EXTERNAL TECHNOLOGY SEARCHING METHODS - A LITERATURE REVIEW

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ABSTRACT

This paper provides a preliminary assessment of the literature available in the field of External Technology Searching. Many methods exist to enable companies to take advantage of new technologies and apply them to achieve a competitive advantage. This literature review focuses on reducing complexity and providing clarity related to the numerous different terms and methodologies used throughout the literature. The main methods found in the literature include: Technology Foresight, Technology Forecasting, Technology Intelligence, and Technology Scouting. However, many additional terms have also been used to describe similar strategies, leading to inconsistency in the use of the terms, resulting in confusion and missed opportunities to innovate for those trying to navigate the field. Synthesis of the results assists in clarifying the differences and conflicts in the literature between the numerous terms. The results serve to display the state of the art on the field and present a basis for further research.

Keywords: Innovation, Open innovation, Technology Scouting, Research methodologies and methods, Technology Foresight

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1 INTRODUCTION

The automotive industry is facing increases in, competition, market volatility, and demand for customization and product variation. The pace of technological advancements is also accelerating, and further challenging the industry. To remain competitive, companies must be able to adapt responsively and always be looking one step ahead (Tschirky, 1998). The automotive industry is being pushed to be more flexible in accommodating re-design and implementing change, however, there is limited research in the area of implementing design methods into industrial settings (Blessing & Chakrabarti, 2009). Kujawa *et al*. (2018) describes the necessity of enabling changes within the life cycle of a production unit to facilitate improvements in the re-design and change process. The more flexibility that can be built into the production unit, the easier it will be to address changes to accommodate production of future models. To ease the development of solutions and stay ahead of technological adaptation, innovation and adaption is necessary. According to Halicka (2017), competitive advantage is largely determined by the adoption of innovative technologies and thus, the early identification of these technologies is therefore critical. One way to increase innovation is to take advantage of Open Innovation, the opening of a permeable boundary of a company's research and development process, allowing innovation to come from other companies (Chesbrough *et al*., 2006). Methods exist which aim to prepare for implementation of future changes and reduce uncertainty, by examining new and emerging technologies (Thom, 2010). These methods can be called External Technology Searches (ETS), and aim to bring new technologies into a company (Madani & Khormaei, 2013). ETS is an umbrella term to cover many of the existing methods in the field.

Many such ETS methods, and much research, exists in this field, however many authors use different wording and terminology to describe their methods, resulting in limited clarity and comprehension (Cuhls, K. *et al*., 2015; Madani and Khormaei, 2013; Halicka, 2017; Daim, Oliver, & Kim, 2013). Multiple authors have highlighted this as a common problem (Halicka, 2017; Cuhls, K. *et al*., 2015; Madani & Khormaei, 2013). A literature review on the subject will help identify and classify the more common terms used to describe ETS, and provide the necessary understanding to help in the selection of an effective method. This paper aims to fill the gap, identified by Blessing and Chakrabarti (2009), in the design research used in practice, by providing a guide to the literature on the topic, and making it easier for companies to select the appropriate process for their needs.

A literature review can assist other scholars by creating a clear and common foundation for advancing knowledge, which accelerates the state of theory within the field, and ultimately leads to development. (Webster & Watson, 2002). The objective of this literature review is to help clarify the numerous terms related to methods, tools, and processes related to ETS, and provide a guide for other researchers to comprehend the existing literature in the field.

Research questions examined in this paper:

- What methods of searching for new technologies exist?
- What methods are used in industry?

According to Chesbrough (2003), Open Innovation is the process of transferring innovation over a company's boundaries. Organizations following this concept are able to make use of ideas detached from their original portfolio. More importantly, there is potential to get ideas for core products or unique products that can help ensure a firm's technological leadership.

One challenge for companies is the handling and usage of unfamiliar knowledge sources, as well as new and simultaneously different resource constellations (Leker & Song, 2014). Therefore, it is of significant importance to get a holistic overview of the terms, methods and the application, hidden behind the buzzword 'open innovation'.

This paper provides a broad overview of the literature in this field, in order to identify the state of the art. Other literature reviews in this area exist including those by Iden *et al*. (2017) and Halicka (2017), however they examine a narrower field and fewer methods.

2 APPROACH

To answer the first research question, a literature review is conducted. In order to answer the second question interviews are performed. The literature review in this paper follows a simplified version of Fink's guide to conducting a research literature review. It has been simplified as the number of reviewers, and time-frame are limited. First is the development of research questions, followed by the

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selection of bibliographic databases and websites. The selection of search terms is next, followed by screening. The review is then completed and results are synthesized. (Fink 2005)
Based on Fink's guide, two research questions were developed and presented in the introduction. The databases in the search were: Science Direct, Scopus, Springer, Taylor & Francis Online, and Wiley Online Library. The languages included in this search were English and German. Key word searches were performed with the terms: Technology Scouting, Technology Monitoring, Technology Searching, and Technology Scanning. In addition to the described setup, the search was supplemented with backwards and forwards searches. Backwards refers to examining the reference section of important pieces and going back to the sources. Forward searches aim to identify the articles that have since cited the important pieces. Using the described boundary conditions, 118 sources were identified. This paper focuses on identifying the various methods and their differences; therefore, limiting the number of sources to only those presenting new methods or definitions of the terms. Following Fink (2005), the quality of the sources was examined and the relevant information extracted.
To answer the second research question, interviews are conducted. Twelve interviewees were questioned about the external searching activities used within their departments. The results of the interviews are presented in Section 4.

3 SYNTHESIZING RESULTS

In this section, the terms found in the literature search are organised, defined, and differences and similarities are identified. First, an overview of the literature is presented, followed by a deeper explanation of the found information.
Since 2000, there has been a dramatic increase in Cross-Industry Innovation. Cross-Industry Innovation, a form of Open Innovation, is when companies get innovation from outside sources, form external partnerships with different industries, develop technologies in partnerships, or commercialize technologies outside of their company boundaries (Dingler and Enkel 2016). This massive increase in innovation crossing company boundaries corresponds to the amount of literature on technology assessment and foresight (Halicka, 2017). Most of the literature falls under the titles Technological Forecasting, Technology Foresight, Technology Intelligence, or Technology Scouting. These terms all have different meanings, but their research has been correlated to time. Figure 1 shows the evolution of the focus of research related to ETS. Madani and Khormaei (2013) and Chan and Daim (2012) describe an additional fifth generation which focuses on policies for global innovation systems and their complex issues. (Gudanowska 2016)

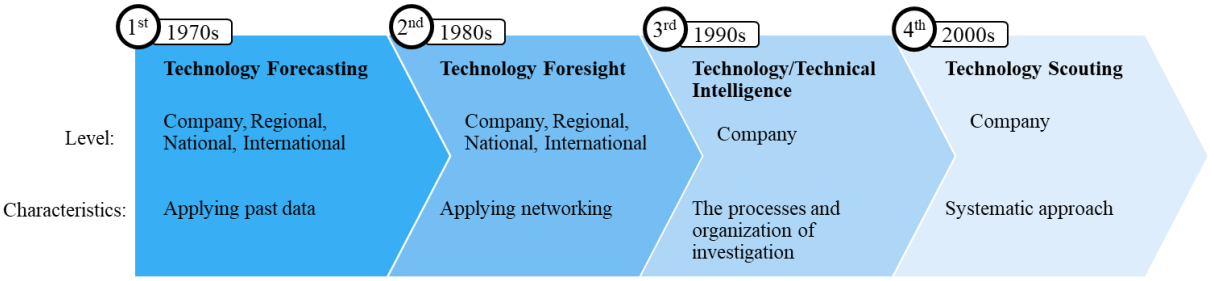

Figure 1: Generations of ETS based on Chan and Daim (2012) and Gudanowska (2016)

Figure 2 is helpful in understanding the various terms. **Technology Forecasting** is generally defined as a method for anticipating future developments. **Technology Foresight** and Technology Forecasting are used interchangeably throughout the literature, however, (Cho and Daim 2013; Rohrbeck, 2007) describe **Technology Foresight** to be the wider ranging term, which includes aspects of networking on large levels as well as preparing for decision making. These terms are used on a very large and long-term scale, including defined to include science, technology, the economy, and society (Cho and Daim, 2013). Various derivatives of the term Technology Foresight exist in the literature, including:

- **Industry Foresight**, refers to using foresight to identify competitive spaces in the industry.
- **Foresight** is alone defined as a personal power of foresight.
- **Managerial Foresight** is to predict the outcome of management decisions.
- **Foresight Research** is research in the field of Technology Foresight (Gudanowska 2014).
- **Strategic Foresight** refers to decision making and management based on foresight.

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- **Corporate Foresight** is watching competitors to seek opportunities (Thom 2010). Iden *et al*. (2017)

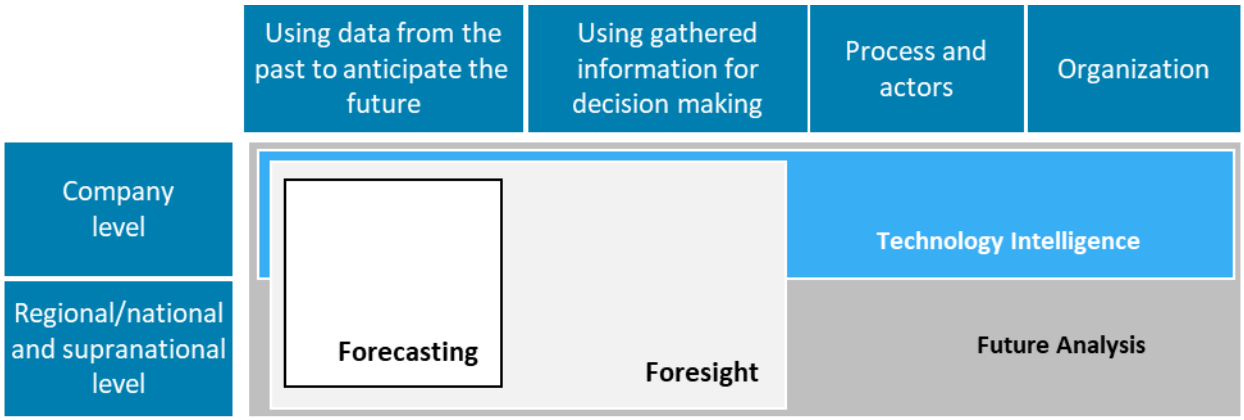

Figure 2: Scientific classification of the terms from Rohrbeck (2007)

Technology Intelligence describes the efforts restricted to the company level and the term **Competitive Technical Intelligence** is used similarly and pertains to using Technology Intelligence for Competitive Adantage (Rohrbeck 2007). The term **Future Studies** has recently been growing and is referred to as **Future analysis** in the diagram. These terms all refer to research about the future and are broad ranging in that they include cultural shifts, market trends and other non-technical aspects (Rohrbeck 2007). Halika (2007) and Gudanowska (2014) use the term **Technology Analysis** as a broad descriptor for all the methods. Porter and Cunningham (2005) write that the terms are describing very wide ranging activities, however they can still be used on a smaller scale, for example in a company for certain technologies, this however, contradicts the other terms listed above specifically relating to corporate focused initiatives. Lichtenthaler (2007) writes that the four terms are similar and chose to use the term Technology Intelligence only because it is the most recently used term. Future-oriented Technology Analysis (FTA) is described by Halicka (2017) as a process aiming to predict future developments of a technology through thorough assessment of its current state, as well as the identification of factors affecting future developments. FTA is therefore a way of combining Technology Assessment and Technology Forecasting.

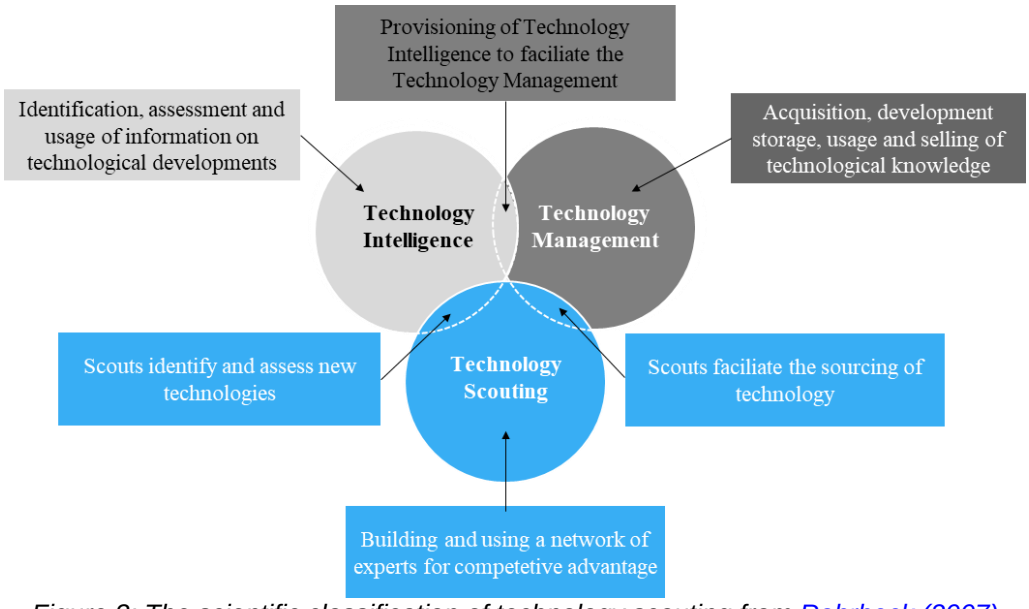

Figure 3: The scientific classification of technology scouting from Rohrbeck (2007)

Technology Management refers to the way intelligence and opportunities are managed within a company. Management includes the integration of strategies for bringing in more intelligence, finding opportunities, developing and implementing technological capabilities and planning within the company (Rohrbeck, 2007). Figure 3 by Rohrbeck (2007) helps to understand the synergy between Technology Management, Intelligence and Scouting. However, conflictingly Kerr *et al*. (2006)

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describes all the aspects of Technology Scouting as being part of Technology Intelligence. It has also been said that the terms feed into each other, Haddad (2014), explains that Technology Scouting feeds into Technology Management which then is a part of Technology Forecasting. It could be said that Technology Scouting is a means to increase Technology Intelligence and facilitate Technology Management.

A cluster of terms is identified as **Auxiliary Methods. Auxiliary Methods** is used by (Halicka 2017) to describe tools supporting main methods. Encyclopaedia Britannica describes Auxiliary as a helping element. Most of these Auxiliary Methods are applied using software programs to quickly sort through data, and perform statistical analysis (Porter and Cunningham, 2005). This in itself will not bring new technologies into a company; however, can be effective tools in various phases of a larger strategy. Some Auxiliary Methods are shown in Table 1, however more can be found in Halicka (2017), and Cho and Daim (2013).

Table 1: Auxiliary methods

Bibliometrics (Cho and Daim, 2013)	Tech Mining (Porter and Cunningham, 2005)
Data Mining (Cho and Daim, 2013)	Technology Portfolio Analysis
Database Tomography (Cho and Daim, 2013)	Technology S-Curve (Schilling & Esmundo, 2009)
Key/Critical Technologies (Gudanowska, 2014)	Text Mining (Porter & Cunningham, 2005)
Patent Analysis (Halicka, 2017)	S & T Indicators (Porter & Cunningham, 2005)
Patent Development Maps (Kim *et al*., 2016)	…

Similar steps are identified throughout the literature, that are associated with many of the different methods. In order to provide a visual aid to the description of the methods, Figure 4 shows 9 Steps used in most of the ETS methods. These nine steps are described in more detail below.

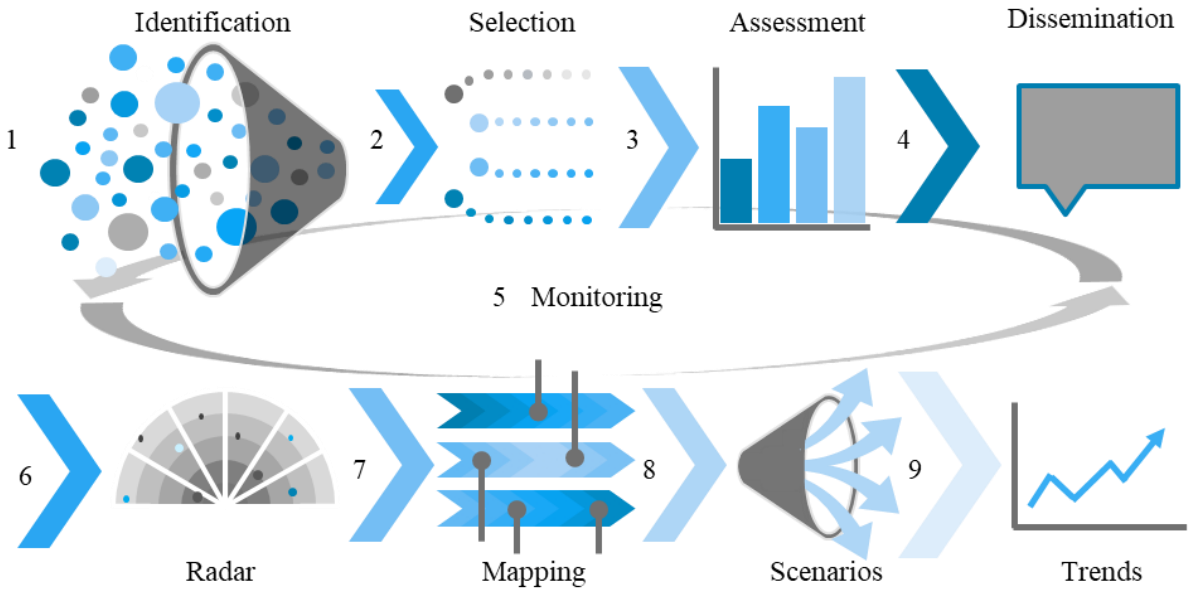

Figure 4: Methods of technology foresight own diagram based on the sources from Table 2

1-*Identification* is a structured search for information about different technologies at all varying stages of development in industry and academia. Essentially a data-gathering phase, where a large range of technologies are collected and taken into the next phase. To determine which technologies are most relevant, step 2 involves a *Selection* phase. The selected technologies then undergo an *Assessment* in step 3, where technologies are ranked based on their degree of innovation, on potential 'market impact', and 'technological realization complexity'. Step 4 involves *Dissemination*, where the technologies are researched in depth, and a technological profile is assigned outlining potential innovation, trends and the latest developments. These profiles are then communicated throughout the company. Step 5-*Monitoring* refers to repeating the first four steps in a continual process, or perhaps

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only for a few specific technologies. Step 6-*Radar* involves developing a diagram from the Cisco Technology Radar to visualise the results of the first four stages. This diagram is often included in dissemination to assist management in understanding the importance of the different technologies. Step 7-*Mapping* refers to tracking and mapping out the evolutionary steps of a technology. This is typically a visualisation like a development path including elements related to the technology and relevant factors. Step 8-*Scenarios* is a process of generating images about the future, building hypothetical sequences of events that could be plausible in the future. Describing these scenarios allows a company to examine the implications of various outcomes and helps to plan in constantly changing environments. Step 9-*Trends* can be described as significant developments constantly developing in the same direction over time. For example, the recognition that many new patents are being published in a new field could indicate a new trend. For more information on Trends, see Rohrbeck (2013).

Table 2 lists the methods and identifies the steps they are associated with. Table 2 and Figure 4 together, provide a general description of most of the methods.

Table 2: Methods of technology foresight

Methods	1	2	3	4	5	6	7	8	9
Environmental Monitoring (Saviz & Blum, 2002)	■	■	■	■	■				
Environmental Scanning (B.L.& Monterde, 2015)	■	■	■	■	■				
External Search (Dong & Netten, 2017)	■								
Future Studies (Porter & Cunningham, 2005)								■	■
Futures Research (Porter & Cunningham, 2005).								■	■
Horizon Scanning (Ricciardi *et al.*, 2017; Douw *et al.*, 2006)	■	■	■	■	■				
Opportunities Analysis (Porter & Cunningham, 2005)		■	■						
Scanning Method (Honda *et al.*, 2017)	■								
Scenario Analysis (Rohrbeck, 2013)								■	
Scenario Foresight (Boe-Lillegraven & Monterde, 2015)								■	
Scenario Planning (Boe-Lillegraven & Monterde, 2015)								■	
Strategic Analysis (Iden *et al.*, 2017)		■	■						
Technology Assessment (Porter & Cunningham, 2005)							■		
Technology Mapping (Halicka, 2017)							■		
Technology Monitoring (Yan & Cai, 2011)	■	■	■	■					
Technology Opportunity Analysis	■	■	■	■				■	
Technology Opportunity Discovery	■	■	■	■				■	■
Technology Radar (Rohrbeck *et al.*, 2006)	■	■	■	■	■	■			
Technology Roadmapping (Gudanowska, 2014)							■		
Technology Scanning (Yan & Cai, 2011)	■								
Technology Scouting (Rohrbeck, 2007)	■	■	■		■				
Technology Search (Greitemann *et al.*, 2017)	■								
Technology Seeking (Yan & Cai, 2011)	■								
Technology Watch (Yan & Cai, 2011)	■	■	■	■					
Trend Extrapolation (Rohrbeck, 2013)									■
Trend Radar (Durst & Durst, 2016)						■			■

Table 2 offers explanations for most of the methods, however some conflicts in the literature exist related to these definitions, and some methods cannot be separated from another based on this table. These conflicts and differences are further explained.

Porter and Cunningham (2005) say that Technology Monitoring, Technology Watch and Environmental Scanning are the same. Technology watch is however, defined by Halicka (2017) as an Auxiliary Method along with Technology Mapping, Technology Roadmapping, and Scenarios. The two terms Technology Scouting and Technology Monitoring are both used in the literature, and frequently describe the same process in different sources (Rohrbeck, 2007; Cuhls, K. *et al.*, 2015). However, the majority of the literature describes **Technology Monitoring** as a continuous process

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characterization, and interpretation of technology development activities and tracking their progress over time (Porter & Cunningham, 2005; Yan & Cai, 2011). Technology Monitoring focuses on the depth of scouting and is more comprehensive and complex than **Technology Scanning** methods (Yan & Cai, 2011).

Environmental Monitoring is described as monitoring process of all environmental sectors (Saviz and Blum, 2002). According to Boe-Lillegraven and Monterde (2015), **Environmental Scanning** describes an extremely broad method including the subset of Horizon Scanning. **Horizon Scanning** is a systematic method for detecting developments, assessing the technologies, assigning priorities, selecting the appropriate technologies followed by dissemination of the information in order for decision making to take place. Horizon Scanning is a broad method with completely varying time horizons from short to long-term and can be continuous (Douw, Vondeling, & Oortwijin, 2006). Technology Scouting can be seen as a more technology specific and focused form of horizon scanning. The Technology Scouting methodology **The Technology Radar** was developed by Deutsche Telekom Laboratories (Rohrbeck *et al.*, 2006) and has brought major contributions to innovation and technology management. The **Technology Radar** is essentially a visual tool used for Technology Scouting, which has been developed and applied in industry. (Thom, 2010; B.L. & M, 2015; Rohrbeck *et al*., 2006). Technology Opportunity Analysis and Discovery are methods with a high level of detail in the execution of the steps with which Auxiliary Methods are to be used.

4 INTERVIEWS

In order to obtain insight into which methods are being applied in industry, employees were interviewed. First, employees were asked to "check-off" which of the nine methods shown in Figure 4 are being used. Following which, open qualitative questioning occurred to discover positive and negative points of interest. Nearly all of the methods described above are in use to some extent. From Figure 4, methods 1, 6, 7, 8, and 9 are used regularly. Monitoring is also being conducted, however it was noted by multiple employees that the dissemination phase is weak. Although most of the methods are already in use, they are not organized and structured together. Multiple tools exist to perform similar functions and external consultants occasionally provide input. The lack of structure leads to poor dissemination and even duplicated work efforts.

5 CONCLUSION

To increase a department's ability to adapt to change, maximize innovation, and provide early identification of changes, a holistic External Technology Searching strategy is recommended. Before this can occur, full comprehension of the state of the art in this field is required. Literature in this field includes numerous methods, which have been identified and explained in this paper. The literature has been organised to provide researchers with a comprehensive guide to the existing literature in this field. Differences between the existing methods and how they fit together has been presented. This paper offers an easy first view into the field of ETS, and helps readers determine where they should be focusing their further research. Additionally, the methods being used in industry are examined. Interviews show that nearly all methods are being used in organizations. However, the use is not structured and organized within the company. Suggestions for further work include the development of a holistic strategy tailored to the needs of the department, including which methods to use, when they should be used, and which Auxiliary methods are best to assist in performing the tasks. To do this, an appropriate needs assessment is required and a matching system to methodically select the optimal method to suit the requirements.

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