Towards a conceptual model for decision-making regarding the incorporation of disruptive technology: Technology scanning for early warning signals

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Abstract. The identification of disruptive technologies and the evaluation of their impact on the own business is a major challenge for technology intelligence. Technology scanning is the technology intelligence sub-discipline for finding weak signals (early warning signals) to technology trends, and as we conjecture also for finding signals on technology-driven impeding changes in evaluation contexts in relevant markets. To do so, technology scanning uses a toolbox of methods including prediction, scenario analysis, and trend analysis methods. The main challenge of dealing with disruptive technologies is the lack of guidance on how organizations can incorporate disruptive technologies into their service operations to improve their service delivery. To address this challenge, we examine whether Information Systems (IS) research can contribute to this guidance by developing a conceptual model. The goal of our research is to design a method to formalize a conceptual model that supports organizations in incorporating disruptive technologies into their service organization. In this paper, we present preliminary results related to requirements for identifying and evaluating disruptive technologies in a company's context. We also present an analysis of existing methods and design options (process, organizations, technology) for technology scanning regarding these requirements.

Keywords: Disruptive technology, precursor, technology, service operations, service delivery, technology scanning, morphology, early warning signals, people, process, technology, strategy, control, operations.

1 Introduction

Disruptive technologies bring to a market a very different value proposition than had been available previously [1]. Generally, disruptive technologies underperform established products in mainstream markets, but they have other features that a few fringes (and generally new) customers value. Disruptive technology can thus be defined as a technology that changes the bases of competition by changing the performance metrics along which firms compete [2].

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The list of leading companies that failed when confronted with disruptive changes in technology and market structure is a long one [25,27]. At first glance, there seems to be no pattern in the changes that overtook them. In some cases, the new technology swept through quickly, in others, the transition took decades. In others, the progressive technologies were simple extensions of what leading companies already did better than anyone else. Common to all these failures, however, is that the decision that led to failure was made when the involved leaders were widely regarded as among the best companies in the world [1].

Introducing a disruptive technology into an existing service market provides new opportunities for firms and customers, often altering the nature of the market [26]. Consequently, new technology often destabilizes market equilibrium, forcing to consider the role of technology will play in determining the new market structure [3].

Failure to react properly to disruptive technologies is considered a major cause for companies losing market share or even economic viability [22]. How should companies react properly to disruptive technologies? How should companies scan for disruptive technologies?

How should companies design their technology scanning activities so that they can properly react to disruptive technologies? Technology scanning is the activity to detect relevant technology changes from outside the scope of the organization. Technology intelligence is responsible for finding and evaluating relevant technology-related information for an organization [4]. Technology scanning is the function of technology intelligence tasked with listing to signals (some examples of early warning signals: production technology, new materials and energy sources, needs and expectations of customers) from outside the organizations identified technological and business context [5]. It thus falls on technology scanning to identify such disruptive technologies [6]. Currently, however, technology scanning can be observed to be a success factor for conducting radical (technology shift-driven) innovation, but not for bringing disruptive technologies into the market [7]. One reason for this may be that technology scanning, largely done by internal R&D experts, still focuses too much on the technological aspects in evaluating potentially relevant trends and signals. However, certain theoretical reasons also allow the conclusion that it may be outright impossible to evaluate potentially disruptive technologies in a way to allow clear categorization into relevant and not (yet) relevant, but that observation needs to be geared into allowing organizations to react more flexibly and swiftly as new information emerges. In his paper Danneels refers to this as “a disruptive technology is a technology that changes the bases of competition by changing the performance metrics along with firms compete”.

What is clear is that companies are in need of methodical guidance regarding the reaction to (and, if possible, anticipation of) emerging disruptive technologies at the same time, they need to maintain their focused attention to incremental technological changes and radical technology shifts inside their business and technology context, as these still from the vast majority of technological changes [15].

With this research, we aim to contribute to forming such methodical guidance by driving towards the derivation of technology scanning architectures suitable for use for companies with different strategic goals regarding their technological portfolio. Imminent market disruption by disruptive technologies is usually only obvious in hindsight.

Disruptive technologies have several characteristics hindering companies from properly evaluating their emergence: inability to create profit in company's current value system, uncertainties about timing and inability to determine in advance which specific technologies will turn out to be disruptive.

This paper describes the interim result of a research aimed to identify and validate requirements to technology scanning, design options for technology scanning and the influences of certain design options. The identification of these requirements and influences is done in preparation for progressing with a larger research of designing suitable model architectures for technology scanning for various companies exposed to technological change. Hence, we formulate our research question as How can technology scanning help organizations incorporate disruptive technology in their service operations to improve service delivery?

2 Problem Analysis and Derivation of Research Objectives

2.1 Problem Analysis

In today's rapidly changing world, organizations more than ever before face the apparently conflicting challenges of dualism, functioning efficiently today to sustain the success of their business models while also incorporating the disruptive innovations that will enable to be competitive in the future [18,19]. Corporations today must simultaneously build internally contradictory and inconsistent structures, competencies and cultures: fostering more efficient and reliable processes while encouraging the experiments and explorations needed to re-create the future.

In an effort to avoid the "tyranny of success", major players are increasingly focusing their energy on anticipating disruptive technologies, new technologies that may affect their competitive position. While the term "disruptive technology" is relatively new in management jargon [20], the challenge facing technology managers is not new and has a long record of coverage in the technology management literature [21].

Reflecting on technology change and innovation provides new ways to view disruptive technologies and gives firms useful frameworks and models to effectively anticipate and minimize the impact of potential disruption. Understanding when and how new technologies are adopted can help companies anticipating future technology introductions, some of which may represent potentially disruptive technologies. It is important to recognize that technology substitution occurs only when there is both an unmet need in a dominant driver and current technologies are incapable of competitively addressing it.

Companies must find a means for the early detection of disruptive technologies. A possible solution is to use technology scanning. Technology scanning is concerned with finding relevant technology-related information from outside the organization's technological and business context. The most basic requirements to technology scanning address its direct results, i.e. statements, forecasts and evaluations, which we will subsume under the word information. One obvious requirement pertaining to such information is their accuracy [21]. The information generated by technology scanning can be inaccurate even though the information it does give is correct, meaning it can lack exhaustiveness. On the other hand, if some information it gives is factually inaccurate, it lacks precision. Exhaustive-ness of the information is important because as many relevant information objects need to be found in order to make further use of them [11]. Precision on the other hand is important as identifying too many irrelevant signals (precursors) and trends will reduce credibility in the scanning process and consume valuable management attention.

Information gained from technology scanning can be about already existing matters (which however are unknown to the information customer and whose impact to the information customer needs to be predicted), predictions about the development of observable signals or predictions beyond observable signals.

Information models differ between widely known and accepted trends or strong signals, or initial yet fuzzy weak signals [13]. Here, detection of weak signals means more timely access to information about the events these signals point to than trend analysis. The requirement of timely or early information can vary greatly depending on the situation: timely or early information may mean “before completion knows” or “before it is generally an accepted trend” to seize opportunities with long lead times such as developing a new product line, “when the trend is clear” to avert risk by stopping obsolete R&D projects and to seize by divestments, portfolio changes and similar measures [23]. One direct requirement to result of foresight functions is that they enable appropriate action. For technology scanning, we consider the dimension of this action to be avoiding surprises in the first place, promoting decision making in the face of uncertainty, and resilience towards unexpected events or wrong decisions.

2.2 State of the Art

How are companies dealing with scanning for disruptive technologies?

The organization of technology intelligence in general has been researched by Lichtenthaler [4]. Technology scanning [8,9] is part of technology intelligence dealing with information from outside the company’s context which turns out to be relevant to the company [5]. The objects of technology scanning are trends and signals, unlike technology monitoring and scouting, which deal with specific technology fields within defined search fields [5]. By its nature, technology scanning is future-oriented (“How will current observable trends and developments coming from outside our organization affect the company?”), and can be classified to be part of the strategic foresight function of a company [10].

Technology scanning is concerned with finding relevant technology-related in-formation from outside the organization’s technological and business context. As the word relevant implies, discovered information is subjected to assessments, which Ansoff considers to be information filters [11]. Such assessment is usually derived in a common intelligence process consisting of the determination of in-formation needs, information acquisition, information evaluation, and information communication [5]. The evaluation of gathered information (and thus the information of statements about relevance of trends and signals, which shall be called predictions) is seen as more difficult and value-creating than the acquisition of information [12].

Ansoff has stated that major changes have weak signals (with varying degrees of specificity) predicting their manifestation [11], Weak signals (or EWS early warning signals) have been analyzed and distinguished from trends and incremental changes according to dimensions such as the impact of the signal in case manifestation, and the likelihood of manifestation of the signal [13]. Güemes Castorena et al [14] classify change drivers emitting such signals into break points breaking current trends, early warnings reflecting common patterns leading to radical change and emerging topics reflecting upcoming topics in a set of environments suitable to incubating new topics (see fig 1).

Fig. 1. Change drivers (after Gümes Castorena et.al. 2013)

2.3 Research Objectives

Our research is based on the assumption that there are generic goals which are valid for all companies (exp. deriving new search fields, building (internal) agreed opinion on technology trends, building (external) consensus and promote own vision of trends externally, finding and assessing impact of long-term trends, preparing for uncertainty, discovering changing evaluation contexts for technology fields), and that an individual company's preference can be captured in a weighting of these generic goals. We refer as this weighting of the generic goals as a company's goal system. Given a goals-requirement-relation mapping the demand of a certain generic goal to the requirements we can then derive the total value a company place on each requirement. To derive specific designs for technology scanning a morphology (the form and the structure) of individual design options needs to be devised. To structure this morphology, a framework of the relevant design dimension of technology scanning (such as processes, organization and methods) is needed. To determine whether a certain choice of design options is adequate for the goal system of a company, the degree of fulfilment of the individual requirements through each design option needs to be evaluated, resulting in the requirements design options relation. Furthermore, the possibility to combine different design options needs to be evaluated in a consistency analysis (see fig 2).

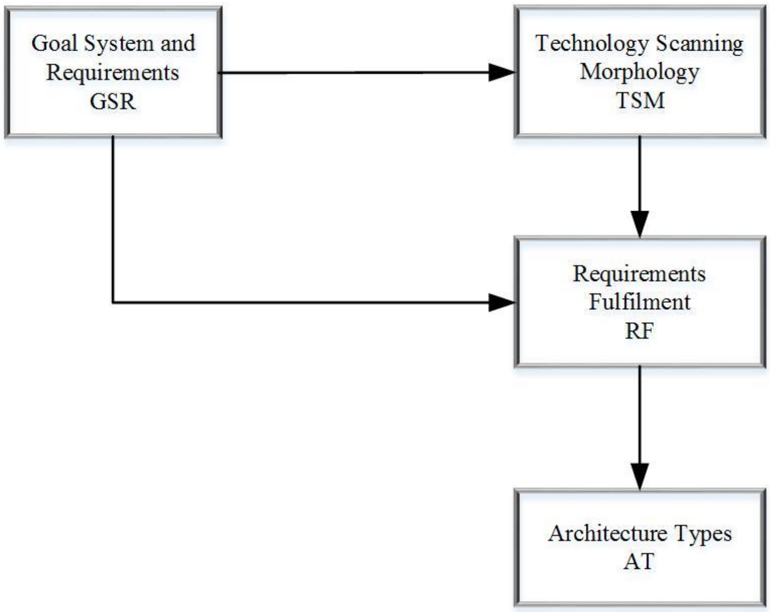

Fig. 2. Research design of deriving technology scanning architectures.

Given this background, the general goal or our research is translated into four research objectives: Create a goals-requirement-relation mapping, build a frame-work to drive specific designs for technology scanning to determine whether a certain choice of design options is adequate for the goal system of a company, to design architecture for technology scanning in combination with the previous goals.

a. Mapping the goals-requirements-relation

The aim is to analyze why companies use technology scanning and what out-comes and qualities technology scanning needs to have in order to be useful to a company.

b. Building a framework for technology scanning and morphology

A morphology of design options is needed to investigate to which extent the individual design options meet the requirements demanded from technology scanning by a company. A framework for technology scanning is needed to determine the decision dimensions in the morphology.

c. To match the requirements

To match the requirements that companies pose to technology scanning with the available design options, the fulfilment of each requirement through use of an individual design option will be analyzed.

d. To design architecture for technology scanning

The objective here is to design an architecture for technology scanning, which the combination of the previous components allows to do. Using the results of GSR, TSM, RF, we can mathematically derive a candidate architecture maximizing the contribution of the architecture to the goals valued by the company's goal system. To ensure logical consistency, the resulting candidate architectures for different goal systems are analyzed for sensitivity to the goal system, clustered and finally tested for logical coherence. The resulting architectures are developed into a typology of technology scanning architecture types for preparation for disruptive technologies.

3 Methodology

In the Information Systems domain, the design science research is considered as a generally accepted research methodology [24]. Typically, design science re-search consists of the following phases: 1) motivation of the problem, 2) definition objectives of the solution, 3) design and development, 4) demonstration, 5) evaluation and communication.

3.1 Motivation of the problem

Companies must find a means for the early detection of disruptive technologies. A possible solution is to use technology scanning. Technology scanning is concerned with finding relevant technology-related information from outside the organization's technological and business context.

Devising architectures for technology scanning is a design problem, as the in-put to the system of technology scanning are known, but its structure is unknown. To solve this design problem one first needs to know the demanded outcome of technology scanning. In order to know the demanded outcome of technology scanning in a specific context, a systematic derivation of a goal system using technology scanning and the resulting requirements for technology scanning is needed

3.2 Definition objectives of the solution

Our research is based on the assumption that there are generic goals which are valid for all companies, and that an individual company's preference can be captured in a weighting of these generic goals. We refer as this weighting of the generic goals as a company's goal system (e.g. whether a company values derivation of new search fields over giving long-term strategic input). Given a goals-requirements-relation mapping (GSR) the demand of a certain generic goal to the requirements, we can then derive the total value a company places on each requirement.

To derive specific designs for technology scanning, a morphology of individual design (TSM) options needs to be devised. To structure this morphology, a framework of the relevant design dimensions of technology scanning (such as processes, organization, and methods) is needed.

To determine whether a certain choice of design option is adequate for the goal system of a company, the degree of fulfilment of the individual requirements through each design option needs to be evaluated, resulting in the requirements-design options relation (RF). Furthermore, the possibility to combine different design options needs to be evaluated in a consistency analysis.
Using the results from GSR, TSM, and RF we can mathematically derive a candidate architecture maximizing the contribution of the architecture to the goals valued by the company's goal system. To ensure logical consistency, the resulting candidate architectures for different goal systems are analyzed for sensitivity to the goal system, clustered, and finally tested for logical coherence. The resulting architectures are developed into a typology of technology scanning architecture types for preparation for disruptive technologies.

3.3 Design and development

The research project must result in the identification of the requirements for a design science artefact (Technology Scanning) will be developed Fig.5:
Artefact Technology Scanning consists of 4 parts:
1. Part 1: Goal system and requirements
2. Part 2: Technology scanning morphology
3. Part 3: Requirements fulfillment
4. Part 4: Architecture type

Part 1: (GSR) Goal system and requirements:
Aim is to analyze why companies use technology scanning and what outcomes and qualities technology scanning needs to have in order to be useful to a company.
This is needed to design technology scanning architectures which address both the reaction to disruptive technologies, a s well as other goals for which companies use technology scanning. The result of this subsystem will allow the translation of the preference of a company when using technology scanning into demands for specific requirements for technology scanning design options.
This artifact will consist of four components:
- A structured analysis of generic goals of using technology scanning
- Definition of the goal system, which is a company's weighting of the generic goals
- An analysis of specific requirements to technology scanning
- And synthesis of the goals-requirements relation

Part 2 : (TSM) Technology scanning morphology
In this framework for technology scanning and morphology of technology scanning design options is derived.
A morphology of design options is needed to investigate to which extent the individual design options meet the requirements demanded from technology scanning by a company. A framework for technology scanning is needed to determine the decision dimensions in the morphology. This framework needs to cover the relevant design dimensions

of technology scanning such as organization forms, processes, methods, interfaces and tools.

Part 3: (RF) Requirements fulfilment
To match the requirements companies, pose to technology scanning with the available design options, the fulfilment of each requirement through use of an individual design option will be analyzed. This analysis is needed to match demands for requirements obtained by the different goals with the fulfilment of each requirement per design option, forming a target function to optimize when building technology scanning architectures. No structured analysis of design options of technology scanning incorporating all relevant dimensions exists. Existing information on individual dimension will be analyzed [16], and the advantages and disadvantages given per design option mapped to the requirements. Scattered evidence on advantages listed in literature, published case studies and given in expert interviews will be synthesized into a coherent analysis.

Part 4: (AT) Architecture type
The goal of our research is to design an architecture for technology scanning, which the combination of the previous information as described in part 1,2 and 3.
To derive the topology of the technology scanning architecture, we proceed in three steps:

- Analysis of a candidate architecture for each given goal system using mathematical optimization (goal-requirements relation and requirements-design option)
- Clustering candidate architectures obtained from various goal systems, and conducting sensitivity analysis to find stable candidate architecture (multiple assumptions are made to facilitate the optimization)
- Logical deduction of a representative technology scanning architecture type for each identified cluster. (to allow identifying of the goal systems to one of the technology scanning architecture types)

Figure 3 provides an overview of the interaction between the parts and the Supersystems (Environment and Company)

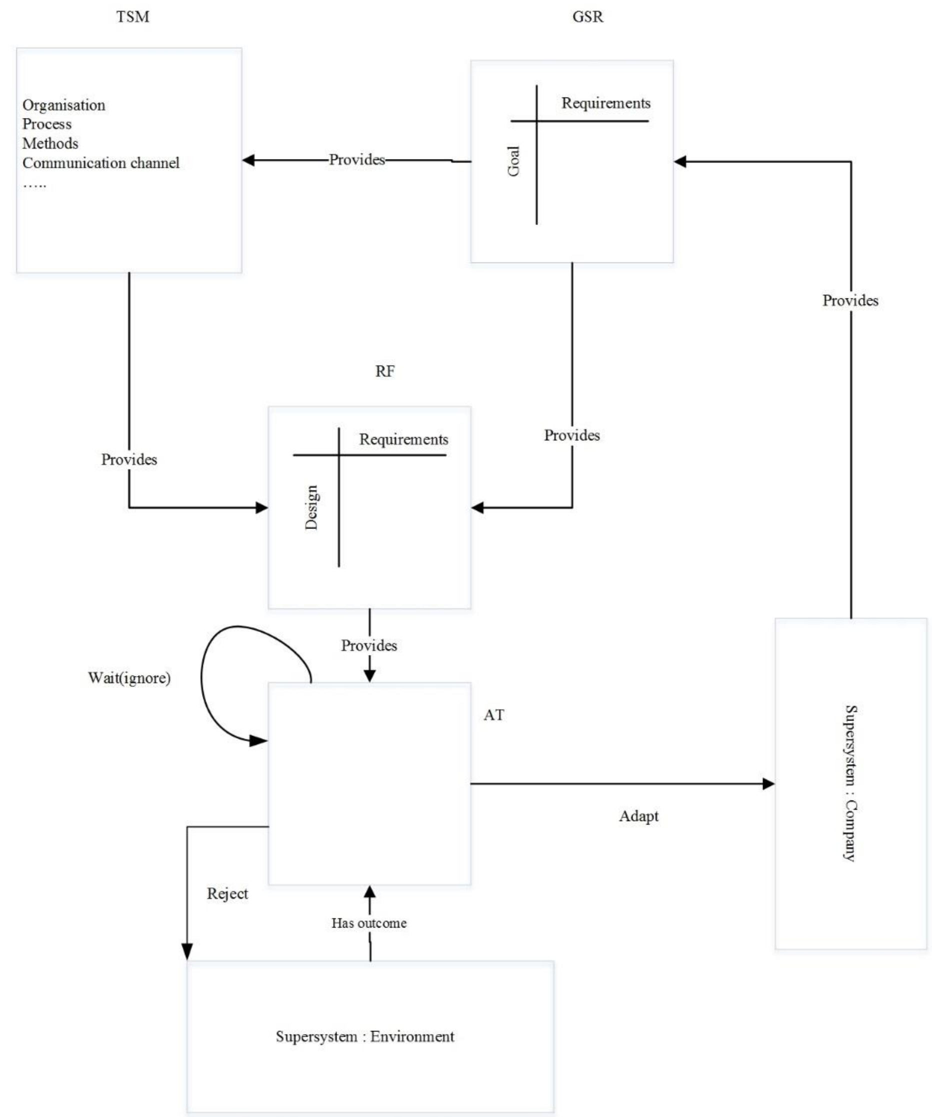

Fig. 3. Conceptual map of interaction between the parts (GSR, TSM, RF, AT) and Supersystem (Environment and Company).

At present, we haven't investigated which Enterprise Modeling would fit for the best solution. We decided to put this analysis out of scope of this paper.

Before analyzing design options for technology scanning, it is necessary to systematically derive the requirements technology scanning needs to fulfil. We will derive these requirements using the system-theoretic view of technology scanning architectures. To design an architecture for technology scanning, the goal is not only to design technology scanning itself as a system, but rather embed it into its Supersystem which included its embedding in the surrounding organization system and environment (see fig 4).

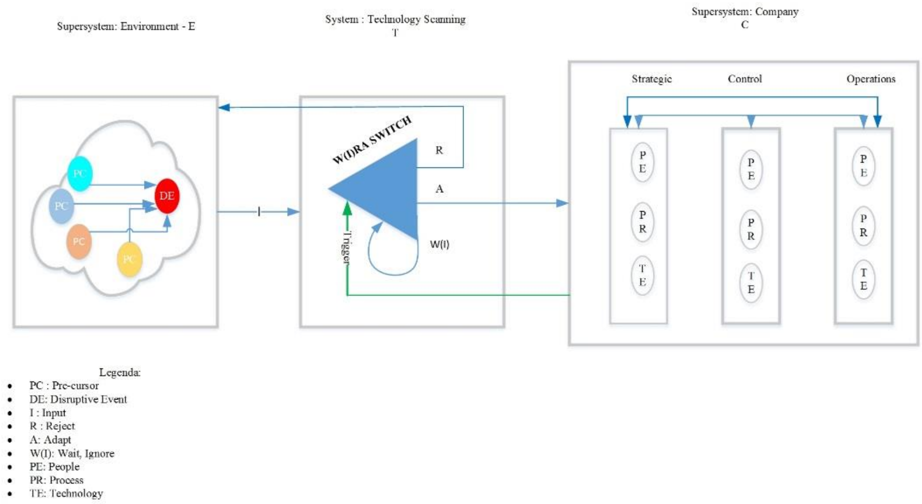

Fig. 4. ETS Diagram (ETC= Environment, Technology Scanning, Company)

Considering the design of technology scanning itself as design problem in sys-tem theory, we have to define requirements regarding the outputs of technology scanning [17]. Due to the design of the embedding into the Supersystems in an architecture, we furthermore have to define requirements to its impact, i.e., the effect of the output of technology scanning on (certain) outputs of the embedding organization system. We stress the difference between these requirements to the impact of technology scanning and the goals of the organization to use technology scanning in the first place: the goals are related to what the company want to do with the information (such as setting a trend, being prepared for beginning a development, challenging R&D strategy) whereas the requirements to the impact of technology scanning concern internal factors and capacity-building needed to achieve these goals (such as being more flexible in the face of change) [12]. Lastly the design of technology scanning itself is not unconstrained, so the inherent de-sign constraints of technology scanning itself (like limited use of resources) also have to be considered.

We thus propose to structure requirements to technology scanning by three main components: requirements to the outputs technology scanning themselves, requirements to the impact of technology scanning and requirements to the functioning of technology scanning.

Summary: Conceptual model of parts artifact Technology Scanning (Fig.5)

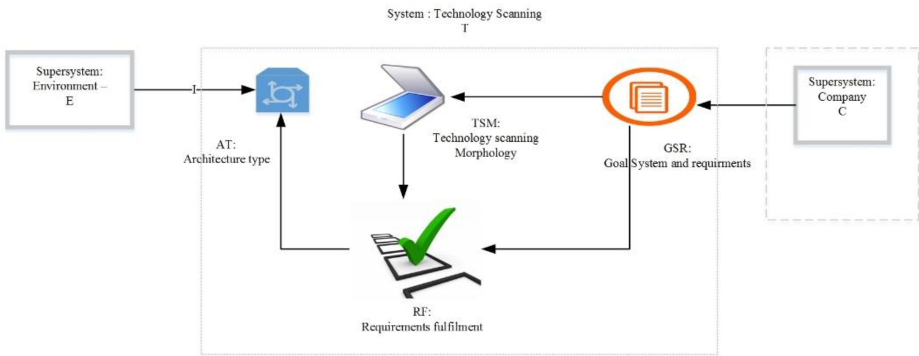

Fig. 5. Conceptual model of parts artifact Technology Scanning.

3.4 Demonstration

Brief description of the relationship between W(I)RA switch and technology scanning. In the environment cloud we identify pre-cursor points (Fig.4). The result of the sum from the outputs of these precursors will initiate a disruptive event. This event is identified as a new type of technology. The W(I)RA virtual switch will notice this disruptive technology (I) and initiating 3 questions: Do we ignore or wait (W(I)), do we reject (R), or do we adapt (A).
The choice of putting the W(I)RA in status Wait(Ignore) can be considered when there is no need at this moment to embrace this type of disruptive technology. It is not a passive state but continue monitoring. The reason can be that the organization decide not be ready for this change.
When decided to Reject (R), the disruptive technology is not taken into consideration. Reason for this decision can be due to major negative impact on the organization.
If decided to adopt (A), the information is screened and prepared for transferring to supersystem Company. The description of the transfer of the information falls out-side the scope of this paper.
The choice of these 3 conditions (R, W (I), A) is determined by the information coming from the output of part 3 (RF) (Fig.5). The input of part 3 (Requirements fulfilment) is determined by the output of part 1 GSR (Goal system and requirements) and part 2 TSM (Technology scanning morphology). The info in part 1 GSR is determined by the information (baseline information) provided by super-system Company (Fig.5).
The following matrix (table 1) gives an overview of the relationship between the input (information coming from the precursor), screening by the WIRA switch and status outcome.

Table 1. Relationship between input, screening and status outcome.

Precursor info (EWS)	W(I)RA screening info	Status	Explanation
I1 (input 1)	Not valid/ Not applicable	R- (Reject)	The disruptive technology is not taken into consideration
I2 (input 2)	Valid / Not applicable	W(I)- Wait (Ignore)	No need at this moment to embrace this type of disruptive technology.
I3 (input 3)	Not Valid / Applicable	W(I) – Wait (Ignore)	No need at this moment to embrace this type of disruptive technology
I4 (input 4)	Valid/ Applicable	A (Adopt)	Transferring to supersystem Company

3.5 Evaluation

Proceedings of this research:
The first step is to organize workshops and case studies with experts and practitioners from the field of technology scanning to get in depth knowledge of the four components. Starting with the part 1 GSR: Goal system and requirements. The outcome of the workshops and case studies will be used for the development of parts 2, 3 and 4. Yin multiple case study research will be used as one of the elements in the evaluation phase of the new artifact [28].

4 Preliminary Result

We conducted a study which performed an exhaustive literature search for disruptive technology used in the past research on disruptive technology. Literature has been considered from the fields of technology intelligence, corporate foresight, forecasting, disruptive technologies and related fields. This literature covered studies that date from 2000 onwards and the selection criteria were the examined adoption of disruptive technology in service operations. We re-viewed 227 published studies on disruptive technology and selected 35 relevant papers. We searched IS journals and citation database with the key words: ‘disruptive’,’ technology’,’ service’ as to obtain the relevant articles.

The outcome of this literature analysis gave us an insight into how companies deal with disruptive technologies. We have noted that companies are having trouble dealing with disruptive technologies. We have identified that there is a gap how companies perceive disruptive technologies. We define this gap as technology scanning

5 Future Research

While we are aware that technology scanning is only one part of the puzzle of preparing for disruptive technologies, we believe that such a method and tool (W(I)RA switch) integrating results from various fields of research on technology intelligence and disruptive technologies in an actionable way significantly helps companies prepare for the next disruptive technologies on the horizon.

Our research will continue with a deeper analysis of the methods, process and prediction which have been employed in various foresight situations, and how these can be combined and adapted to address the requirements identified. Furthermore, we will investigate which requirements are of greater importance to what kind of companies based on the goals these companies have from their involvement with technologies outside their established strategic context.

We will use the research design presented in this paper to systematically re-search the derivation of technology scanning architectures in order to provide practitioners with a usable model for challenging their existing technology scanning activities as well as designing new technology scanning activities for companies which so far have not systematically conducted such activities.

The ultimate goal of this research is to provide a model for decision-making regarding the incorporation of disruptive technologies into companies.

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