship example, a substantial body of knowledge about environmental scanning systems exists. However, these concepts often go unused in practice. The 2008/2009 economic crisis provided a strong, ongoing impulse for redesigning such information systems (IS). This article develops six guidelines for the conceptual design of environmental scanning systems that are more applicable than those specified by previous research. We start with literature research, which reveals three gaps in existing approaches. Then we develop design guidelines to fill these gaps with the help of "modern" IS. To address the lack of sound requirements analysis, our first design principle proposes 360-degree environmental scanning systems for executives and suggests how to select the most important scanning areas. Three further findings cover weaknesses in the IS model perspective, focusing on more effective implications of weak signals. In terms of method, we propose incorporating scanning results more closely into executives' decision-making processes. Applying the design guidelines at a raw materials and engineering company, we arrive at a prototype we call the "corporate radar." It includes an IS-based tree with economic value added at risk on top. The

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resulting lessons learned help to evaluate our findings and the research method presented here, as well provide concrete starting points for future research.

Keywords Corporate management · Balanced threat and opportunity management · "Modern" information system technology · Information systems (IS) design

1 Introduction

The increasing *volatility* of company environments is a growing concern for 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 provided a strong, ongoing impulse for focusing earlier on *emerging threats and opportunities* (Hopwood 2009; Makridakis et al. 2010) and the volatile environment in 2011/2012 ensures that this topic stays relevant (Cinar and Gulgun 2010). *Environmental scanning*—ideally, based on information systems (IS)—can help to manage this challenge. The functions of such scanning systems are to gather, interpret, and use pertinent information about events, trends, and relationships in an organization's environment to assist management in planning the organization's *future course of action* (Aguilar 1967). Because environmental scanning leads to a fact-driven decision-making process and additional time for proactive corporate management (Rohrbeck 2011), companies that use these IS will have brighter prospects than those that do not (Ansoff 1980).[1]

With Ansoff's (1975) article "Managing Strategic Surprise by Response to Weak Signals" as a flagship example, a substantial body of knowledge exists, but these concepts often go unused in practice (Krystek and Herzhoff 2006; Day and Schoemaker 2005). Practitioners perceive the task as a difficult one per se (Lesca and Caron-Fasan 2008), and some may not even know how to start (Albright 2004).

Increasing acceptance of IS among today's executives (Vodanovich et al. 2010) and the technological advances of the Internet era (Cheung and Babin 2006) make the present moment favorable for an environmental scanning redesign. Focusing on the role of "modern" IS, this article develops guidelines for the conceptual design of environmental scanning systems that are more applicable than those specified by previous research.

We follow the tenets of design science research (DSR) in IS, which aims to create useful artifacts that solve relevant design problems in organizations (Hevner and Chatterjee 2010). Focusing on "build" and "evaluate" activities (March and Smith 1995), we apply the six-step research process model outlined by Peffers et al. (2006). The first step is to identify a problem and motivate the research. The 2008/2009 economic crisis showed that environmental scanning could help executives to focus earlier on emerging threats and opportunities. The next step is to define objectives for an (IS) solution. After revisiting foundations (Sect. 2) and the need for improving

[1] Some may argue that improvisation could be an alternative approach (Ciborra 1999). However, in light of the homo oeconomicus theory (Ménard and Shirley 2008), we believe the best way to tackle the increasingly volatile environment is to reason with cause-effect chains based on a sound framework consisting of the most important scanning areas (in detail, Sect. 4.4).

environmental scanning systems (Sect. 3), we perform literature research to identify discrepancies between concepts and their use in practice. We assume that addressing gaps in the body of knowledge would bring substantial gains (Sect. 4). Step 3 contains the designing and developing activities. For us, this entails giving a structure to existing guidelines and adding new ones to fill the gaps to complete our approach (Sect. 5). To accomplish step 4, demonstrating the new approach, we apply the findings at a raw materials and engineering company to create a prototype which we call the "corporate radar" (Sect. 6). Step 5 involves evaluation: here, lessons learned from the prototype provide feedback on our findings and the research method presented (Sect. 7). The final step is to communicate the results: our key findings provide concrete starting points for future research (Sect. 8).

2 Foundations

A company's *environment* covers relevant physical and social factors within and beyond the organization's boundary (Duncan 1972). While operational analysis focuses on (short-term) difficulties in the implementation of strategic programs with the aim of fully leveraging identified potential (Davies et al. 2006), *strategic* environmental scanning, in turn, aims at anticipating (long-term) environmental shifts and analyzing their potential impact. This article concentrates on the latter, hereafter referred to as "*environmental scanning*." As strategic issues can emerge both within and outside a company, environmental scanning reflects changes in both the external and internal environment (Ansoff 1980).

The literature suggests "management support systems (MSS)" as a label for IS to support managerial decision making. The term MSS covers management information systems (MIS), decision support systems (DSS), executive information systems (EIS) and, more recently, knowledge management systems and business intelligence[2] (BI) systems (Carlsson et al. 2009). *Environmental scanning systems*, in turn, have their roots in management literature (Aguilar 1967) focusing on executives' need to be aware of environmental trends (Narchal et al. 1987). They specify the sectors to be scanned, monitor the most important indicators of opportunities or threats for the company, cover the IS-based tools to be used (Yasai-Ardekani and Nystrom 1996), incorporate the findings of such analyses into executives' decision making processes and, often, assign responsibilities to support environmental scanning (not covered in this article, but Lenz and Engledow 1986).

Choudhury and Sampler (1997) distinguish two modes of information collection: reactive and proactive. 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* opportunities and threats. As a result, this article looks at environmental scanning systems conceived as structured, reticulated IS that allow executives to scan their environment from an overall perspective for proactive corporate management.

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

3 Improving environmental scanning systems

3.1 Regulatory needs

Environmental scanning is not just "nice to have," as Kajüter (2004) shows in his multicountry comparison. In the wake of several cases of fraud around the turn of the millennium that were neither detected by internal controls nor by auditors, legislators expressed a need for a more detailed approach to risk management. The best known example is the U.S. *Sarbanes–Oxley Act*. In particular, Section 404 requires companies listed on the New York Stock Exchange to extensively establish, document, and maintain internal controls; establish independent audit committees; and conduct mandatory audits of internal controls' effectiveness (Sherman and Chambers 2009). Furthermore, financial statements are normally prepared on the assumption that a company will continue operating for the foreseeable future (IASB Framework 4.1; ISA 1.25). This requires forecasts of at least 1 year (Choo 2009). In the wake of the 2008/2009 economic crisis, such "going concern" assessments have gained increased importance.

3.2 Empirical evidence

Fuld (2003) exposed that 97 percent of 140 corporate strategist surveyed said their companies have no early warning system in place. Furthermore two-thirds of them had been surprised by as many as three high-impact events in the past 5 years. According to findings from a survey by Krystek and Herzhoff (2006), 30 percent of European chemical companies do not have environmental scanning systems in place. 15 percent said the instruments available are not accepted for practical use.

Day and Schoemaker's (2005) survey of managers found that 81 percent considered their need for scanning capabilities to exceed their current capacity. Other statements come from companies listed in the FT "Europe 500" report (Mayer 2010): executives consider environmental-scanning concepts to be too complex and even too difficult to implement. Therefore, we propose that findings of environmental scanning play no substantial role in executives' decision-making processes in most cases.

4 State of the art

4.1 Framework for literature systematization

Following Webster and Watson (2002) a literature review should be concept-centric. Looking at elements of IS design theories in combination with their research method used offer a rigorous framework for structuring the literature (Fig. 1). The framework is taken from prior work (Mayer et al. 2011) and the findings are based on Mayer (2011), expanded with another five publications (Mayer 2012).

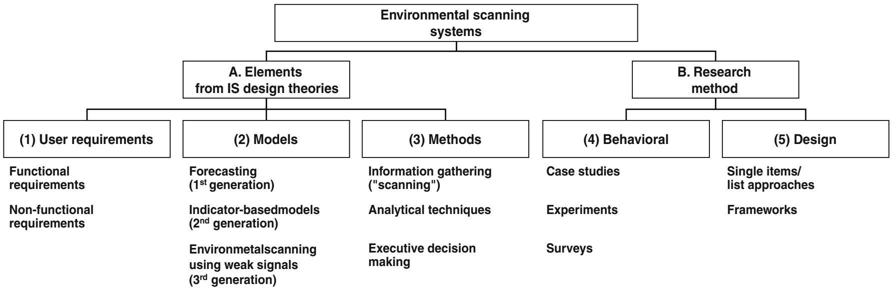


Fig. 1 Framework for literature systematization. Taken from prior work: Mayer et al. (2011)

4.1.1 Elements from IS design theories

According to Walls et al. (1992), IS design theories consist of three elements: (1) *Userrequirements* can be defined as prerequisites, conditions, or capabilities needed by users to solve a problem or achieve an objective (IEEE 1990). They delineate what IS should do in two respects (Kotonya and Sommerville 1998). Functional requirements address "what" IS should or must do; i.e., their purpose. Non-functional requirements, in contrast, reflect "how well" IS perform in the given environment, e.g., in terms of response time or reliability (Paech and Kerkow 2004). (2) *Models* outline concrete systems, features, or combinations of these (Gregor 2006). We distinguish between forecasting as the first generation of environmental scanning systems, indicator-based systems as the second, and environmental scanning using weak signals as the third. (3) *Methods* cover the process of environmental scanning. Here, we differentiate between information gathering ("scanning"), analytical techniques to identify latent or pending changes ("use"), and the incorporation of the scanning results into executives' decision-making process ("interpretation").

4.1.2 Research methods

The research approach influences the granularity of requirements and design guidelines (Urbach et al. 2009)—starting with high-level findings from a survey regarding "appropriate technology" to detailed IS features such as "drill-down functionality to an upstream ERP." (4) Papers with a *behavioral focus* explain phenomena from practice and, therefore, rely on observation and empirical methods. These can take one of three forms: case studies to learn from a single design, experiments, and surveys. (5) *Design approaches* involve ideas and frameworks for creating a "better world" and provide more direct recommendations for IS (Walls et al. 1992). They can focus on a single item or broader lists of items, or they can specify frameworks (sets of requirements and design guidelines).

4.2 Search strategy

Our literature search strategy follows Vom Brocke et al. (2009) four-step process. First, using the MIS Journal Ranking (AIS 2007), we selected six of the most

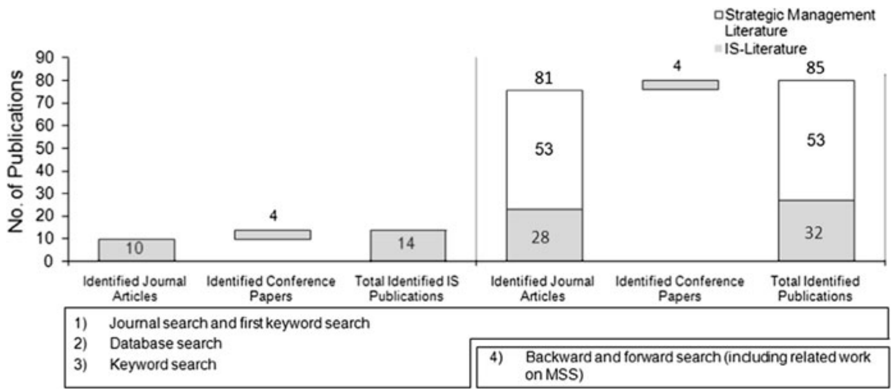


Fig. 2 Selection of the relevant publications. Based on: Mayer (2011, 2012)

relevant IS journals[3] in terms of ranking[4] and impact factor (Webster and Watson 2002). Furthermore, we expanded our list with proceedings from the two "A"-ranked international conferences in this field: the International and European Conferences on IS (ICIS, ECIS). Second, we used EBSCO host, Google scholar, Science Direct, and Wiley InterScience to access the journals. Third, we performed a search using the keywords "environmental scanning system" and the terms "early warning system, weak signal, leading indicator," producing 14 relevant hits (left hand side, Fig. 2). Fourth, we generated another 53 hits with a backward and forward search of strategic management literature.[5] We completed the literature search with related work from the area of MSS (including DSS, MIS, EIS, KMS, and BI, see Sect. 2), leading to another 18 IS articles on environmental scanning systems. In the end, we arrived at 85 relevant publications in total (right hand side, Fig. 2; in detail Table 1 of Appendix).

4.3 Related work

Figure 3 presents the 85 publications within the framework described in Sect. 4.1. A comprehensive *requirements analysis* (Sect. 4.3.1) is the proper starting point for information systems (IS) design (Walls et al. 1992). In terms of the *model perspective*, we focus on translating weak signals into action and on how to start working with environmental scanning (Sect. 4.3.2). From the *method perspective*, we identify articles that help to incorporate findings from environmental scanning into executives' decision making processes (Sect. 4.3.3).

The most conceptually and practically relevant publications are discussed below. Their insights allow us to develop guidelines for environmental scanning systems

[3] MIS Quarterly, Decision Support Systems, Information and 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), and WKWI (2008).

[5] 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).

(Sect. 5) that are more applicable than the state of the art (Sect. 7). In doing so, we focus on the elements of IS design they cover, because this matters more for developing design guidelines than the way the findings were generated.

4.3.1 User requirements

Just six out of 85 publications focus on functional requirements. Of particular relevance is Xu et al. (2003). To develop a corporate radar, these authors conducted a cross-industry study and found that *task-related environmental areas* are perceived to be more important than more distant, general environmental information. For example, in the computer and electronics industry, the supplier sector was assessed as a fundamental area for environmental scanning. The remaining five studies reviewed executives' functional requirements in terms of their scanning practices. For example, Yasai-Ardekani and Nystrom (1996) emphasize a link between scanning areas and *strategy*. Especially in volatile industries, environmental scanning should consider the "*periphery*"—a metaphor describing latent changes due to, e.g., political movements (Day and Schoemaker 2004). As described in Daft et al. (1988), at the minimum this periphery should cover *science, politics, law and justice, and international relationships*.

Just two references focus on the non-functional perspective. El Sawy (1985), for example, deals with executive scanning requirements and suggests that solutions should cover a *limited number of scanning areas and sources*.

4.3.2 Models

Of our 85 articles, 25 publications cover models for environmental scanning. Early warning systems were first mentioned in the late 1960s by Cohen and 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 *plan and actual data*, but also *plan and extrapolated as-is data.*

Second-generation environmental scanning systems identify latent threats and opportunities. 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., high staff turnover could signal inadequate performance by Human Resources. Since random or natural fluctuations occur, the authors recommend *reference values and ranges of tolerance* to avoid overreactions.

After companies failed to act proactively on the oil crisis, Ansoff (1975) introduced the concept of strategic surprises and weak signals. The spread of carbon fiber offers an example. Use of this material has increased steadily in recent years, and its potential to serve as a substitute for steel represents a strategic issue for steelmakers. If not monitored, this situation could create serious difficulties in adopting production capacity to changes in the environment. In the 1990s, Rockfellow (1994) identified the passage of "green taxes" which could have been an indicator of an imminent no-carbon economy. As the latter example illustrates, weak signals can turn out to be overvalued. Generally, their implications may be difficult. Furthermore, it may even be problematic to distinguish them from inconsequential day-to-day fluctuations. Weak signals thus lack the "grasp" to apply in practice due to the fact that they do not necessarily correspond to real events or processes. Therefore, some practitioners may not even know how to work with weak signals (Rossel 2009; Albright 2004).

In any case, Ansoff's concept is still highly important in recent literature. As shown in Fig. 3, 19 out of 25 references about models for environmental scanning systems (76 percent) use his approach. Finally, Narchal et al. (1987) claim that *systematic scanning and monitoring* is more effective in predicting future developments than ad hoc scanning. To make such scanning possible, they stress descriptors indicating developments in the environment, and argue for quantifying *dynamics* within the scanning areas.

4.3.3 Methods

Aguilar (1967) was the first to examine four different modes of scanning, namely undirected viewing, conditional viewing, informal search, and formal search. *Attainingstrategic advantages* by gathering information is a subject of great interest; 62 percent of the articles on methods refine this concept.

The literature distinguishes analytical techniques for environmental scanning, which account for 17 percent of the researched publications. *Mathematical methods* facilitate the systematic integration of quantifiable figures into environmental scanning systems, but, as the 2008/2009 economic crisis showed, they have shortcomings for practitioners. Often, their premises are too complicated (Makridakis et al. 2010) or the use of confidence intervals excludes improbable, yet high-impact events (Fuld 2003). Heuristic approaches, such as the Delphi method, can serve as alternatives (Ansoff 1980). The *Delphi method* is a three-step process. First, responses from experts to a topic are collected anonymously using questionnaires. Second, feedback is provided to the experts in several iterations. Finally, once the results have stabilized, an aggregated group response is determined (Dalkey 1969). Narchal et al. (1987) recommend *influence diagrams* focusing on levers and their

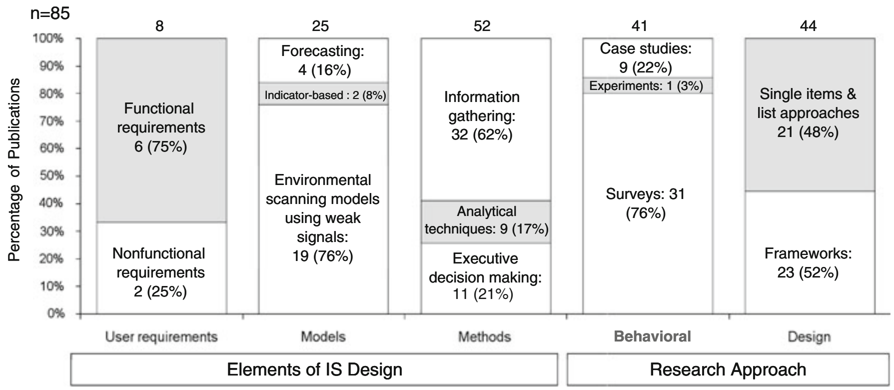


Fig. 3 Classification of the publications. Taken from prior work: Mayer (2012)

impact on environmental indicators. In order to model dependencies between separate items, *cross-impact matrices* evolved (Fontela 1976). Some researchers also argue that such matrices can contribute to finding the most probable future *scenario*.

One-dimensional performance measurement systems often do not meet a company's complete information needs. More importantly, Fuld (2003) showed that companies often fail to act on information generated by environmental scanning, either by measuring the impact of identified opportunities and threats on (financial) performance indicators or *incorporating the results of environmental scanning systems in executives' decision making processes* per se. Frolick et al. (1997) argue for embedding EIS into the environmental scanning process at different stages: when identifying issues, establishing the means of scanning, delineating sources of external information, and making decisions. Finally, EIS can help to incorporate anticipated changes into planning and reporting.

Value at risk (VaR) is a *common indicator* for monitoring market risks (Young et al. 2011). However, Makridakis and Taleb (2009) argue against the application of mathematical methods, because even though these methods' assumptions, such as Gaussian distributions, may fit historical data, such models are not suitable for predicting events with unknown probability and impact. Furthermore, users often do not understand limitations and blindly follow their recommendations. Taleb et al. (2009) criticize these models because even small errors in the assumptions can be devastating. In particular, over-reliance on measures such as VaR to assess risk contributed to the financial crisis (Kim et al. 2011). Furthermore, different assumptions about return distributions and historical time periods can produce different values for VaR (Hull 2010), since any measure of VaR is a function of the time period over which the historical data is collected. Nocera (2009) argues that VaR could be a useful indicator for corporate management, but only if combined with *judgement*. For example, managers that performed well during the 2008/2009 crisis monitored the VaR numbers of their mortgage-backed securities and other risk models, but also relied on their "experience and gut feeling" when deciding to get rid of the securities before the market collapsed (Nocera 2009).

4.3.4 IS support for environmental scanning

Gleißner and Füser (2000) propose *artificial neural networks* to support information gathering. These networks are not limited by psychological barriers, can deal with many different variables simultaneously, and are robust. Although widely used for fraud detection (Ngai et al. 2011), they are not common in environmental scanning. However, Qi (2001) predicts recessions with leading indicators via neural network models.

Recent developments in the World Wide Web, namely *Web 2.0* and *social networking*, provide useful information on customers and competitors that can be gathered for environmental scanning. For example, customers who evaluate goods they have purchased could offer useful information on product quality and future offers (Chen et al. 2011). However, such analyses can only be performed for time sequences (Zhou et al. 2011), based on analysis of the “right” subset with the highest impact (Nohuddin et al. 2012).

Besides the Internet, *capital markets* provide information on customers, suppliers, competitors, and economic development (Plambeck and Weber 2010). Because they are influenced by demand and supply, share prices can indicate perspectives on growth rates or net sales, and, if aggregated, for a complete sector or economy.

Understanding BI in a broader sense, Goul and Corral (2007) call for *data warehouses* (DWH) to better include information about external issues, such as competitors or regulations, and to make measuring strategic advantages possible. Lönnqvist and Pirttimäki (2006) perform a literature review to evaluate methods for determining the *value of BI* within the organization, such as measuring user satisfaction. Finally, in light of the approaching information overload, Cecchini et al. (2010) propose semantic search as way to predict upcoming events.

4.4 Synthesis

The literature systematization in Sect. 4.3 reveals three major gaps to overcome in order to make environmental scanning systems more applicable. (1) *User requirements: lack of sound requirements analysis*. Just six out of 80 publications focus on functional requirements, and an even smaller number—two—on non-functional requirements. As a comprehensive requirements analysis is the proper starting point for IS design (Walls et al. 1992) and just eight of 85 researched references focus on such an analysis, we define this issue as a first gap in current environmental scanning system design. Following the homo oeconomicus theory (footnote 1) and the bounded rationality concept—taking account of human limitations in memory and processing capabilities (Simon 1959; Besnard et al. 2004)—we believe the best way to tackle the increasingly volatile environment is to reason with *cause-effect chains* based on a framework consisting of the most important scanning areas (Rohrbeck 2011). In other words, it is possible to collect a series of indicators that reveal threats and opportunities and thus allow proactive corporate management.

(2) *Models: because the “grasp” of their implications is insufficient, weak signals cannot be applied in practice*. The *weak signals* approach still is the most widespread way to find indicators for proactive decision making (Fig. 3). However, it is often difficult to determine which changes in an organization’s environment are weak signals of significant turbulence and to distinguish them from inconsequential day-to-day fluctuations. We therefore employ this concept, while aiming to improve their “grasp” by deriving criteria to determine the relevance of weak signals (Fig. 7). Thereby, we will contribute to a more effective differentiation between weak signals and ordinary deviations.

(3) *Methods: approaches are needed to more closely incorporate environmental scanning results into executive decision making*. While 32 references cover information gathering, just eleven out of 85 publications focus on how to integrate scanning results into executive decision making processes. We define this issue as a third and final gap, because environmental scanning is useless as long as its findings

are *not* integrated into executives' decision-making processes. Our research uncovered two interrelated issues. First, only a few references argue for such integration and show how to accomplish it (Frolick et al. 1997). Second, managers are not used to work with mathematical models such as VaR in their day-today work (Sect. 4.3.3). We are looking towards a *hybrid approach* complementing mathematical models with gut feeling and experience of experts.

5 Design guidelines

To perform a sound requirements analysis, we propose 360-degree environmental scanning systems for executives and suggest how to select the most important scanning areas (Sect. 5.1). Then, in a hybrid approach, we complement a mathematical model with a heuristic method to build scenarios on environmental development and better "grasp" the implications of weak signals (Sects. 5.2–5.4). To better integrate scanning results into executives' decision-making processes, we propose more applicable IS support (Sects. 5.5, 5.6). We start with ideas for a corporate radar from Narchal et al. (1987) and Wurl and Mayer (2012).

5.1 Take a 360-degree approach, but select only the most important scanning areas to maintain focus

In light of the environment's increasing diversity and complexity, we recommend starting with the widespread conceptual design of Xu et al. (2003) and prioritizing environmental areas that have the greatest impact on the company (Sect. 4.4). Environmental scanning for executives should provide a 360-degree framework (Fig. 4) that reflects the *company's vision and strategic program* (internal perspective, Yasai-Ardekani and Nystrom 1996). Following Ontrup et al. (2009), it is important to concentrate on the most relevant topics. In the industrial sector, for example, the *value chain* along procurement, production, and sales can serve as a starting point for selecting the "right" scanning areas (Day and Schoemaker 2005). Following El Sawy (1985), we recommend capital supply, research and development, and human resources as supporting areas to be scanned as well, since they generate indicators such as employee satisfaction or the innovation rate (the number of new products based on new technologies as a share of all products, Ansoff 1980).

The external environment comprises the *task environment*,[6] sectors that directly interact with the company such as customers, suppliers, and competitors, and the *general environment*, which affects companies more indirectly and on a long-term basis (Yasai-Ardekani and Nystrom 1996). In the PESTL scheme (Daft et al. 1988), peripheral areas for environmental scanning include changes in social or political behavior, shifts in legal and compliance issues or the economy, and the emergence of new technology.

This first activity of setting up a corporate radar requires no IS support. But the more volatile the company's environment becomes (Chang et al. 2006)—i.e., as

6 A more complex model is presented in Porter (1985).

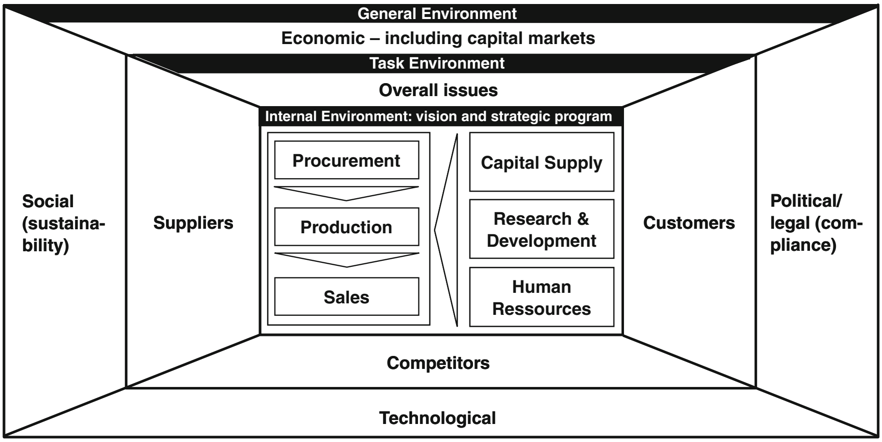


Fig. 4 Scanning areas for reworked environmental scanning systems (example for the industrial sector). Following Xu et al. (2003), scanning sectors can be diversified according to company characteristics and are selected here as a starting point

customers change their behavior more often, competitors launch new products faster or leverage new production technologies more often (Fig. 4)—the more we recommend *collaboration technologies* to share information from the most important scanning areas, both inside a company and among the partners in the company's network. Tele-, video-, and web-conferencing, electronic meeting systems, or other web-based tools (Bajwa et al. 2008) can speed up information-gathering about the latest trends and become increasingly important as partners become more dispersed (Volberda et al. 2010; Malhorta et al. 2005).

5.2 Define concrete indicators and use IS to proactively identify relevant cause-effect chains

Once they have determined the scanning areas, companies should monitor them to anticipate future discontinuities. Within our strategic perspective on environmental scanning (Sect. 2), extrapolating past data is a suitable forecasting method for the short run (Ansoff 1975) as long as no discontinuities occur. As the monitoring method, we adopt the idea by Davies et al. (2006), defining indicators as measures of how risky or promising an activity is, and thus, its potential for future adverse or beneficial impact. Thus, indicators are not only quantitative measures, such as the number of customer complaints, but also vaguer information, such as tendencies in political decision making.

Two levers make it possible to better "grasp" the implications of the indicators used. First, we propose looking at the lead time, clarity, and cost/impact ratio of potential indicators to identify *tangible indicators* from the bulk of data available (Davies et al. 2006; Narchal et al. 1987).[7] Ontrup et al. (2009) propose using

[7] Many indicators already exist, i.e. for the economic situation, but often they are not reviewed. For example, if sales is a scanning area, composite indicators for each country provided by the Organisation for Economic Cooperation and Development (OECD) can indicate turnover.

self-organizing maps to assess the relevance of scanning topics, their most important indicators, and associated cause-effect chains.

The second lever to improve the "grasp" of indicators' implications is using IS to overcome barriers that prevent people from identifying and processing indicators (Hand 2009). Mental models are useful because assumptions and beliefs they hold enable us to make inferences and predictions even under low levels of predictability (Niu et al. 2008). However, these models result from individual's past experiences. As a result, adopting such perspectives when making a decision can be biased (Rossel 2009).[8] A *thinking module* for creative processes could enlarge mental models and provide past experiences from different perspectives (Niu et al. 2008) and even more important challenge dominant mental models that may restrict the view of decision makers (Rohrbeck 2011). Such a module could combine a base of experiences from past decisions with a base of models to deliver strong *cause-effect chains* (Sterman 2001).[9]

To identify indicators, IS can support environmental scanning with *data mining* and *semantic search* (Elofson and Konsynski 1999). Data mining entails database management, data preprocessing, model and inference considerations, "interestingness" metrics, complexity considerations, post-processing of found structures, visualization, and online updating (ACM SIGKDD 2012). As a prerequisite for effective data mining in environmental scanning, internal and external information is typically integrated into a corporate data warehousing architecture (March and Hevner 2007). Furthermore, IS researchers should focus on techniques to extract non-trivial, previously unknown, and potentially useful patterns. Most currently, *keyword text search* has been used to scan for future events (Cecchini et al. 2010).

Following Qi (2001), we also propose using *neural networks* to generate signals of economic recession and expansion. Neural networks are mathematical or computational models used to show complex relationships between input and output or find patterns in data. IS-based *Bayesian causal maps* provide a framework for representing the causal knowledge of experts in terms of the uncertainty of variables in the map, as well as the effect of variables that the map does not include (Nadkarnia and Shenoy 2004).

Following Narchal et al. (1987) to select just the most important indicators for each scanning area, we propose using a *cost/benefit matrix* (Mayer 1999) that groups the indicators in terms of how experts assess their value in representing a company's success and the cost of gathering the information they require. Environmental scanning systems should incorporate *A information*, which is highly indicative of company success and costs little to gather. *B information*, which is highly representative of company success but entails high costs to gather, should be considered on a case-by-case basis. *C information*, which offers little benefit for understanding company success yet is expensive to gather, should typically not taken into account.

[8] For example, forecasts tend to be anchored in plans and scenarios for success rather than on past company results, and thus might be considered too optimistic (Kahneman and Lovallo 1993).

[9] Cause-effect chains provide an image of reality. They do not describe reality in every detail, however, they can offer guidance on how a company's world functions and what interlinkages need to be managed. Following system dynamics theory, cause-effect chains do not anticipate every side effect. Feedback loops are needed for a continuous learning process (Forrester 1977).

5.3 Leverage IS to automate day-to-day routines and to follow indicators' movements

The third step involves determining sources for the indicators, as well as how often they should be collected. A trade-off is necessary between the cost of data collection (e.g., license fees, additional employees) and the indicator's ability to signal opportunities and threats. As data sources, we emphasize the *Internet* (Day and Schoemaker 2005) and *capital markets* (Plambeck and Weber 2010, in detail Sect. 4.3), as both can provide useful, condensed information on competitors, suppliers, and customers at a good cost/benefit ratio.

For automating day-to-day routines, *news monitoring systems and scanners* are useful (Ma et al. 2009). For example, Wei and Lee (2004) have developed a technique for detecting events based on information extraction and proven its effectiveness in an empirical evaluation.

The *vector space model* offers a suitable method for scanning the World Wide Web (Aasheim and Koehler 2006). It converts text-based information into numerical vectors that are then used for discriminant analysis. For example, it is possible to scan articles and determine whether stock returns will probably increase or decrease. Furthermore, to avoid information overload filtering and synthesizing information is becoming more important. We propose leveraging *artificial intelligence techniques* to explore the impact of the most significant indicator movements on the cause-effect chains in question (Sect. 5.2). Supporting predefined, simple *interfaces* for accessing data or common IS languages such as *XBRL* (eXtensible Business Reporting Language) make it easy for automated routines to access these information sources and, if possible, systematically monitor the movements of indicators (XBRL International 2012).

5.4 Use an impact matrix to translate indicator outcomes into a balanced opportunity-and-threat portfolio

Once indicators and their data sources have been defined, it is necessary to model their impact on company performance. Following Taleb's and Makridakis' criticism of mathematical models (Taleb et al. 2009),[10] we argue for not relying on these models exclusively. In line with Nocera (2009), we propose complementing mathematical models with experts' experience and gut feeling, e.g., by using a heuristic approach such as the Delphi method described in Sect. 4.3.3. Two arguments support this *hybrid approach*. First, some indicators comprise qualitative information, which requires transformation before it can be used in quantitative analyses. Second, instilling a company's employees with a basic understanding of opportunities and threats and their implications for company performance is as important as exact statistical calculations.

In the Delphi method, experts first qualify the impact of various indicators on assumptions used in strategic planning. For rating purposes, we propose that the experts use a scale of −2 (strongly negative) to 2 (strongly positive) as *correlation*

[10] Taleb's "The Black Swan: The impact of the highly improbable" (2010) has been strongly criticized. For example, Aldous (2011) argued that "Taleb is sensible in his discussion of financial markets and in some of his philosophical thought, but tends toward irrelevance or ridiculous exaggeration otherwise."

measures. An *impact matrix* can be used to summarize the findings (Fontela 1976; Fig. 5). This matrix then goes back to the experts so they can compare their assessments with the overall results. This process is reiterated until the assessments converge or remain stable.

The impact matrix should cover the assessment of both the indicators themselves and their impact on strategic planning assumptions (see Fig. 5). The assessments appear in the row "critical" and their impact is reflected in the matrix below. The "sum" column measures the overall impact of all the indicators examined on the critical assumptions. If a particular indicator, such as the number of suppliers, exceeds or falls below a critical value, it is given a score of "above" or "below," as appropriate. The columns "opportunity alert/threat alert" are then calculated based on the number of positively or negatively assessed indicators compared to the total number affecting an assumption.[11] The opportunity alert is the ratio of all positive critical indicators times their heuristic correlation measures (1×1 for competitive situation), divided by the total number of indicators with impact (e.g. 4)—for a result of, e.g., 25 percent. Substantial deviations in the values of single indicators or in the assumptions are treated as "breaking news" that refute prior assumptions.

Using the portfolio technique, an *indicator map* then quantifies threats and opportunities (Fig. 6, left hand side). The x-axis shows the scores for each indicator's impact on strategic planning assumptions, while the y-axis shows their estimated lead time. Indicators are then bundled according to the extent changes to their value signal opportunities or threats. In order to coordinate the experts' perspectives, we again propose using *collaboration functions* (Sect. 5.1). Rajaniemi (2007) describes an example from patent analysis. IS tools search for new patents, which are then provided in a common database. Experts receive a notification when a patent is registered and can provide an assessment of its relevance and impact.

Bundling indicators reveals the most important opportunities and threats for the company (Fig. 6, right hand side). This procedure involves a second Delphi analysis. To incorporate the findings into the executives' decision-making process, we transfer the bundled indicators into a *balanced opportunity and threat portfolio*. The indicators, along with their scores and lead times, help to quantify the likelihood that these important opportunities and threats will occur, as well as their potential impact (Fontela 1976). Visualizing this information as a portfolio has two advantages: it is comprehensive in terms of content, but still offers a condensed presentation of important opportunities and threats for the organization.

5.5 Generate scenarios to incorporate scanning results into executive decision-making processes

To ensure that executives receive these findings in an amount and form that facilitate decision making (Singh et al. 2002, in detail Fig. 7), we propose linking the opportunities and threats with the company's approach to management control

[11] For example, in Fig. 5 the number of suppliers and the assumption of the competitive situation are correlated. The number of suppliers is above its critical value. This has a positive impact on the competitive situation, as the firm's position in the supplier market improves. Therefore, it is scored with "1." No negatively correlated indicators are critical. Thus, the threat alert is "0."

Scores: **-2** - strongly negative; **-1** - negative; **0** - no correlation; **1** - positive; **2** - strongly positive

Scanning Area	Suppliers			Buyers			…	Political/Legal		Sum**	Alert Oppor-tunity*	Alert Threat*
Indicator	No.	Quality	…	No.	Solvency	…	…	Elections	…			
critical	above	below	…	not critical	not critical	…	…	not critical	…			
Assumption **1**	1	2	…	0	-2	…	…	1	…	6	17%	33%
e.g. competitive situation	1	0	…	2	0	…	…	1	…	4	25%	0%
…	…	…	…	…	…	…	…	…	…	…	…	…
Assumption **n**	2	-1	…	2	0	…	…	0	…	5	40%	20%
Sum**	4	3	…	4	2	…	…	2	…		* threshold = 30% ** absolute values	

Fig. 5 Impact matrix

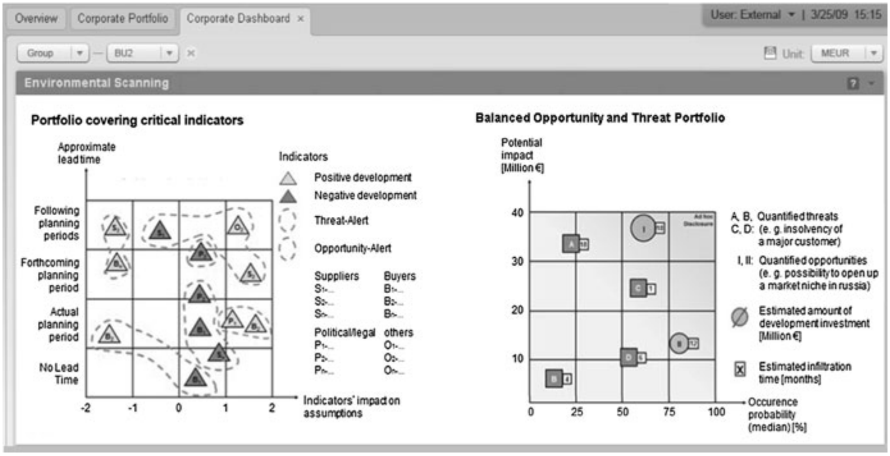
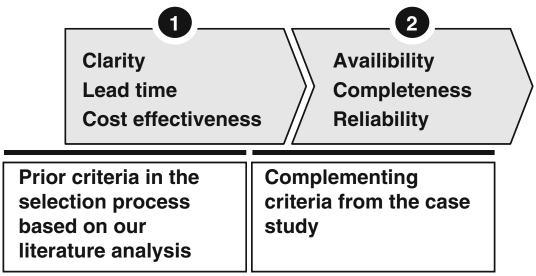


Fig. 6 Incorporating the results of environmental scanning into executive decision making with the scenario technique (first instantiation)

Fig. 7 (Expanded) structure to determine the relevance of indicators for environmental scanning



(Frolick et al. 1997). We liked the idea of aggregating different risks into a single number (Sect. 4.3.3, Young et al. 2011). In doing so, we go forward with *risk-adjusted KPIs* (Linsmeier and Pearson 2000) in our instantiation (Sect. 6) following a value-driver tree representing *economic value added (EVA) at risk* on top (Fig. 8).

The balanced opportunity and threat portfolio is the basis for three scenarios: worst, most probable, and best (Narchal et al. 1987). Unlike statistical VaR models, however, our approach uses the heuristic Delphi method described in Sect. 5.4, which involves assessment by various experts. This procedure should be supported by a *data warehouse* which consolidates decision-relevant information into a single database (March and Hevner 2007). New business applications and user-friendly interfaces ("frontend") should make it possible to switch between visualizations of the scenarios (Fig. 8, left). The best and worst case scenarios define the range of the most important value drivers, such as net sales and costs. Mathematical connections between them define the (lagging) financial performance indicators EBIT, ROCE and EVA (Fig. 8, right). The slider is originally set to the position corresponding to the most probable scenario. All drivers can be moved to the right or to the left to simulate changes and show their direct impact on the financial KPI of the value-driver tree, no matter which scenario is selected. Furthermore, "breaking news" and "turning points" that refute prior assumptions can be provided on an ad hoc basis.

5.6 Use retrospective controls to update the is and collaborate to share findings day to day

The findings from the scenarios can be used to verify assumptions and check whether the methods used need modification. To monitor the need for new indicators, it is helpful to check the totals for the absolute values of each line and column in the impact matrix (Fig. 5). Assumptions linked to only a few indicators will have to be monitored to a better extent. From the IS perspective, automated *time series analysis* can be used to evaluate indicators (Veloce 1996). In particular, the disappearance of opportunities or threats can trigger changes to the set of indicators for the next strategic planning and reporting session. In day-to-day work, *collaboration or groupwaretools* allows e-mailing and other forms of collaboration (Salmeron 2002).

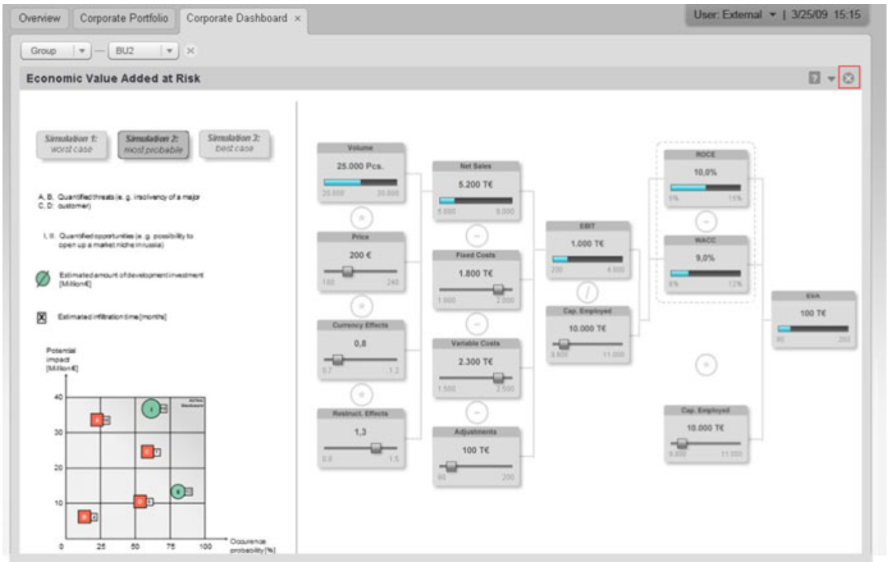


Fig. 8 Incorporating the results of environmental scanning systems into interactive scenarios for executives' decision making (screen shot)

6 Demonstration

An instantiation at a large, international company in the raw materials and engineering sector (Europe, sales: USD 56 bn; employees: 174,000) helped us to evaluate these design guidelines and make our findings more concrete.

During the 2008/2009 economic crisis, both the business side and IT department recognized that they could better contribute to executives' decision making about potential opportunities and threats. A 360-degree environmental scanning system was required that met two main objectives:

- Enhanced analysis should provide more information on company's environment, going beyond standard business parameters to analyze trends that could radically alter the company's future.
- For executives, an integration of the scanning findings into corporate reporting with EVA was mandatory.

6.1 Results

We applied our method from July 2010 to March 2011. The first step was to delineate areas for environmental scanning (Sect. 5.1). An early lesson learned was that scanning areas differed more than expected between the company's strategic business units (SBU). Not only were there regional differences in terms of content, but the importance of scanning areas diverged as well.

When we selected the indicators, we added another three aspects to the proposed evaluation criteria of clarity, lead time, and cost effectiveness (Sect. 5.2). The first was *availability*: Indicators that cannot be monitored on time do not help in the decision making process. *Completeness*: Opportunities and threats from the scanning areas should be described without any gaps. *Reliability*: Indicators that lead to "alerts" more than once for no reason place the integrity of the whole environmental scanning system at risk. These additions produce the following expanded guidelines for determining which indicators are relevant (Fig. 7).

Then, data sources were identified and their update frequency was determined (Sect. 5.3). The resulting demands on the SBUs were not excessive. Furthermore, tolerance limits were defined to avoid overreactions (Sect. 5.4). The next lesson learned was the importance of presenting the results visually. As shown in Fig. 6, the balanced opportunity-and-threat portfolio quantifies the impact of each indicator on the most important threats and opportunities facing the company.

To provide executives with the environmental scanning results, we linked the opportunities and threats in the portfolio with the client's EVA tree (Sect. 5.5) to produce the "worst-case," "most probable," and "best-case" scenarios (Fig. 8). The end product, the *corporate radar*, culminates in an IS-based value-driver tree showing EVA at risk on top. A SAP BO business application "dashboard" provides a visualization of EVA at risk.

New IS capabilities can leverage the corporate radar in day-to-day work in a number of ways (Sect. 5.6). For example, paper-based reports still define how decisions are made in executive boardrooms. Instead, managers could use the system's user interface to examine EVA at risk, and companies could even turn their boardrooms into "*management centers*" with interactive screens to help executives stay up to date and get the big picture. Second, new end-user devices for *mobile computing* can make information available to executives not only at their desks, but in mobile situations as well. Third, *in-memory technology* should enable "drill-throughs" into opportunities and threats via deep dives in transaction systems (ERP), the most important source systems for generating information.

6.2 Lessons learned from the CIO's perspective

The instantiation showed that one factor determining the success of such IS design methods is *direct* interaction with executives to align their overwhelming business requirements with existing IS capabilities. Practitioners can better pursue modular guidelines that focus on tangible "hands-on" outcomes than the hypotheses provided by structural models, with which they are often unfamiliar.

(1) *The design of environmental scanning systems is a top-down business project, and should be communicated that way.* One challenge arising at the beginning of the project was aligning executives' individual perspectives with the company's vision and strategic program (Sect. 4.1). Our information-needs analysis thus involved jointly rethinking the company's strategic program, as well as how indicators can make an actionable, proactive contribution toward meeting its goals. A range of forward-looking information was available that needed to be streamlined.

(2) *Project managers can establish a role in environmental scanning system design if they act as mediators between business requirements and IS capabilities.* The most important analyses were useful in achieving a second type of alignment: one between business requirements and IS capabilities. By connecting the right parties across the company, the CIO brought in an interdisciplinary business/IT perspective that makes him the ideal mediator.

(3) *Executives must champion the complete IS development process, devoting time not just to the analysis of their information needs, but to reviewing the prototype as well.* Besides participating in the information-needs analysis, executives must take an active role in challenging the prototype as well—an area in which they are, for the most part, unfamiliar. They are best served by providing them with hands-on "clickable" prototypes and then making enhancements step by step.

7 Evaluation

To evaluate our findings, we compared them to relevant contributions of quantitative research, action research, and other combined approaches from the body of knowledge. In terms of quantitative research, we relied on the IS success (Davis 1989) and technology acceptance model (TAM, DeLone and McLean 2003) in the absence of structural equation models for environmental scanning systems.

Following the objective of this article, we evaluate the approach's *practical utility*, selecting evaluation criteria based on Bischoff et al. (2012) and use a five-

○ very bad ◔ bad ◑ somewhat ◕ good ● very good

Evaluation criteria	Action research: Fink et al. (2005)	Combined approaches, for example: Calori (1989)	Frolick et al. (1997)	Narchal et al. (1987)	Approach here (2012)	Quantitative research: Davis 1989, DeLone & McLean 2003
Completeness	somewhat	good	good	good	good	good
Distinctiveness	bad	somewhat	somewhat	somewhat	good	very good
Bias prevention (intersubjectivity)	bad	somewhat	somewhat	somewhat	somewhat	good
Traceability and applicability of the findings (especially for practitioners)	somewhat	somewhat	good	somewhat	good	somewhat
Handling and direct use of findings – Grasp of weak signals' implications – Incorporating scanning results into executives' decision-making process	good	bad	somewhat	bad	good	bad

Fig. 9 Combined research methods for environmental scanning systems in between action research and quantitative research

step rating scale from "very bad," to "very good." The results are shown in Fig. 9 and can be detailed as follows.

7.1 Completeness

Taking a literature analysis as a starting point not only makes it feasible to identify current design gaps, but to leverage the body of knowledge for future developments. Thus, combined methods—Calori (1989); Frolick et al. (1997); Narchal et al. (1987); and the approach presented here (2012)—offer greater compatibility with the body of knowledge and, thus completeness than action research such as Fink et al. (2005, "somewhat" evaluation, Fig. 9). Furthermore, the continuous learning specified in Sect. 5.6 leads to greater completeness. Incorporating publications from practitioners would further expand the combined methods with insights from day-to-day operations. Their "completeness" in reflecting the body of knowledge is thus evaluated as "good." We consider quantitative research models to be as good as the combined methods. We base this evaluation on the history of the IS success model (DeLone and McLean 1992) and TAM (Davis 1989), their refinement over time, and the fact that alternative versions such as TAM 2 and 3 (Venkatesh and Bala 2008) lead to a multifacted body of knowledge. Furthermore, both approaches have been applied and evaluated in a number of situations (Venkatesh et al. 2003).

7.2 Distinctiveness

A literature review, which is essential to a combined approach, produces a set of facts that, in comparison to action research, provides a rich basis for different aspects of distinct design work. We therefore assess the capability of combined approaches to arrive at distinct design guidelines between "somewhat" and "good." More specifically: Narchal et al. (1987) propose connecting environmental scanning systems and strategic planning. Frolick et al. (1997), in turn, aim to leverage cost-reduction potential by integrating EIS and environmental scanning. The corporate radar described here can be integrated into a BI architecture and requires standard software only. Furthermore, a rigorous framework to structure the literature review (Fig. 1) aids orientation. For these reasons, our approach receives a "good" evaluation. Only structural equation models using statistical approaches produce more distinct findings and, thus, are rated "very good." Because action research employs individual case examples, its findings are typically not very distinct ("bad" evaluation).

7.3 Bias prevention (intersubjectivity)

Because they typically test hypotheses with a broad sample, qualitative research methods are both rigorous and intersubjective. Thus, we evaluate them as "good" at preventing bias. Combined approaches offer more rigorous environmental scanning system design than action research does (Fig. 9). Compared to structural equation models, however, the approach described here involves some subjectivity—as a consequence of not using broad samples to generate findings. We evaluate combined research methods as "somewhat" capable of preventing bias. Even if well conducted, documented, and reported, action research is most often driven by single issues regarding a companies' objectives and usually fails to generalize the case results ("bad").

7.4 Traceability and applicability of the findings (especially for practitioners)

Combining results from a literature research with "build and evaluate" activities provides rigor without losing the DSR objective of building new artifacts. Furthermore, the lessons learned from the case example (Sect. 6.2) show that practitioners can better pursue modular guidelines than the hypotheses generated by structural models. Thus, the former are evaluated as "good," while the latter receive a rating of "somewhat." Practitioners are not used to handling complex structural models and, thus, from their perspective, the findings of such models often remain questionable and theoretical. Action research, in turn, typically focuses on a single company only. The findings are thus often easy to follow, but because general findings may be missing, the results are often not directly applicable to or even incompatible with other companies' situations. We therefore evaluate their traceability and applicability as "somewhat." Other combined research methods do not evaluate their findings in such a straightforward way. Using an example from the solar industry, Calori (1989) introduces the topic, but does not explain how he derives his method ("somewhat"). Narchal et al. (1987) use weak signals without explaining their nature ("somewhat"). Only Frolick et al. (1997) give concrete examples of how to integrate environmental scanning systems into EIS ("good").

7.5 Handling and direct use of findings

Here, action research is evaluated as "good" because it provides recommendations from a practitioner perspective. The guidelines developed in combined approaches should be easier to directly work with than hypotheses generated by structural equation models ("bad"). For example, guidelines can be applied one by one to not only specify how IS should be reworked, but to evaluate existing IS. Fink et al. (2005) earn a "good" evaluation by proposing the "future" scorecard, a reporting tool enhancing balanced scorecards with forward-looking information. This approach ensures that environmental scanning results are integrated into group reporting, just as they are in the corporate radar with its balanced opportunity-and-threat portfolio (Sect. 5.5) and depiction of EVA at risk (Fig. 8). To inform executives about the external environment and future developments, Frolick et al. (1997) combine environmental scanning with EIS, but they leave the EIS black-boxed ("somewhat"). Calori (1989) is the only that quantifies costs for scanning systems, assuming 60 man days, and Narchal et al. (1987) set up organizational units within the company. While they aggregate their results, they do not make it possible to present them. Both approaches therefore receive a score of "somewhat" for this area.

7.6 Overall classification

Action research has the practitioner vote, thanks to the applicable information it produces on single cases if it is well conducted, documented, and reported. However, we assessed such approaches negatively in terms of their overall completeness, traceability, and applicability. Combined approaches offer greater rigor than action research (Fig. 9), but the guidelines they produce are more subjective than structural equation models. Overall, we classify the quantitative methods as good research methods for environmental scanning systems design. However, their application faces obstacles, and combined approaches offer a solution that balances these extremes.

Over the last 20 years, the "business scanning systems" proposed by Calori (1989) and Narchal et al. (1987) have not achieved acceptance. One problem with the latter might have been the difficulty in focusing only on weak signals. In any case, no further integration of EIS into environmental scanning systems has occurred in practice. In contrast, the approach here, while initially based on ideas from Narchal et al. (1987), arrived at six guidelines for leveraging IS to create environmental scanning systems that are more applicable than the state of the art. Using this business-to-IT approach, the company implementing our prototype achieved a more fact-driven decision-making process while gaining time for proactive corporate management.

8 Outlook and future research

Much work has been done on environmental scanning systems since Aguilar (1967) and Ansoff (1975). Focusing on how "modern" IS can contribute to environmental scanning, this article specified several ways to redesign environmental scanning systems. We examined three gaps identified in our literature research and developed six design guidelines to address them.

Addressing the lack of a sound requirements analysis (1), our first design guideline proposes 360-degree environmental scanning systems for executives and presents how to select the most important scanning areas. Three further guidelines cover the IS model perspective (2), focusing on getting a better “grasp” of the implications of weak signals by a hybrid approach: define concrete indicators and use IS to identify relevant cause-effect chains; leverage IS to automate day-to-day routines and monitor the variety of indicators’ movements; and leverage expert experience with an impact matrix, translating the results into a balanced opportunity-and-threat portfolio. In terms of methods (3), we propose to more closely incorporate scanning results into executives’ decision-making process by generating scenarios from a set of environmental assumptions, using retrospective controls to continuously update the environmental scanning system and collaborating to share the scanning findings day to day.

Applying the design guidelines at a raw materials and engineering company, we arrived at a prototype we call the “corporate radar.” Capabilities to simulate scenarios and their impact on the most important financial KPIs complete the results.

For *practitioners* this article offers concrete advice to improve their existing environmental scanning systems or even a starting point to set up such IS. As Ansoff (1980) shows, companies that do so have brighter prospects than those that do not. *Researchers* receive a comprehensive overview about the body of knowledge, as well as three major gaps to overcome in order to make environmental scanning systems more applicable. Furthermore, our design guidelines provide a literature-based starting point for future discussion.

Our research opens several avenues for future work. The literature review should be expanded with *practitioner publications* to illustrate additional environmental scanning systems and identify issues in day-to-day business. However, this should be a secondary issue. More urgently, additional *cases* are needed to determine the generalizability of our findings. Furthermore, a *survey* could provide direct insights about executives’ perspectives on requirements for environmental scanning systems. Also, a behaviorally motivated paper should follow to test our findings. From the content perspective, future research should identify ways to better handle *strategic surprises*. One approach could be to incorporate more forward-looking expert focus groups in the information gathering process.

Finally, if the researched body of knowledge seems more like wishful thinking than a sound basis for applicable design guidelines, it would be interesting to define a set of evaluation criteria, choose four or five successful implementations, evaluate them, ascertain what they have in common, and compare these findings with the design guidelines presented here.

These shortcomings and the subjectivity inherent in our evaluation (Sect. 7) mean that, so far, it is not possible to determine for sure whether our guidelines lead to more applicable environmental scanning systems. However, the guidelines provide practical starting points for future research.

Appendix

See Table 1.

Table 1 Full list of researched articles

No.	Author(s)	Years	Title	Publication	Elements of IS design	Research approach
1	Aasheim, C. and Koehler, G. J.	2006	Scanning the World Wide Web documents with the vector space model	Decision Support Systems	Information gathering	Case study
2	Aguilar, F.	1967	Scanning the business environment	Macmilian	Information gathering	Survey
3	Ahituv, N. et al.	1998	Environmental scanning and information systems in relation to success in introducing new products	Information & Management	Information gathering	Survey
4	Albright, K.	2004	Environmental scanning: radar for success	The Information Management Journal	Information gathering	Single/list approaches
5	Anderson, M. H. and Nichols, M. L.	2007	Information gathering and changes in threat and opportunity perceptions	Journal of Management Studies	Information gathering	Experiment
6	Ansoff, H. I.	1975	Managing strategic surprise by response to weak signals	California Management Review	3rd generation IS	Framework
7	Ansoff, H. I.	1980	Strategic issue management	Strategic Management Journal	3rd generation IS	Framework
8	Arnott, D. and Pervan, G.	2008	Eight key issues for the decision support systems discipline	Decision Support Systems	Information gathering	Single/list approaches
9	Boyd, B. and Fulk, J.	1996	Executive scanning and perceived uncertainty: a multidimensional model	Journal of Management	Information gathering	Survey
10	Calori, R.	1989	Designing a business scanning system	Long Range Planning	3rd generation IS	Framework
11	Chen, H. et al.	2011	Enterprise risk and security management: data, text and web mining	Decision Support Systems	Information gathering	Single/list approaches
12	Cho, T.	2006	The effects of executive turnover on top management teams: environmental scanning behaviour after an environmental change	Journal of Business Research	Information gathering	Survey
13	Choo, C. W.	1999	The art of scanning the environment	Bulletin of the American Society for Information Science	Information gathering	Framework

Table 1 continued

No.	Author(s)	Years	Title	Publication	Elements of IS design	Research approach
14	Choo, C. W.	2001	The knowing organization as learning organization	Education + Training	3rd generation IS	Framework
15	Cohen, J. B. and Zinsbarg, E. D.	1967	Investment analysis and portfolio management	Homewood	1st generation IS	Single/list approaches
16	Daft, R. and Weick, K.	1984	Toward a model of organizations as interpretation systems	Academy of Management Review	Information gathering	Framework
17	Daft, R.L. et al.	1988	Chief executive scanning, environmental characteristics and company performance: an empirical study	Strategic Management Journal	Functional requirements	Survey
18	Daheim, C. and Uerz, G.	2008	Corporate foresight in Europe: from trend based logics to open foresight	Technology Analysis & Strategic Management	3rd generation IS	Survey
19	Davies, J. et al.	2006	Key risk indicators—their role in operational risk management	RiskBusiness International Limited	2nd generation IS	Framework
20	Day, G. S. and Schoemaker, P. J. H.	2004	Driving through the fog: managing at the edge	Long Range Planning	Information gathering	Single/list approaches
21	Day, G. S. and Schoemaker, P. J. H.	2005	Scanning the periphery	Harvard Business Review	Functional requirements	Single/list approaches
22	El Sawy, O.	1985	Personal information systems for strategic scanning in turbulent environments: can the CEO go online?	MIS Quarterly	Nonfunctional requirements	Survey
23	Elofson, G. and Konsynski, B.	1991	Delegation technologies: environmental scanning with intelligent agents	Journal of Management Information Systems	Information gathering	Case study
24	Elofson, G. and Konsynski, B.	1993	Performing organizational learning with machine apprentices	Decision Support Systems	3rd generation IS	Framework
25	Fink, A. et. al.	2005	The future scorecard: combining external and internal scenarios to create strategic foresight	Management Decision	3rd generation IS	Framework
26	Fontela, E.	1976	Industrial applications of cross-impact analysis	Long Range Planning	Analytical techniques	Single/list approaches

Table 1 continued

No.	Author(s)	Years	Title	Publication	Elements of IS design	Research approach
27	Frolick, M. et al.	1997	Using EISs for environmental scanning	Information Systems Management	3rd generation IS	Framework
28	Fuld, L.	2003	Be prepared	Harvard Business Review	3rd generation IS	Survey
29	Garg, V. et al.	2000	Chief executives scanning emphasis, environmental dynamism and manufacturing firm performance	Strategic Management Journal	Information gathering	Survey
30	Gelle E. and Karhu K.	2003	Information quality for strategic technology planning	Industrial Management and data systems	Information gathering	Case study
31	Glassey, O.	2008	Exploring the weak signals of start-ups as a folksonomic system	Technology Analysis & Strategic Management	3rd generation IS	Framework
33	Gleißner, W. and Füser, K.	2000	Moderne Frühwarn- und Prognosesysteme für Unternehmensplanung und Risikomanagement	Der Betrieb	Analytical techniques	Single/list approaches
34	Goul, M. and Corral, K.	2007	Enterprise model management and next generation decision support	Decision Support Systems	Information gathering	Single/list approaches
35	Gray, P.	2008	From hindsight to foresight: applying futures research techniques in information systems	Communications of the Association for Information Systems	Analytical techniques	Single/list approaches
36	Hahn, D. and Krystek, U.	1979	Betriebliche und überbetriebliche Frühwarnsysteme für die Industrie	Zeitschrift für betriebswirtschaftliche Forschung	2nd generation IS	Framework
37	Hambrick, D. C.	1981	Specialization of environmental scanning activities among upper level executives	Journal of Management Studies	Information gathering	Survey
38	Hand, D.	2009	Mining the past to determine the future	International Journal of Forecasting	Analytical techniques	Single/list approaches
39	Hough, J. and White, M.	2004	Scanning actions and environmental dynamism	Management Decision	Information gathering	Survey
40	Jain, S. C.	1984	Environmental Scanning in US Corporations	Long Range Planning	Information gathering	Survey

Table 1 continued

No.	Author(s)	Years	Title	Publication	Elements of IS design	Research approach
41	Jourdan, Z. et al.	2008	Business intelligence: an analysis of the literature	Information Systems Management	Information gathering	Single/list approaches
42	Krystek, U.	1993	Frühaufklarung für Unternehmen: Identifikation und Handhabung zükunftiger Chancen und Bedrohungen	Schäfer-Poeschel	3rd generation IS	Framework
43	Kuvaas, B.	2002	An exploration of two competing perspectives on informational contexts in top management strategic issue interpretation	Journal of Management Studies	Executive decision making	Survey
44	Lauzen, M.	1995	Toward a model of environmental scanning	Journal of public Relations Research	3rd generation IS	Survey
45	Lenz, R. and Engledow, J.	1986	Environmental analysis units and strategic decision-making: a field study of selected leading edge companies	Strategic Management Journal	3rd generation IS	Survey
46	Lenz, R. and Engledow, J.	1986	Environmental analysis: the applicability of current theory	Strategic Management Journal	3rd generation IS	Framework
47	Lesca, N. and Caron-Fason, M.-L.	2008	Strategic scanning project failure and abandonment factors: lessons learned	European Journal of Information Systems	Information gathering	Survey
48	Liu, S.	1998	Data warehousing agent: in seeking of improved support for environmental scanning and strategic management	ECIS-Proceedings	Information gathering	Case study
49	Liu, S.	2000	Agent based environmental scanning system: impacts on managers and their strategic scanning activities	AMCIS-Proceedings	Information gathering	Case study
50	Lönnqvist, A. and Pirttimäki, V.	2006	The measurement of business intelligence	Information Systems Management	Functional requirements	Single/list approaches
51	Makridakis, S.	2010	Why forecasts fail. what to do instead	MIT Sloan Management Review	1st generation IS	Single/list approaches
52	Malhorta A., Gosain S., El Sawy, O. A.	2005	Absorptive capacity configurations in supply chains: gearing for partner enabled market knowledge creation	MIS Quarterly	Analytical techniques	Case study
53	McMullen, J. et al.	2009	Managerial (in) attention to competitive threats	Journal of Management Studies	Executive decision making	Survey

Table 1 continued

No.	Author(s)	Years	Title	Publication	Elements of IS design	Research approach
54	Menon, A. and Tomkins, A.	2004	Learning about the markets periphery: IBM's webfountain	Long Range Planning	Information gathering	Case study
55	Müller, R. M.	2010	Business intelligence and service-oriented architecture: a delphi study	Information Systems Management	Information gathering	Survey
56	Nanus, B.	1982	QUEST—quick environmental scanning technique	Long Range Planning	Executive decision making	Framework
57	Narchal, R. M. et al.	1987	An environmental scanning system for business planning	Long Range Planning	3rd generation IS	Framework
58	Nastanski, M.	2003	The value of active scanning to senior executives	Journal of Management Development	Information gathering	Survey
59	Nemati, H. et al.	2000	A multi-agent framework for web based information retrieval and filtering	AMCIS-Proceedings	Analytical techniques	Single/list approaches
60	Ngai, E. W. T. et al.	2011	The application of data mining techniques in financial fraud detection: a classification framework and an academic review of literature	Decision Support Systems	Information gathering	Framework
61	Nick, A.	2009	Wirksamkeit strategischer Früherkennung	Gabler	3rd generation IS	Case study
62	Ontrup, J., Ritter, H., Scholz, S. W., Wagner, R.	2009	Detecting, assessing, and monitoring relevant topics in virtual information environments	IEEE Transactions on Knowledge and Data Engineering	Information gathering	Survey
63	Plambeck, N. and Weber, K.	2010	When the glass is half empty and half full: Ceo interpretation	Strategic Management Journal	Executive decision making	Survey
64	Prahalad, C. K.	2004	The blinders of dominant logic	Long Range Planning	Information gathering	Single/list approaches
65	Qi, M.	2001	Predicting US recessions with leading indicators via neural network models	International Journal of Forecasting	Executive decision making	Survey

Table 1 continued

No.	Author(s)	Years	Title	Publication	Elements of IS design	Research approach
66	Qiu, T.	2007	Scanning for competitive intelligence: a managerial perspective	European Journal of Marketing	Information gathering	Survey
67	Reichmann, T. and Lachnit, L.	1979	Unternehmensführung mit Hilfe eines absatzorientierten Frühwarnsystems	Zeitschrift für Betriebswirtschaft	1st generation IS	Framework
68	Romeike, F.	2005	Frühaufklärungssysteme als wesentliche Komponente eines proaktiven Risikomanagements	Controlling	3rd generation IS	Single/list approaches
69	Rossel, P.	2009	Weak signals as a flexible framing space for enhanced management and decision-making	Technology Analysis & Strategic Management	3rd generation IS	Framework
70	Schoemaker, P. J. H. and Day, G.S.	2009	Gathering information: how to make sense of weak signals	MIT Sloan Management Review	Information gathering	Single/list approaches
71	Simon, H.	1959	Theories of decision-making in economics and behavioral science	The Economic Review	Executive decision making	Framework
72	Smallman, C. and Smith, D.	2003	Patterns of managerial risk perceptions: exploring the dimensions of managers accepted risks	Risk Management	Executive decision making	Survey
73	Sonnenschein, O.	2005	DV-gestützte Früherkennung	Controlling	3rd generation IS	Framework
74	Suh, W. et al.	2004	Scanning behaviour and strategic uncertainty	Management Decision	Executive decision making	Survey
75	Taleb, N. et al.	2009	The six mistakes executives make in risk management	Harvard Business Review	Executive decision making	Single/list approaches
76	Tan, S. et al.	1998	Environmental scanning on the internet	ICIS-Proceedings	Nonfunctional requirements	Survey
77	Thomas, J. B. et al.	1993	Strategic sensemaking and organizational performance: linkages among scanning, interpretation, action and outcomes	Academy of Management Journal	Executive decision making	Survey

Table 1 continued

No.	Author(s)	Years	Title	Publication	Elements of IS design	Research approach
78	Tseng, F. S. C. and Chou, A. Y. H.	2006	The concept of document warehousing for multi-dimensional modeling of textual-based business intelligence	Decision Support Systems	Analytical techniques	Framework
79	Vandenbosch, B. and Huff, S. L.	1997	Searching and scanning: how executives obtain information from executive information systems	MIS Quarterly	Executive decision making	Survey
80	Walters, B. et al.	2003	Strategic information and strategic decision making: the EIS-CEO interface in smaller manufacturing companies	Information & Management	Functional requirements	Survey
81	Wei, C.-P. and Lee, Y.-H.	2004	Event detection from online news documents for supporting environmental scanning	Decision Support Systems	Analytical techniques	Single Item
82	Wheelwright, S. and Clarke, D.	1976	Probing opinions	Harvard Business Review	1st generation IS	Single/list approaches
83	Wixom, B. H. et al.	2008	Continental airlines continues to soar with business intelligence	Information Systems Management	Information gathering	Case study
84	Xu, K. et al.	2011	Mining comparative opinions from customer reviews for competitive intelligence	Decision Support Systems	Analytical techniques	Framework
85	Xu, X. et al.	2003	UK executives vision on business environment for information scanning. A cross industry study	Information & Management	Functional requirements	Survey
86	Yasai-Ardenaki, M. and Nystrom, P.	1996	Designs for environmental scanning systems: tests of a contingency theory	Management Science	Functional requirements	Survey

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