Technology Roadmapping at High-Tech Small and Medium Enterprises: A manual

Author: Wouter Rietveld
University of Twente
P.O. Box 217, 7500AE Enschede
The Netherlands

ABSTRACT

Since the first records of technology roadmapping in 1980, more literature on the innovation planning tool has been developed and published. The increasing interest is also noticed in the small and medium enterprise sector, where organizations with less resources try to compete with the ever growing international market. Managing future innovations is therefore interesting for SMEs but they lack hands-on methods to do so. Current literature suggests that SMEs do not have resources to apply TRM, or that they should do so together. This research tries to identify how high-tech SMEs can individually engage in technology roadmapping. Using a systematic literature approach, an integrative synthesis is searched and found for reasons to roadmap, and the generic approach to do so. Based on that literature a to-the-point manual is developed in order to help high-tech SMEs in applying TRM. The results show that if high-tech SMEs are looking to discuss their vision, align their departments or innovation methods, make strategic decisions or engage in innovation planning TRM should be applied. By either using the technology push, or the market pull manual this research tries to provide an implementable step-by-step method for high-tech SMEs to follow. Making TRM accessible for high-tech SMEs.

Graduation Committee members: Dr. M. de Visser & Dr. M. L. Ehrenhard

Keywords

Technology roadmapping, manual, implementable method, technology push, market pull, literature review & high-tech SMEs

9th IBA Bachelor Thesis Conference, July 5th, 2017, Enschede, The Netherlands.

1. INTRODUCTION

1.1 Situation

Technological developments and globalization increase the competition between companies, bringing innovation management to the core of corporate decision making (Carayannis, Grebeniuk, & Meissner, 2016). Managers in the past 10 years seem to have realized that the relationship between business goals and technology development needs to be understood and discussed. Giving rise to technology roadmapping [TRM] as an approach to do so.

This is interesting since the method is not new. The first records of TRM can be found at 1980's Motorola, where they realized that more complex products and processes could cause them to neglect other important elements, using an overarching planning tool as a reaction to this challenge (Willyard & McClees, 1987). More companies have been adopting TRM since.

It was not until 2004 however, when the first broad used systematical approach was published. Phaal et al. (2004) proposed the T-plan, a set of activities which can be done in workshops over a short period of time within the organization.

The other majority of previous contributions are either, like the T-plan, describing a general methodology for roadmapping (Vojak & Chambers, 2004) or report the results of adopting TRM (Barker & Smith, 1995; Bray & Garcia, 1997; Caetano & Amaral, 2011; Groenveld, 1997; Jun, Seo, & Son, 2013; Kappel, 2001; Mirbel & Ralyte, 2006; Walsh, 2004; Willyard & McClees, 1987).

However, for smaller companies, and managers who just start with TRM, these contributions offer little practical help (Battistella, De Toni, & Pillon, 2015).

1.2 Complication

In 2012, 99,8 % of all companies registered in the European Union where classified as a small or medium enterprise and these companies employed 67 % of all FTEs at work in the union (European commission, 2015). Despite their important role in the economy, the reality shows that a lot of these SMEs are at a disadvantage compared to large corporations in terms of financing, growth and pursuing technological innovations (Jun et al., 2013). Most consultancy tools and methodologies seem to be developed for larger corporations with many of resources.

However, contributions have been found on the application of TRM at SMEs. Some propose an open innovation solution in which SMEs work together to generate a roadmap (Lindermann, Valcarcel, Schaarschmidt, & von Kortzfleisch, 2009) while other researchers propose a division between steps that SMEs can take together and steps they should take individually (Battistella et al., 2015). Both articles argue that SMEs do not have the knowledge, capabilities, and resources available to perform TRM on their own.

Other articles are case studies on Singaporean (Holmes & Ferrill, 2005) or Korean SMEs (Jun et al., 2013) who identify a broad methodology and argue for the success of TRM, even at smaller firms, but lack an implementable step-by-step method.

In Twente, an upcoming region in the Netherlands close to the University of Twente, a lot of technology-driven start-ups and spin-offs are founded ("Kennispark Twente,"). These high-tech SMEs are looking for ways forward: scaling up or strengthening their position in the market. Good innovation planning could help, but the current literature lacks easily implementable methods to assist (Battistella et al., 2015).

Therefore, this contribution will propose an easy to follow manual to roadmapping for high-tech SMEs. The goal is to break through the idea that TRM is not for individual SMEs, and if that is the case: why and how should SMEs apply TRM.

First, the research questions are defined, after which the research methodology is explained. A systematic literature study was conducted to find a synthesis on roadmapping. This general approach was then strengthened by the literature to make an easy to implement manual for SMEs in the high-tech sector.

1.3 Question

This research intends to understand 1) why organizations roadmap and 2) how high-tech SMEs could apply existing roadmapping techniques. Suggesting a TRM manual for high-tech SMEs. Therefore, the research question is: How can existing technology roadmapping techniques be used by high-tech SMEs? The following sub questions were defined:

A. How are Technological Roadmapping and high-tech SMEs defined?
B. Why do companies apply TRM?
C. What are existing TRM techniques?
D. Is there one way to roadmap for high-tech SMEs?

2. METHODOLOGY

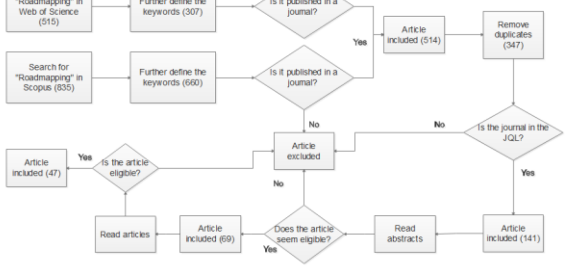
A literature study was used instead of an empirical one. It is Rousseau, Manning, and Denyer (2008) who wrote that in order to move forwards in management studies, cherry-picking should be countered with a systematic literature review [SLR]. A systematic literature review is a critical assessment and evaluation of all contributions that address a specific issue (Navimipour & Charband, 2016). To perform a SLR, the researchers use an organized method of locating, assembling, and evaluating a body of literature on a particular topic using a set of specific criteria (Navimipour & Charband, 2016). Relying on any sampling or subset of literature would risk misrepresenting the diversity in its findings (Rousseau et al., 2008).

That is why this research methodology followed the "synthesis" procedure (Rousseau et al., 2008). Applying SLR, comparing articles to find a common ground or synthesis to use in the proposed manual.

The integrative synthesis involves collection and comparison of evidence involving two or more data collection sources (Rousseau et al., 2008). Using Web of Science and Scopus patterns across published research studies were studied, compensating for single-study weaknesses, in order to improve the internal and external validity of the various findings. Only peer reviewed articles from indexed journals (Journal quality list [JQL]) were used. The methodologies related to the different research steps are now discussed per step.

2.1.1 Systematic literature review

In order to define TRM (A), to find TRM circumstances (B) and to identify the different roadmapping techniques (C) the workflow as represented in figure 1 was followed.



Graphic 1: Article workflow of this research.

The broader term: "roadmapping" was used as a keyword across the search engines in order to ensure multiple angles on the keyword, avoiding only articles that are based on Phaal et al. (2004). Only articles that live up to the previously mentioned criterium were used. In the last step, a check on eligibility was performed: articles must contain relevant qualitive information on TRM or encompass information on the circumstances under which TRM is applicable.

The findings are summarized in the concept matrix in appendix A. In the following paragraphs the methodologies per sub-question are clarified.

2.1.1.1 *Definitions of TRM and high-tech SMEs*

"Technology roadmapping" is a term that has grown in popularity since Phaal et al. wrote their article in 2004. To ensure that this research does not end up with variations on their article, the term "roadmapping" was used. To do so, the SLR summarizes the definitions that other authors use regarding roadmapping. These definitions were used to find a broad and general definition of roadmapping that should also apply to "high-tech SMEs".

"High-tech SMEs" was put into the research question to differentiate between already existing literature for SMEs, that can share roadmapping processes together, and more research intense SMEs, that cannot. Since R&D spending determines a high percentage of the available resources, the definition given by the European Commission (2012) was used.

2.1.1.2 *Reasons to roadmap*

The body of research regarding the why and when of roadmapping is limited, however these questions are rather crucial if high-tech SMEs want to apply the TRM manual immediately. That is why the SLR is used to identify the circumstances in which existing articles have applied roadmapping and why they did so. These can be used to classify the different roadmapping techniques in the SLR and could help to make the manual more specific for certain circumstances. The findings can be found in the definition of TRM, chapter 3.2.

2.1.1.3 *Roadmapping techniques - synthesis*

The core of the SLR was about the roadmapping techniques that are used in literature. The different methods should be classified based on the circumstances, after which a synthesis can be found.

Rousseau et al. (2008) identify different ways to synthesize from existing studies. Synthesis by interpretation seeks to translate key interpretations from one study onto another in order to build higher-order theoretical constructs. Thus, in this step the imagery and themes that surface across the studies will be compared (Beck, 2001). Interpretive synthesis should compile descriptive data and exemplars from individual studies, building them into a mosaic or map (Hammersley, 2001).

2.1.2 TRM for High-Tech SMEs manual

A SLR is interesting, and should provide new insights for high-tech SMEs nevertheless, as established before, the main gap lies in applicable methodologies that SMEs and their consultants can directly use (Battistella et al., 2015; Bray & Garcia, 1997; Jun et al., 2013; Lindermann et al., 2009; Walsh, 2004). That is the reason that one of the deliverables is a manual to support High-Tech SMEs in their application of TRM.

The manual is based on the interpretive synthesis of SLR and will be a new business process for SMEs that want to use TRM. Chinosi and Trombetta (2012) argue that business processes are best visualized using Business Process Model and Notation [BPMN] while Dijkman, Dumas, and Ouyang (2008) claim that BPMN has become standard for capturing business processes in the early phases of development. The notation inherits and combines elements from a number of previously proposed notations and is easy to read (Dijkman et al., 2008), which makes it perfect for the proposed manual.

As described before, a synthesis is used as general methodology. The goal is to generate a broad manual that builds forth on the different literature that has been published on this topic. When the general methodology is established based on synthesis, the same idea of overlap is sought for the specific steps. To generate a roadmap manual that is based on current contributions on this topic, only steps that are suggested by multiple articles will be included in the manual. Lastly, the manual will be made to-the-point with ideas that are selected by the author. These should be read as tips and options to make the identified steps more accessible.

3. DEFINITIONS

3.1 High-tech SMEs

The definition of high-tech SMEs is important since it will define the users of the developed manual.

Companies that fulfil the criteria as proposed by the European Commission (2003) qualify as micro, small and medium enterprises. See table 1.

Company category	**Staff headcount**	**Turnover**	**or**	**Balance sheet total**
Medium	<250	≤ € 50 m		≤ 43 m
Small	<50	≤10 m		≤10 m

Table 1. Definition of SMEs. Adjusted from European Commission (2003).

The notion "High-tech", has been defined on bases of R&D expenditure (OECD Science, 2007; Parida, Westerberg, & Frishammar, 2012). That is why the definition as formed by the Innovation scan developed at the University of Twente is used (Munster, 2011).

Type of enterprise	**Percentage of turnover spent on R&D**
High-tech	> 10%
Medium-tech	5-10%
Low-tech	< 5%

Table 2. Definition of high-tech. Adjusted from: Munster (2011)

This means that high-tech SMEs are companies with less than 250 employees and less than 43 million euros on its balance sheet, or with less than 50 million euros turnover, of which it spends at least 10% on R&D.

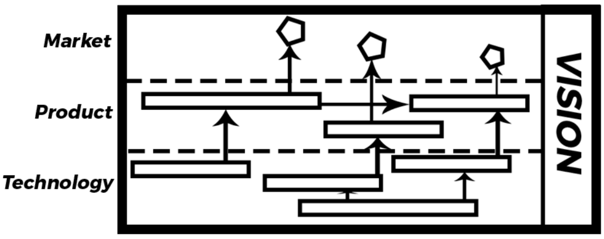
3.2 Technology Roadmapping

Technology roadmapping is the act of making, maintaining and implementing a technology roadmap (Saritas & Aylen, 2010). In the SLR most of the definitions on roadmaps were the same, but to show the subtle differences and come to one understanding of the term, the findings are summarized in two stages. 1) What does a roadmap look like? 2) What are reasons to roadmap?

3.2.1 What does a roadmap look like?

According to the literature, a roadmap is a multi-layered graphic with a time component (Abe et al., 2009; Carvalho, Fleury, & Lopes, 2013; Cheng et al., 2016; Phaal & Muller, 2009) and there is a broad consensus on the main three layers that a roadmap should have (Carvalho et al., 2013; Dissel, Phaal, Farrukh, & Probert, 2009; Groenveld, 1997; Phaal et al., 2004):

- Market
- Product
- Technology (see graphic 2)



Graphic 2: General form of a roadmap. Based on Phaal, Farrukh, and Probert (2004).

3.2.2 Reasons to roadmap
The SLR showed that the current contributions on TRM see four main goals for roadmapping. These are the main themes that recur in the contributions.

Roadmapping is for:

1. Vision discussion
2. Alignment
3. Decision making
4. Planning

3.2.2.1 *Vision discussion*
Advantages of roadmapping include the facilitation of interorganizational communication (Oliveira & Rozenfeld, 2010) and the transparent formulation of a long term vision (Ahlqvist et al., 2012). The contributions who mention vision either argue that roadmapping helps in formulating or developing the vision (Ahlqvist et al., 2012; Fenwick, Daim, & Gerdsri, 2009; Foden & Berends, 2010; Groenveld, 1997; Phaal & Muller, 2009) or that the roadmap should fit with the vision and that current policies and strategies shape the roadmap (Caetano & Amaral, 2011; Carayannis et al., 2016; Dissel et al., 2009; Gerdsri et al., 2010).

The interorganizational discussion about vision is especially interesting for high-tech SMEs since they have limited resources but employ relatively involved and trained staff who are assumed to want to give input on the long-term vision of the company.

3.2.2.2 *Alignment*
Alignment happens in the roadmapping process in two ways.

Through the vision discussion, because of the involvement in this discussion, the different functions and perspectives will be more aligned when the roadmap is finished. Everyone should know the goal and its own part to play towards it.

Secondly, the roadmap should summarize already existing planning and development processes in the company (Oliveira & Rozenfeld, 2010). Ensuring that all efforts are made in the same direction.

3.2.2.3 *Decision making*
The tool should provide structured information to support decision making and be a basis for strategic choices (Battistella et al., 2015). It can help with making R&D investments (Cho, Yoon, & Kim, 2016) or aid in deciding which technology and market gaps a company should consider (Fenwick et al., 2009). Furthermore, different contributions suggest implementing analytic hierarchy process [AHP] within roadmapping to quantify and assist in the decision making within the roadmapping process (Fenwick et al., 2009; Gindy, Morcos, Cerit, & Hodgson, 2008; C. Lee, Kim, & Lee, 2016; H. Lee & Geum, 2017).

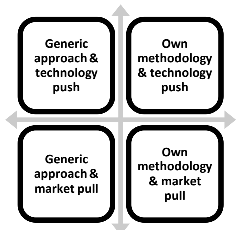
3.2.2.4 *Planning*
The main goal, however, is similar to that of normal roadmaps: people use it to find their way (Saritas & Aylen, 2010). Technology roadmapping is a strategic planning tool (Gerdsri et al., 2010; Oliveira & Rozenfeld, 2010; Vishnevskiy, Karasev, & Meissner, 2016; Zhang, Robinson, et al., 2016; Zhang, Zhang, et al., 2016) that is used to map the paths to commercial exploitation (Phaal, Routley, Athanassopoulou, & Probert, 2012). Shortly said: Roadmaps can be used for planning (Cheng et al., 2016; Kappel, 2001). Cosner et al. (2007) even argue that when properly done, roadmapping could identify gaps or contradictions in current planning processes.

Using it for planning means that they should have outputs and demonstrators along the way (Phaal et al., 2012), for example action plans, technology development schedule, product planning or policy measures (Amer & Daim, 2010; C. Lee et al., 2016; J. H. Lee, Phaal, & Lee, 2011; S. Lee, Yoon, Lee, & Park, 2009).

3.2.3 Definition
Technology roadmapping is the act of making, maintaining and implementing a technology roadmap, which is a multilayered planning tool with a time component which is used to discuss corporate vision, to align different functions, perspectives, and processes and to assist in strategic decision making.

4. ROADMAPPING TECHNIQUES – A SYNTHESIS
Summarizing the results from the SLR show that there is one generic approach recurring among them (Carvalho et al., 2013). Furthermore, the SLR identified two strategies used in TRM, either technology push or market pull.

Therefore, the methodologies can be divided in a two by two matrix. The Y-axis represents the strategy behind the TRM, either technology push or market pull and the X-axis divides between approaches who use the recurring standard approach and ones who have their own methodology. The division of the articles can be found in Appendix B.



Graphic 3: Generic approach, technology strategy division of TRM contributions

4.1 The generic approach
Most of the literature regarding TRM uses a generic approach (Carvalho et al., 2013), which originates from Bray and Garcia (1997) and was renewed by Phaal et al. (2004)

The consensus is about three main phases that need to be considered: 1) Preparation 2) Roadmapping) and 3) Implementation

These steps are differently described throughout the literature, for example, Cuhls, de Vries, Li, and Li (2015) write in their TRM case comparison contribution that they found three steps in all their cases: 1) information gathering 2) drawing the roadmap and 3) designing the output. Or Gerdsri et al. (2010) who define

1) Initiation 2) Development and 3) Integration, and for example, Saritas and Oner (2004) who argue for 1) Preliminary activity 2) Development of the roadmap 3) Follow-up activity. More can be found in appendix B.

The contributions that apply the generic approach are either business cases that apply the methodology or are studies that try to combine TRM with different approaches to gain more value out of roadmapping (see Appendix B). These specific combinations can be used in the manual to strengthen the TRM process.

Furthermore, the SLR showed that the contributions on TRM agree that there are two methods to gather the data necessary for the TRM process: experts in workshops and literature/desk research. (see Appendix B)

4.2 Market pull vs Technology push

When companies plan their technologies, they may choose one of two technology-product integration strategies: technology push or market pull (Caetano & Amaral, 2011).

For the market pull strategy, a synthesis was found in the generic approach. These contributions are either case studies or studies which try to combine TRM with different approaches. Examples of these combinations are, collective industrial roadmaps (Cho et al., 2016), value drivers (Fenwick et al., 2009), change management (Gerdsri et al., 2010), scenario's (Hansen, Daim, Ernst, & Herstatt, 2015; J. H. Lee, Kim, & Phaal, 2012; Saritas & Aylen, 2010; Siebelink, Halman, & Hofman, 2016) or risk management (Ilevbare, Probert, & Phaal, 2014).

In the SLR, six articles were identified who solemnly focus on technology push, and thirteen articles argue that the generic approach they suggest should work for both strategies. From the six articles, two articles propose a way to identify technology using outside knowledge (Kostoff, Boylan, & Simons, 2004; S. Lee et al., 2009) and the other four seem to fit to the generic approach (Bildosola et al., 2017; Caetano & Amaral, 2011; Dissel et al., 2009; Foden & Berends, 2010). So, for the technology push strategy a synthesis is identified in the generic approach as well.

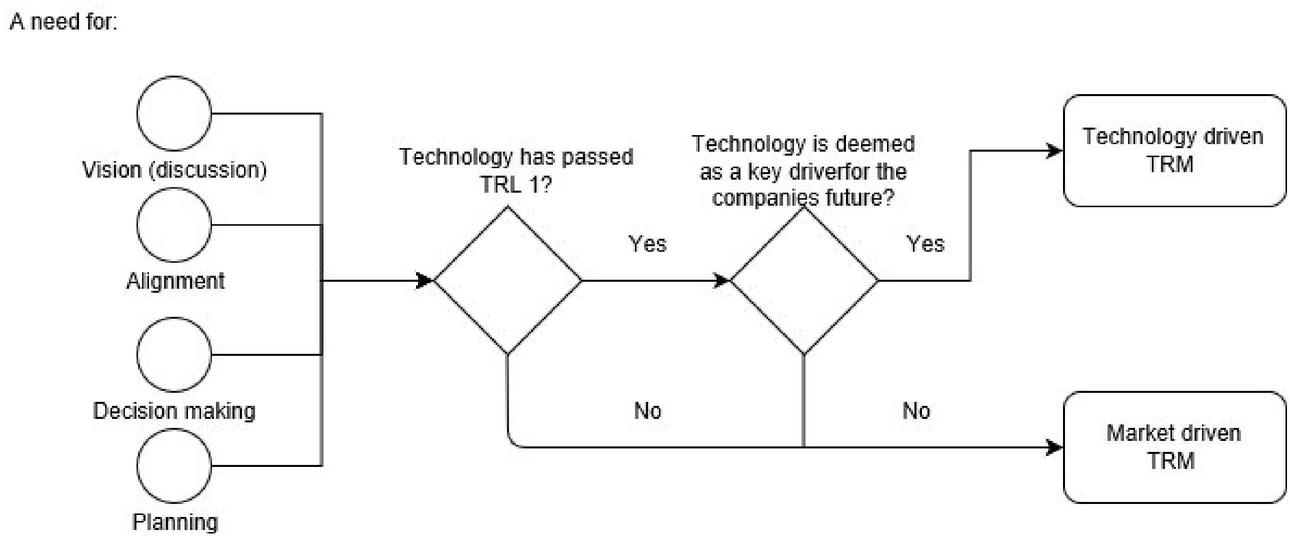
The main difference between the two strategies is the starting phase. A market pull strategy starts looking at market opportunities, while a technology push strategy starts with the technology available. This choice is influenced by the technology readiness of the technology available (Dissel et al., 2009). Companies who already have developed technologies available should opt for technology push compared to companies who just started on R&D, or are looking for brand new opportunities.

Thus, even though the three main stages stay the same, a shift can be seen in the exact steps within the methodology and this contribution, therefore, suggests two main roadmapping manuals for high-tech SMEs.

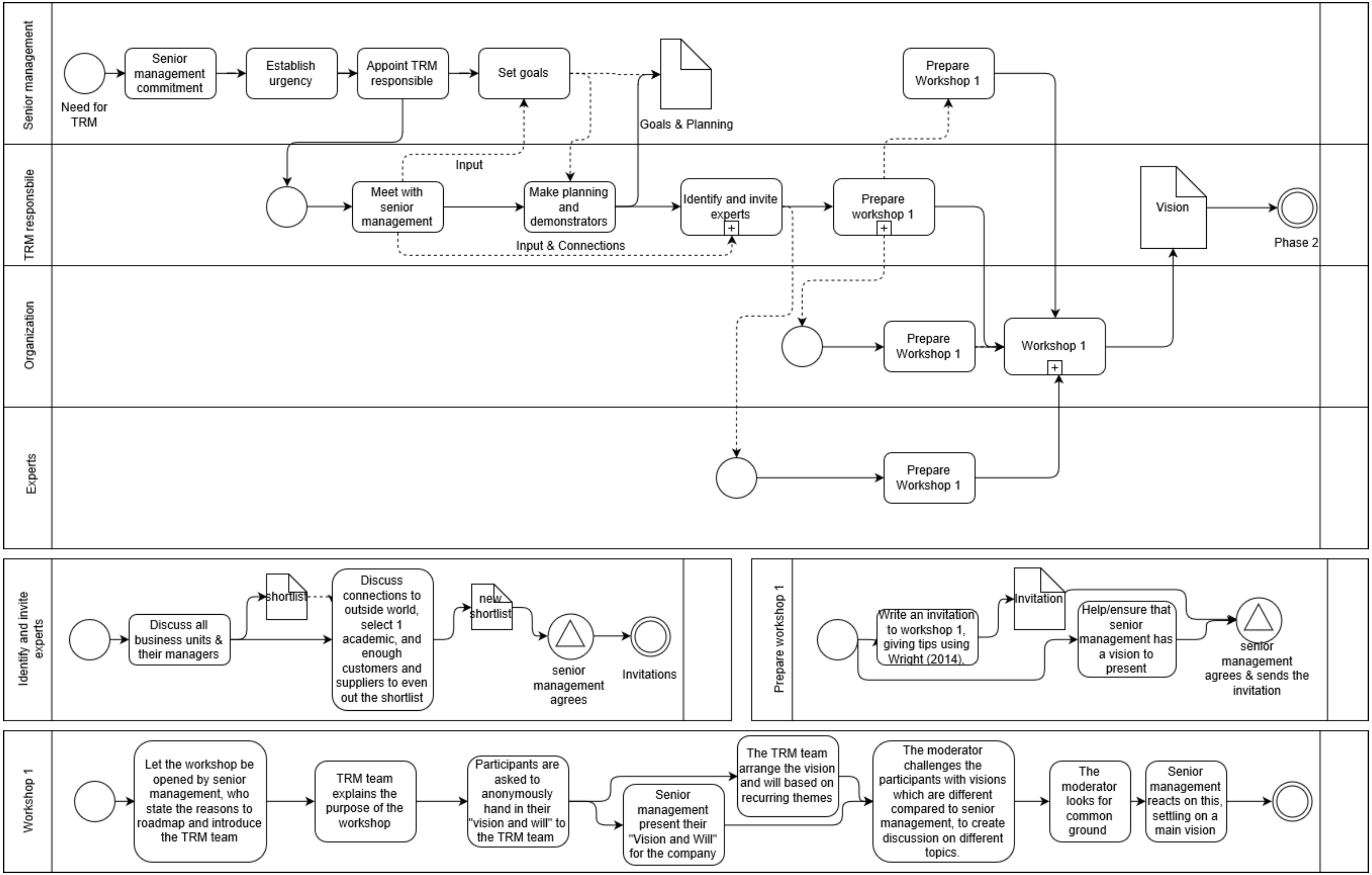
5. THE "TRM FOR HIGH-TECH SMES" MANUAL

The goal was to generate two manuals who support managers in applying TRM at high-tech SMEs. As identified in the synthesis, the two technology-product integration strategies have different methodologies towards TRM (Caetano & Amaral, 2011). Choosing the right strategy will speed up the process. In this manual, management should decide between the two strategies, using graphic 4. The SLR was inconclusive on this topic of selecting either, showing no active decision between the two strategies.

This research suggested four reasons to roadmap. These form the backbone of the roadmapping process and help to identify the need for TRM. Two main questions help to choose between the two strategies. According to Dissel et al. (2009), when considering technology driven TRM, a company will need to assess business potential of early-stage technologies. They suggest that if the technology has passed Technology Readiness level 1 [TRL] it can be considered (Dissel et al., 2009). Secondly, it is important to establish that the technology is a core competence: how important is the technology for the company's future (Caetano & Amaral, 2011)?



Graphic 4. Choose between technology driven or market driven TRM



Graphic 5: Phase 1 of the market pull TRM manual

5.1 Market pull

Using a market pull strategy means that organizations are looking for brand new opportunities to target. Therefore, the roadmap starts at the market layer, working through the product layer, towards the technology layer.

5.1.1 Phase 1: Preparation

In phase 1 the main goal is to prepare for the roadmapping process. Four main steps have to be taken. See graphic 5.

5.1.1.1 *Management commitment & Urgency*

In order to effectively start with TRM, senior management should be committed to the process: Kostoff et al. (2004) write that senior management commitment is the most important factor in formulating a high-quality roadmap and other research suggest that sponsorship is one of the first steps to be taken (Amer & Daim, 2010; Gerdsri et al., 2010). This should be a commitment to a long-term roadmapping process, not to a one-time exercise (Kostoff et al., 2004).

Furthermore, the management team should realize that in order to get the rest of the organization committed to TRM, a sense of urgency must be established. Therefore, one of the first steps is to determine the company need (Cheng et al., 2016; Gerdsri et al., 2010). Research even indicates roadmapping enjoyed more success in the presence of an external thread (Kappel, 2001). Examples could be: lack of vision, alignment and planning or even competitors closing in. The assumption is made that the urgency is needed for management to ask commitment to TRM from its employees.

5.1.1.2 *Project management, goals, and planning*

The next steps to be taken are to determine a project manager and establish the goals and planning together.

The research showed that the TRM process will need a responsible TRM team: a dedicated committee (Cho et al., 2016), a working group (Gerdsri et al., 2010; Vishnevskiy, Karasev, & Meissner, 2014), a project team (Cheng et al., 2016; Groenveld, 1997) or an external intermediary (consultant) (Amer & Daim, 2010; Battistella et al., 2015). The most important thing about selecting a project team or individual is to ensure that enough knowledge about the organization and the roadmapping process is combined (Gerdsri et al., 2010; Kostoff et al., 2004). It is suggested that at least one individual should have expertise in innovation management and/or roadmapping (Siebelink et al., 2016). Furthermore, logic suggests that, the TRM team composition should fit the reasons to roadmap. To illustrate: a team set out to align planning activities should not consist out of employees from one department only.

Consequently, it is important to set goals and if applicable: conditions, scope or boundaries of the TRM process (Amer & Daim, 2010; Battistella et al., 2015; Cheng et al., 2016; Cosner et al., 2007; Gerdsri et al., 2010; Oliveira & Rozenfeld, 2010; Zhang, Guo, Wang, Zhu, & Porter, 2013). These goals can be based on the reasons to roadmap: vision discussion, alignment, decision making, and planning. The SLR is inconclusive on who should set these goals. Therefore, it is suggested that a good TRM team can help to uncover them, but the senior management should set the final goals, based on the urgency.

These goals can be used to determine a planning for the TRM process (Battistella et al., 2015; J. H. Lee et al., 2012). When making such a planning, smaller demonstrators and intermediate results should be considered (Phaal et al., 2012) since research showed that if the TRM users see results of the TRM process more will consistently use the roadmap (J. H. Lee et al., 2012).

To-the-Point: Setting goals
Based on: Cosner et al. (2007)
The following examples are suggested by Cosner et al. (2007) to set roadmapping goals:

- Driving individuals to think about what will be required for their success beyond next year.
- Identifying key assumptions associated with current R&D and identifying future events that could invalidate these plans.
- Flowing top-level strategies and policies downwards in the organization. (TRM helps aligning business units)
- Prioritizing internal investment proposals and opportunities.
- Ensuring that all investments work towards the same goal.
- Enabling rapid re-planning in event of internal budget fluctuations.

5.1.1.3 *Identification of experts*

As established before, the two main ways to collect data for the roadmap is through literature search and expert workshops. For the latter, experts should be selected by the TRM team and senior management.

Not much has been written on the number of experts needed. Abe et al. (2009) and Saritas and Aylen (2010) wrote that the number of participants should be between five and seven, but Amer and Daim (2010), who researched roadmaps for the energy sector, argued that around a 100 should also work. However, most contributions do write that the experts need to contribute unique knowledge on the industry, market or technology (Abe et al., 2009; Battistella et al., 2015; Cheng et al., 2016; Cho et al., 2016; Gindy et al., 2008; Groenveld, 1997; Kostoff et al., 2004; Vishnevskiy et al., 2014). For example, someone from R&D, sales, marketing, top management, operations, HRM and finance. (Abe et al., 2009). For high-tech SMEs, this should limit the number of experts available.

Bearing in mind the market pull strategy, it is important to have market knowledge. That is why it is recommended to combine experts from inside the company with experts from outside the company (Amer & Daim, 2010; Caetano & Amaral, 2011; Carayannis et al., 2016; Cho et al., 2016; Saritas & Aylen, 2010; Vishnevskiy et al., 2014). As a rule of thumb Cho et al. (2016) selected 50% of their experts from inside the company and Saritas and Aylen (2010) argued that a senior academic, some suppliers, (end)customers and a business development expert should be involved. In an open innovation scenario, even competitors could be involved (Caetano & Amaral, 2011).

5.1.1.4 *Workshop 1: Vision (discussion)*

Unstable environments cause the short- and medium-term time frames to be considered the most interesting for SME roadmaps (Bildosola et al., 2017; Jun et al., 2013). However, before market opportunities in these time frames can be determined, it is important to understand and discuss the long term vision of the company (Abe et al., 2009; Ahlqvist et al., 2012; Amer & Daim, 2010; Gerdsri et al., 2010; Oliveira & Rozenfeld, 2010). The long term vision could either be collected from senior management, or a workshop could be organized as a tool to aid in the vision discussion within an organization (Ahlqvist et al., 2012). The latter option supports one of the main reasons to roadmap at a high-tech SME and is therefore suggested.

Besides the experts, it is important to invite (representatives of) the organization since this contributes to the internal discussion regarding the corporate vision. Valuable to high-tech SMEs is to make sure that the researchers and engineers are involved (Abe et al., 2009). Abe et al. (2009) suggested to let all participants generate “My vision and will” and the methodology suggested here is based on that premise.

To-the-Point: “My vision and will”
Adapted from: Abe, Ashiki, Suzuki, Jinno, and Sakuma (2009); Wright (2014)
Tips for the experts in helping them to formulate “my vision and will”.
- Create your pinnacle of the funnel, to which all actions contribute.
- A memorable and inspirational summary the reason for existence of the company.
- If needed: a limiter to apply focus and rule out certain opportunities.

For the final formulation of the vision statements, Wright (2014) argue the following:
- They should be short
- They need to be specific for this business
- Do not use words that are open for interpretation
- Keep it simple
- It should be ambitious but reachable
- It needs to align the values that your people exhibit when they work

To determine a shared vision, all attendees should prepare a “my vision and will”-document before the meeting. A small document containing their ideas and foresights for the company in 10 years. This does not have to be exact since it will be used as a point on the horizon during the discussion. During the workshop, management will present their vision after which comparisons can be made with the different attendees. The goal of the moderator is to facilitate discussion and work towards a consensus regarding the long term vision.

5.1.2 *Phase 2: Roadmapping*
In the second phase, the three layers of the roadmap are developed: market, product, and technology. Workshops will be prepared and led by the TRM team, and the results of the workshops can be used by the team to make the final roadmaps.

Scenario planning is introduced in the product/service phase to ensure that multiple scenarios are developed regarding the found market opportunities (Saritas & Aylen, 2010). See graphic 7.

5.1.2.1 *Workshop 2: Market gap*
The main goal of this step is to find opportunities or gaps within the market that fit with the long term vision of the company.

A vast amount of techniques have been developed for identifying these opportunities. The vision formed will serve as the long term goal for the company. Short- and midterm are the most interesting for SMEs and that is why the workshop should be focused on a planning of 2 to 5 years in the future (Jun et al., 2013).

The first step is to perform a market analysis (Battistella et al., 2015; Hansen et al., 2015; Jun et al., 2013; Oliveira & Rozenfeld, 2010; Vishnevskiy et al., 2014; Wells, Phaal, Farrukh, & Probert, 2004). The contributions on this topic name SWOT (Amer & Daim, 2010; Carayannis et al., 2016; Cho et al., 2016; Fenwick et al., 2009; Phaal et al., 2004), PESTEL (Abe et al., 2009; Amer & Daim, 2010; Saritas & Aylen, 2010), Porter’s 5 forces (Abe et al., 2009; Fenwick et al., 2009) and the value proposition canvas (Cho et al., 2016; Fenwick et al., 2009; Holmes & Ferrill, 2005; Siebelink et al., 2016) as methods to do so.

The SLR showed that these methods are applied for two reasons: to identify market drivers/trends and to visualize customer needs. That is why this manual proposes two of the proposed methods to capture these drivers and needs. The idea of Fenwick et al. (2009) is used.

1	Create a SWOT diagram to provide both an internal (strengths and weaknesses) and external (opportunities and threats) analysis of the company
2	Understand the value proposition for current customers to determine the performance dimensions: create a value proposition canvas
3	Use the value proposition to identify the market drivers (opportunities) for these customers
4	Prioritize the drivers based on the long term vision

The SWOT analysis is used to identify trends and opportunities within the market and the value proposition canvas can be used to identify value drivers (pains and gains which are unattended to). These tools can be used in a workshop with the identified experts.

To-the-Point: SWOT
Adapted from Renault (2014)
Internal analysis: Strengths and Weaknesses.
The composition of the experts ensures that both from an internal, as from an external look the strengths and weaknesses are found.
The general factors they should consider are:
- Human resources - staff, volunteers, board members, target population
- Physical resources - your location, building, equipment
- Financial - grants, funding agencies, other sources of income
- Activities and processes - programs you run, systems you employ
- Past experiences - building blocks for learning and success, your reputation in the community

External analysis: Opportunities and threads.
Assembling trends and other external forces and facts that cannot be controlled. These include:
- Future trends in your field or the culture
- The economy - local, national, or international
- Funding sources - foundations, donors, legislatures
- Demographics
- The physical environment
- Legislation
- Local, national or international events

To-the-Point: Value proposition canvas
Adapted from: Strategyzer.com
The value proposition canvas consists out of two parts and is assembled by experts, especially customers involvement is valuable.
The first part is the customer profile, in which the goal will be to describe the jobs your customer wants to get done. These can be functional, social or emotional. Then the customers pains are highlighted, these annoy customers and are in the way of getting the job done. Thirdly, the customer gains are outlined, which are positive outcomes customers hope to achieve, like results, benefits or aspirations.
The second part is the value map, in which the current products and services are listed. The experts need to identify how these products and services relieve customer pains, and outline how they are gain creators: creating the gains customers hope to achieve.

At the end of the workshop, the team should have collected a SWOT diagram, value proposition canvas and a list of all the potential drivers prioritized.

5.1.2.2 *Workshop 3: Product/Service gap*
Based on the findings from the previous workshop, the team is looking to identify which products or services need to be developed to fill the market gap.

The experts should first determine and agree on the customer requirements of the product or service (Amer & Daim, 2010; Carayannis et al., 2016; Carvalho et al., 2013; Groenveld, 1997), which can be used from the value proposition canvas. These form the input for scenario building. From the contributions in the SLR, seven suggest combining TRM with scenario building (Abe et al., 2009; Hansen et al., 2015; H. Lee & Geum, 2017; Saritas & Aylen, 2010) and this is with reason: scenario-planning is applied in TRM to reduce uncertainty and risk (Cheng et al., 2016; Cho et al., 2016; Siebelink et al., 2016).

In the second workshop customer needs, trends and opportunities were formed into driving forces that should drive tomorrow's market. Siebelink et al. (2016) argue that scenarios should be developed based on these driving forces, that is why during the third workshop these drivers are used to create scenarios on how to deal with the future. Not only to decrease uncertainty regarding the assumed future (Cheng et al., 2016) but also to stimulate creative thinking and the generation of disruptive technologies (Kappel, 2001).

For the third workshop, this contribution suggests the methodology of Cheng et al. (2016), which divides the group of experts into three groups. The experts with experience in the industry/market form the scenario building team (see to-the-point). These scenarios are assessed by the second group of experts based on corporate vision, forming the scenario assessment team. The last team is formed by senior management: the decision team, who select the most plausible scenarios (Cheng et al., 2016).

To-the-Point: Scenario building team
Based on: Cheng, Wong, Cheung, and Leung (2016)
In the preparation the TRM team can assemble possible products/services through the earlier performed SWOT and through literature search. More information on literature search can be found in chapter 5.2.

During the workshop, the scenario building team is asked to individually make at least a pair of possible scenarios to consider. The scenario building worksheet is used for this, which can be found in Appendix C. The principles of the six thinking hats method is used.

- Blue hat: describe what, when, where, and who.
- White hat: what are the fact to back your scenario?
- Red hat: extra intuitive information or forecast
- Yellow hat: what are the benefits of the scenario?
- Black hat: what are difficulties and potential problems?
- Green hat: what are other possibilities, alternatives and solutions with this scenario?

If Cheng et al. (2016)'s process is finished, the TRM team should have a handful of scenarios that are worth roadmapping.

5.1.2.3 *Workshop 4: Technology*

In the fourth workshop, the experts come together to identify all the different components that are necessary for the product/service. The goal is to identify and prioritize potential technologies to be developed for the previous stage (Caetano & Amaral, 2011)

The experts should identify the available technologies and evaluate their ability to deliver the product features (Oliveira & Rozenfeld, 2010): the technology gaps should be identified (Holmes & Ferrill, 2005; Phaal et al., 2004). This can be done using the technology development envelope [TDE] (Fenwick et al., 2009), which is a technique to rate and represent a series of technologies with maximum impact on company's competitiveness over time (Gerdsri & Kocaoglu, 2003). Gerdsri and Kocaoglu (2003) write that the result of TDE can be used as strategic input on the TRM process.

To-the-Point: TDE
Adapted from Gerdsri and Kocaoglu (2003)
In order to identify possible technology gaps, the expert groups should be split up in two panels (EP-1 and EP-2). EP-1 should combine of the external experts with the technology developers from inside the company, while EP-2 should exist of the managers, operations, and marketing experts who have an implementation role.
Preparation: The TRM team develops the pre-determined list of technologies related to the market gap. Patent and literature databases will be searched on these gaps, keywords can be clustered and potential technologies can be established. More information can be found in chapter 5.2.
Step 1: EP-1 undergoes two rounds (Delphi) in which they modify and validate the pre-determined list of technologies.
Step 2: EP-2 generate a list of criteria and technological factors.
Step 3: EP-1 is asked to value all technologies based on the criteria.
Step 4: EP-2 prioritizes all the criteria based on their relative importance
Step 5: The TRM team puts it together, rating all technologies based on the criteria of EP-2 and the scores of EP-1. They put the final scores together to generate a TDE.

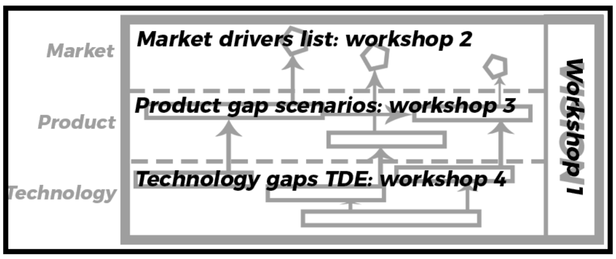
The TDE identified the different possible technologies for the different scenarios. The TRM team can use these to link all scenarios to (future) technologies. Scenarios that cannot be linked will be eliminated.

Possible technology gaps will need a make-or-buy decision which is made in the implementation (unless the ability to make the technology is one of the higher weighted criteria in the TDE). To help make this decision, possible technology [TP] and financial partners [FP] need to be identified (Caetano & Amaral, 2011).

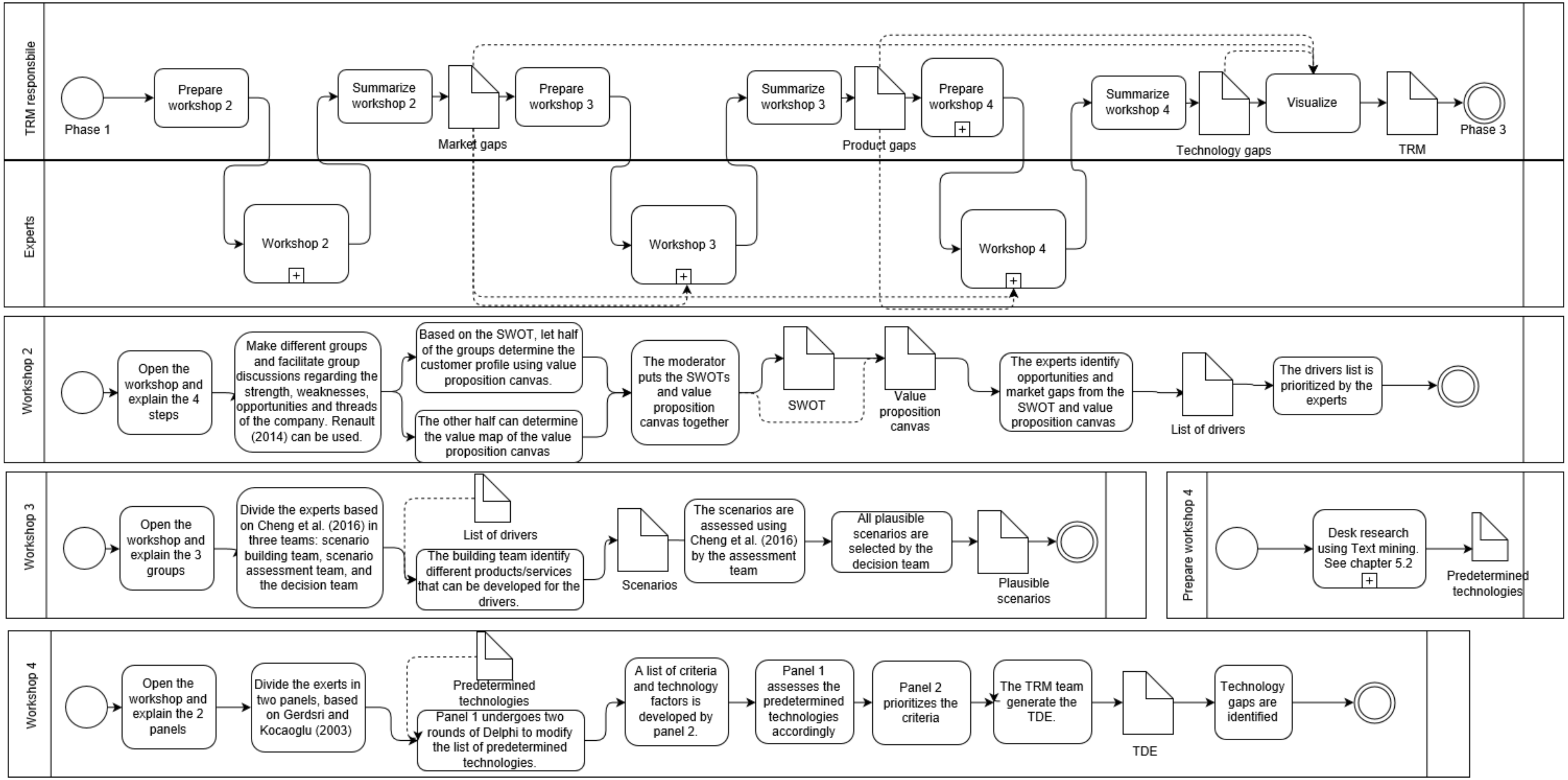
To-the-Point: Identifying TPs
The final make-or-buy decision and the selection of partners is done in the implementation phase of the TRM. However, the TRM team can assist in that process, now that the specific technology gap has been identified. By making a list of potential TPs and FPs, the final implementation will be easier. To find technology partners, Google Patent Search is suggested. The experts have identified the specific technology gap, and this means that the TRM team can use these terms to identify patents regarding that topic, either identifying organizations who have a technology that could fill that gap, or who have experience in that field and could help development.

5.1.2.4 *Visualizing*

The TRM team has collected all the necessary data for the three layers of the roadmap and can put the different scenario roadmaps together. Graphic 6 shows for each layer where the information can be found.



Graphic 6: Visualizing the layers



Graphic 7. Phase 2 of the market pull TRM manual

5.1.3 Phase 3: Implementation

In the last phase, the selection of the final scenario needs to be taken, and feedback plus buy-in from the organization should be acquired. This leaves the final stage to be set: roll-out of the roadmap throughout the organization. See graphic 8.

5.1.3.1 *Assessment & Selection*

The scenario assessment team and the decision team from the third workshop are reconvened. Now they fully know the different scenario roadmaps, including the technology layer, and the assessment team can assess them. For this, the 5-point assessment scale for scenario assessment of Cheng et al. (2016) is recommended.

5-Point scale scoring system for scenario assessment.

Scores	1	2	3	4	5
Feasibility	Very low	Low	Moderate	High	Very high
Degree of innovativeness	Very low	Low	Moderate	High	Very high
Impact	Very low	Low	Moderate	High	Very high
Estimated market share	Very low	Low	Moderate	High	Very high
Estimated investment	Very high	High	Medium	Low	Very low
Government support	No	Less	Moderate	More	Fully

Table 3 the 5 point scale scoring system for scenario assessment by Cheng et al. (2016)

The decision team can validate these scores and decide on the most fitting scenario. Besides the scores of the assessment team, they have to consider the original goals in mind (Cosner et al., 2007). This means that they could deviate from the assessment of the assessment team, or at least validate what has been done before.

5.1.3.2 *Implementation plan*

A rough implementation guideline for the TRM should be developed (Amer & Daim, 2010; Carayannis et al., 2016; Ilevbare et al., 2014; Jun et al., 2013; J. H. Lee et al., 2012).

Keeping the roadmap alive is considered to be one of the main challenges of roadmapping (Phaal et al., 2004). This is also pinpointed by Ahlqvist et al. (2012) and Fenwick et al. (2009) who argue that the roadmap should be periodically revisited, to see if any market, product or technology drivers have changed. In order to do so, demonstrators (Phaal et al., 2012) or small gains (Gerdsri et al., 2010) have to be established by the TRM team. These ensure that the roadmap is revisited over time and process is marked. This is also supported by Kotter's eight steps of change (Kotter, 1995). As the seventh step, he writes that the momentum of short-term wins should be used to move the change forward.
The literature is inconclusive on how often the roadmap should be revisited, but Gerdsri et al. (2010) suggest that roadmapping should become part of day-to-day processes.

To do so, a solid implementation plan should be developed. However, Phaal et al. (2004) write that the second main challenge of roadmapping is the roll-out. They argue that this can be done in two ways: either top-down, or bottom-up. This contribution argues for the latter because it is believed to better fit the proposed roadmap process. During the roadmap process, many different individuals, from many different departments have been involved, giving them ownership of the final product. Including them in the implementation should proof to be most effective.

The TRM team, that has taken note of all the discussion throughout the process should translate the critical parts of the TRM into action points (Ahlqvist et al., 2012; Cho et al., 2016). The TRM team has to ensure that the roadmap will become part of the ongoing business planning process, and the corporate strategic plan (Gerdsri et al., 2010). This means that the right people should be found to transfer the TRM to.

To-the-Point: Implementation plan
Based on: Gerdsri, Assakul, and Vatananan (2010)
The implementation plan should consist out of:

- Demonstrators or small wins that can be achieved in the near future – planning forwards and marking revisiting of the project. These could be technology developments that need to be made, or funding for a new R&D department that has to come to live.
- Action points for the organization to reach these demonstrators, marking who should do what.
- The names of the people who are going to lead the implementation of the roadmap.
- The organizational structures in which the roadmap will be discussed or monitored.

5.1.3.3 *Validation & Feedback*

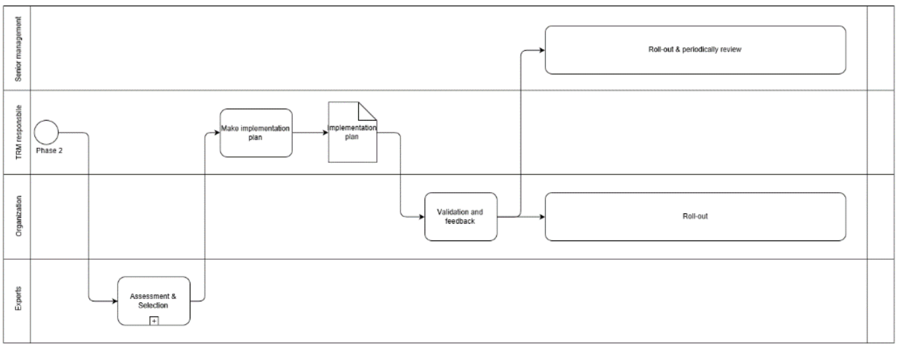
Even though the TRM has been validated by the top management, it is important that the final TRM is exposed to a much larger group for validation and buy-in for two reasons (Bray & Garcia, 1997). First, the roadmap must be critiqued and reviewed. Second, there must be buy-in from the broader corporate group that will be involved in implementing the plan.

Thus, as the last event, the experts and the organization come together to talk about the results of the TRM process. This is also the moment for the TRM team to transfer ownership of the roadmap to the implementation team (Gerdsri et al., 2010).

5.1.3.4 *Roll-out*

Following the implementation plan, the new team can start with implementing the roadmap.

The exact implementation of a roadmap is a major organizational change and should be addressed appropriately by using change management techniques (Cosner et al., 2007; Gerdsri et al., 2010). That is also why the implementation will be different throughout different organizations. However, the implementation plan should help then in keeping the roadmap alive and consolidating small wins.



Graphic 8. Phase 3 of the market pull TRM manual

5.2 Technology push

Compared to the market pull approach, the technology push approach looks to identify opportunities for a specific technology. Furthermore, the task for the TRM team and the experts are different, the technology driven process is much more literature extensive (Bildosola et al., 2017; Foden & Berends, 2010; Kostoff et al., 2004; S. Lee et al., 2009) compared to the workshop heavy market pull approach.

This strategy is selected if companies already have a technology available which need to be brought to market. This could happens when the technology is not much more than an idea or when the technology is already further in development stages. As long as the technology is valued as the core reason for future business at the company.

5.2.1 Phase 1: Preparation

The first phase of the technology driven roadmapping process is comparable to that of the market driven manual. The main differences will occur in the second phase. However, there are some points in the first phase that have a different focus.

To start, it is important to notify that if the technology is already in final development stages, this could mean that a lot of money and time has already been invested in the idea. This increased urgency is good in starting phases, it will get everyone on board, but is questionable in the later phases when careful research needs to be done.

The latter part is also why the TRM team might need additional team members. Internal, or external researchers could complement the team, because they have access to literature and know how to do research.

The vision workshop is also a bit different. The goal is still to develop and discuss a vision which will be the final destination of the roadmap, but the role of the technology should be explicitly stated in that future. The chosen technology should be communicated to the participants so that all see the strategic value.

5.2.2 Phase 2: Roadmapping

The three layers are compiled differently compared to the market pull approach.

The literature on technology push roadmaps apply two different methods regarding the roadmapping process. Caetano and Amaral (2011) and Dissel et al. (2009) first look to identify which future developments of the technology, so that they can link that to future opportunities, while others, like Bildosola et al. (2017), Foden and Berends (2010) and Kostoff et al. (2004) first identify alternative applications using literature.

For this manual, both methods will be applied. While the TRM team is retrieving and collecting the literature, the experts can be used to map future developments and potential market trends. In the end coming together for validation. See graphic 9.

5.2.2.1 *Desk research*

The desk research approach involves literature research and patent analysis (Carayannis et al., 2016; Vishnevskiy et al., 2016). At this stage, all available and accessible codified knowledge in the respective field is analyzed by the TRM team (Vishnevskiy et al., 2016). When collected, text mining tools can assist in analyzing the database (Bildosola et al., 2017; Kostoff et al., 2004; S. Lee et al., 2009; Zhang et al., 2013). Bildosola et al. (2017) and Kostoff et al. (2004) argue that the next step is ontology generation, where keyword reduction is used to select the most used keywords and cluster the data accordingly. Those keywords can then be used to find alternative applications for the technology researched, or pinpoint technology gaps that need to be developed (Kostoff et al., 2004; S. Lee et al., 2009; Zhang et al., 2013)

To-the-Point: Desk research
Adapted from Bildosola, Rio-Belver, Garechana, and Cilleruelo (2017)
Step 1: A specific database is generated regarding the selected technology or work field. Access to SCOPUS and Web of Science must be obtained (students + academics). Furthermore, Google Scholar and Google Patents Search might be used.
Step 2: Using a text mining tool (for example Rapidminer, which is free) cluster the keywords in the database.
Step 3: Keyword reduction, based on the frequency they are mentioned, focus on techniques, alternative technology or applications for the technology that is researched.
Step 4: Identify and read the articles regarding the alternatives, look to make a list of the possible applications or further developments of the technology at hand.

At the end of the desk research stage, the TRM team should have a research paper regarding the applications and/or developments of the technology at hand.

5.2.2.2 *Workshop 2: Developments & Market trends*

Caetano and Amaral (2011) and Dissel et al. (2009) argue that first, the experts should identify future developments, and write down where they think the technology should be applied to. This workshop might need a presentation about the specific technology by the lead developer, but should be a brainstorm session for all to show their expert views on how the technology can be used.

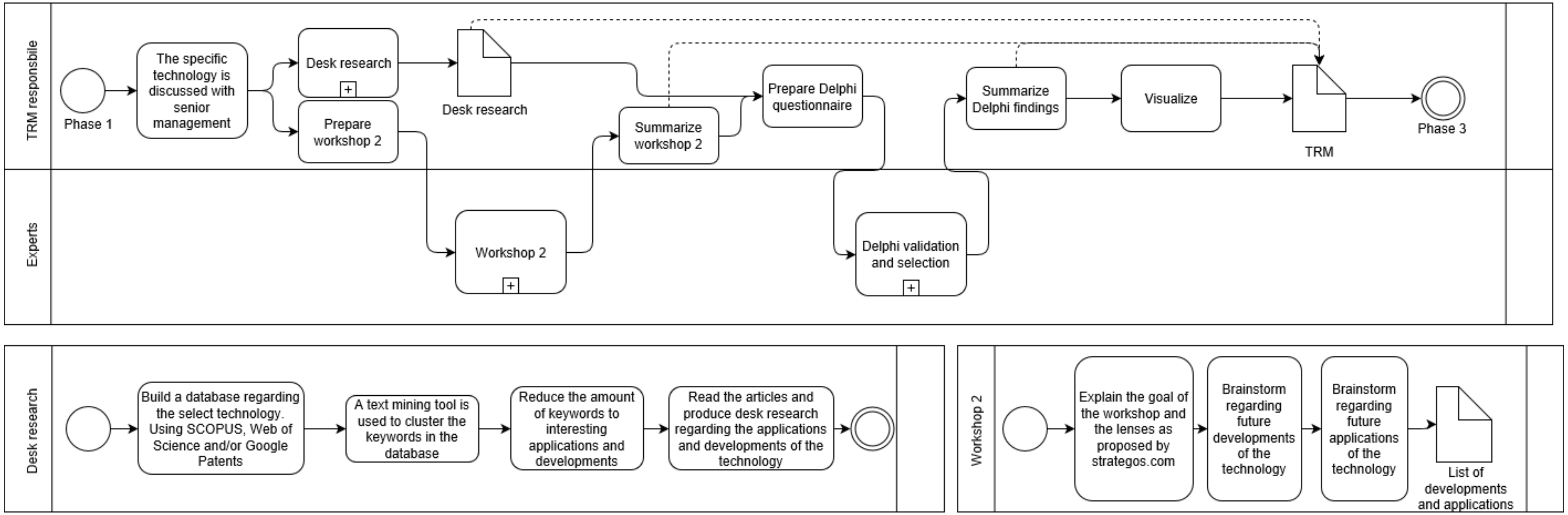
The first step is about identifying technology developments. The internal experts are asked to map the technology development project milestones, in terms of technical capabilities that will be achieved in the future, together with any knowledge of complementary or competing technologies (Dissel et al., 2009).

The second step is proposed by Caetano and Amaral (2011) who write that it is important to prioritize the market and market partners for which the technology could be developed. The experts are therefore asked where they see opportunities in the market for this technology.

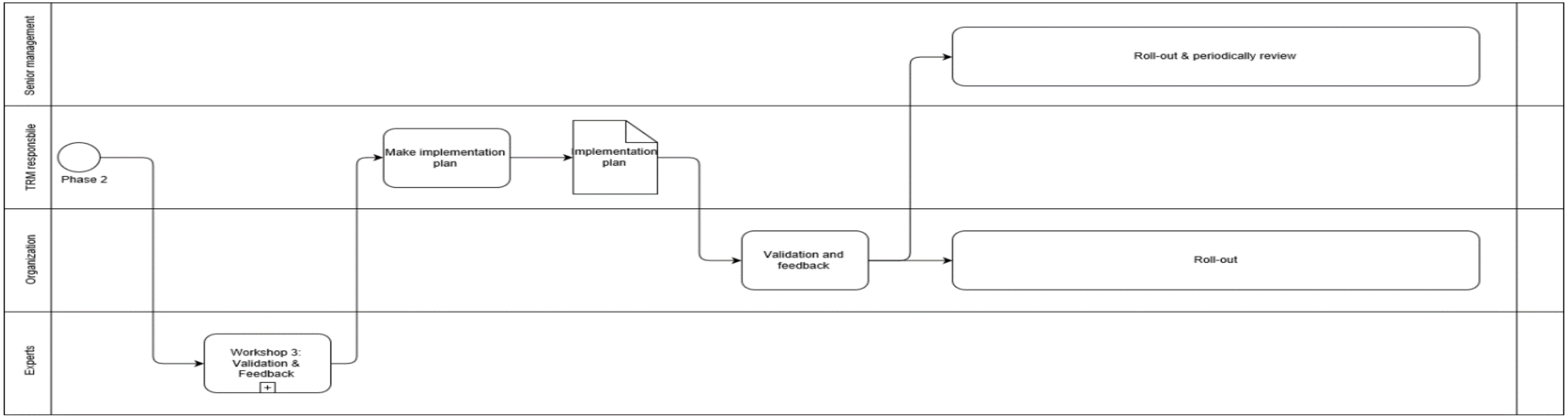
To-the-Point: Spotting opportunities
Based on: Strategos.com
Looking through different lenses helps to develop fresh insights to generate more ideas. That is why brainstorming, while using different lenses is proposed:

- Customer lens
- Orthodoxies: what if customers are not precisely how we think they are?
- Discontinuities: what if the industry is about to change?
- Core competencies: what are we good at, and how can we use it?
- Analogies: What are pioneers in other industries and what can we learn from them?

At the end of the second workshop, the TRM team should have a list of possible technology developments and market opportunities.



Graphic 9. Phase 2 of the technology push TRM manual



Graphic 10. Phase 3 of the technology push TRM manual

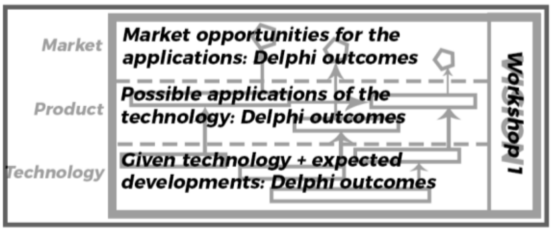
5.2.2.3 *Delphi: validation and selection*

The TRM team has two sources of information now, the desk research who identified opportunities and developments, and the experts who did the same. The TRM team can bring both findings together to different scenarios and possibilities for the technology. In this stage, the Delphi method is employed to validate the findings in the former steps and to bring the experts to reach a consensus (Carayannis et al., 2016).

To-the-Point: Delphi method
Adapted from Pfeiffer (1968)
For the Delphi method the experts are asked to personally rate the different possibilities, in the hope to reach consensus in the best one. The TRM team can set out small surveys for that. If consensus is not reached the lower scoring possibilities are removed and the experts are asked to reassess the remaining possibilities. If that does not lead to a consensus either a discussion can be organized to reach a final decision or the TRM team can make the decision.

5.2.2.4 *Visualizing*

The final step is for the TRM team to map the chosen decision into a roadmap. Using the technologies and their developments as the technology layer, the identified applications in the product/service layer and the market opportunities in the market layer. Graphic 6 shows for each layer where the information can be found.



Graphic 11: visualizing the technology push layer

5.2.3 *Phase 3: Implementation*

In the last phase, roughly the same steps will be taken compared to the market pull approach. The difference is, that a scenario has already been selected using Delphi. Instead of assessing and selecting, the TRM team has one extra moment to bring the experts together to brainstorm on the final roadmap. See graphic 10.

5.2.3.1 *Implementation plan, Validation & Feedback, and Roll-Out*

The technology push literature is not conclusive regarding the implementation of the TRM. Zhang et al. (2013) argue that TRM should be an iterative process, and Dissel et al. (2009) write that TRM should be embedded in the organization's processes. Thus that is why the last three steps are comparable to the market driven approach.

The TRM team should make an implementation plan with action points and possible decision making suggestions. Then, even though the experts have already validated the final roadmap, the full organization should be brought together to see the final product and the implementation plan attached, ensuring the buy-in for further roll-out.

Finally, this contribution argues for a bottom-up roll-out where the roadmapping process is embedded in the organization's structure.

6. REFLECTION

This research set out to generate an easy to implement method for high-tech SMEs to apply roadmapping. By means of a systematic literature review 47 articles have been examined in order to look for a integrative synthesis regarding roadmapping.

This contribution tried to bring these information streams systematically together. Comparable to a roadmap, this manual came together in three phases. The general methodology, the specific steps, and the to-the-point methodologies that are used to perform the step.

The SLR found a synthesis in the general methodology: the general approach was discovered throughout most roadmap contributions. The split between technology push and market pull provided insight in the different steps that would need to be taken in the general approach. For market pull, a lot of contributions argued the same build up, which has been validated through case studies. However, the technology pull contributions were divided between more value stream mapping and desk research methodologies and were less in quantity. For the manual, this article opted to combine both, comparable to Kostoff et al. (2004), which is peer reviewed and published but not validated through case implementation. The technology push manual is therefore based on the available literature but has been exposed to more variety in the findings.

The methodologies that have been chosen to make the manual easy to implement, were scarce throughout the literature. For some steps, multiple methodologies were presented (e.g. market analysis), but for others (e.g. vision discussion) fewer options were available. In the end, all the methodologies that are used in the manual were used in at least two of the articles, which were selected based on peer-review and the journal quality list.

For the to-the-point methodologies are selected based on the experience of the author, these are not systematically convened and could be susceptible to cherry-picking. They should be read as suggestions.

6.1 Message to the user

The market pull and technology push manuals are made to be used and should help to apply TRM at high-tech SMEs. The manual should be used as a guideline, aiding the process. It does not mean that this is the only way to roadmap, as can be read in this research, multiple methods are combined to provide this overview and to make the steps as explicit as possible. However, in using the manual, the user should be critical on how the steps relate to the company. Personal experience in the organization with applying different stages can help to adjust and personalize the approach, especially regarding the to-the-point suggestions.

In order to see results of the whole TRM process, the roadmap should successfully be embedded within the organization. That process depends on the state and structure of the organization and that is why the urgency and need that have been established at the beginning of the process are so important to determine success.

Finally, it is important to note some of the hypothesis that J. H. Lee et al. (2012) accepted in their research. The implications of these hypotheses are mentioned throughout the manual, but by explicitly stating them the user can be made aware of their importance.

- The stronger the TRM team's willingness to cooperate with the TRM users, the more credible the TRM becomes.
- The more the TRM team is willing to reduce the uncertainty associated with TRM forecasts, the more credible the TRM becomes.
- The more often the communication between the TRM team and TRM users, the more credible the TRM becomes.
- The more TRM users perceived the TRM as credible, the more they will use it.

Making cooperation, uncertainty reduction and communication valuable tools for the user to bring the TRM to a successful implementation.

6.2 Limitations & further research

The goal of the research was to present an easy to implement plan for SMEs searching for innovation management tools.

However, these findings should be considered in the scope of the limitations. Regarding the systematic literature review, Rousseau et al. (2008) state that multiple extractors are to be used when making the article sample. This in order to avoid omission and reduce mistakes. However, for this literature review only one extractor was used. Even though the selection criteria are clearly written down and the findings were discussed with a second researcher, the subjectivity of the extractor could have influenced the research.

The chosen literature showed a strong synthesis on the higher level of application but lacked that consensus at an operational level. The research design tried to conquer that by using an systematic approach, but some cherry picking cannot be avoided. That is why academic validation through empirical testing is needed on the manual, in further research. Real experience with the manual could make it more precise and to the point.

Academically, most contributions assumed the effects of roadmapping, since no long-term studies were found. That is why there is a need for quantifying the results of roadmapping, providing insights over a longer period. Practically, such a research design could shed more light on the return on investment of applying TRM. This should help decision making for managers who want to apply the manual and use TRM.

Another limitation regarding the TRM literature, and therefore also this contribution, is the notion that companies should be able to implement the roadmap when finished. Some suggestions have been made regarding this topic, but rewiring an entire company to work towards new market opportunities or technologies can be difficult to accomplish. More research regarding change management and TRM could have interesting findings, both for the academic world and for the real world.

Lastly, besides validation, future research can validate if this manual is applicable to lower technology SMEs or bigger companies, where experts might be less easy to identify or other challenges might occur. This could lead to a general approach in which the specific steps can be modularized and picked to fit with the TRM company.

7. CONCLUSION

This paper is a contribution to innovation management tools: a manual for applying TRM at high-tech. Giving answer to the research question regarding the "how" of roadmapping at smaller organizations.

Using an integrative synthesis, a clear division was found and proposed. First, a generic approach was recognized in the majority of the research. An overlap of three phases that the majority of the literature used. Secondly, a majority of the contributions could be divided based on the technology strategy the company should use: either technology push or market pull. Making it clear that the generic approach should be used for the manual, and two separate manuals should be made regarding the technology strategy.

Secondly, this contribution tried to identify the reasons for companies to start with roadmapping. Using the same method as before, four main reasons to apply TRM were found: vision (discussion), alignment, decision making and planning. The goal was to show why SMEs might attempt roadmapping.

If that decision is made, the proposed manual should be used as a step-by-step guideline throughout the roadmapping process. Following it, its users will find a fitting method depending on the technology strategy. The market pull strategy argues for an expert based process of 4 workshops, identifying market needs, product/service gaps and the technologies to be developed. The technology push strategy however, starts with an incremental technology covering its basis, trying to identify future developments and opportunities. Combining experts and literature search, the technology push strategy manual is pushing towards a better release into the market.

The manuals therefore offer a to-the-point method of implementing roadmapping at all high-tech SMEs willing to look forward. Arguing that there are reasons to apply innovation management tools, like technology roadmapping at high-tech SMEs, can add value to high-tech SMEs and showing how they could use it.

8. REFERENCES

Abe, H., Ashiki, T., Suzuki, A., Jinno, F., & Sakuma, H. (2009). Integrating business modeling and roadmapping methods - The Innovation Support Technology (IST) approach. *Technological Forecasting and Social Change, 76*(1), 80-90. doi:10.1016/j.techfore.2008.03.027

Ahlqvist, T., Halonen, M., Eerola, A., Kivisaari, S., Kohl, J., Koivisto, R., . . . Wessberg, N. (2012). Systemic transformation, anticipatory culture, and knowledge spaces: Constructing organisational capacities in roadmapping projects at VTT Technical Research Centre of Finland. *Technology Analysis and Strategic Management, 24*(8), 821-841. doi:10.1080/09537325.2012.715490

Amer, M., & Daim, T. U. (2010). Application of technology roadmaps for renewable energy sector. *Technological Forecasting and Social Change, 77*(8), 1355-1370. doi:10.1016/j.techfore.2010.05.002

Barker, D., & Smith, D. J. H. (1995). TECHNOLOGY FORESIGHT USING ROADMAPS. *Long Range Planning, 28*(2), 21-28. doi:10.1016/0024-6301(95)98586-h

Battistella, C., De Toni, A. F., & Pillon, R. (2015). The Extended Map methodology: Technology roadmapping for SMES clusters. *Journal of Engineering and Technology Management, 38*, 1-23. doi:10.1016/j.jengtecman.2015.05.006

Beck, C. T. (2001). Caring Within Nursing Education: A Metasynthesis. *Journal of Nursing Education, 40*(3), 101-109.

Bildosola, I., Rio-Belver, R. M., Garechana, G., & Cilleruelo, E. (2017). TeknoRoadmap, an approach for depicting emerging technologies. *Technological Forecasting and Social Change, 117*, 25-37. doi:10.1016/j.techfore.2017.01.015

Bray, O. H., & Garcia, M. L. (1997). *Technology roadmapping: The integration of strategic and technology planning for competitiveness*. New York: I E E E.

Caetano, M., & Amaral, D. C. (2011). Roadmapping for technology push and partnership: A contribution for open innovation environments. *Technovation, 31*(7), 320-335. doi:http://doi.org/10.1016/j.technovation.2011.01.005

Carayannis, E., Grebeniuk, A., & Meissner, D. (2016). Smart roadmapping for STI policy. *Technological Forecasting and Social Change, 110*, 109-116. doi:10.1016/j.techfore.2015.11.003

Carvalho, M. M., Fleury, A., & Lopes, A. P. (2013). An overview of the literature on technology roadmapping (TRM): Contributions and trends. *Technological Forecasting and Social Change, 80*(7), 1418-1437. doi:10.1016/j.techfore.2012.11.008

Cheng, M. N., Wong, J. W. K., Cheung, C. F., & Leung, K. H. (2016). A scenario-based roadmapping method for strategic planning and forecasting: A case study in a testing, inspection and certification company. *Technological Forecasting and Social Change, 111*, 44-62. doi:10.1016/j.techfore.2016.06.005

Chinosi, M., & Trombetta, A. (2012). BPMN: An introduction to the standard. *Computer Standards & Interfaces, 34*(1), 124-134. doi:10.1016/j.csi.2011.06.002

Cho, Y., Yoon, S. P., & Kim, K. S. (2016). An industrial technology roadmap for supporting public R&D planning. *Technological Forecasting and Social Change, 107*, 1-12. doi:10.1016/j.techfore.2016.03.006

Cosner, R. R., Hynds, E. J., Fusfeld, A. R., Loweth, C. V., Scouten, C., & Albright, R. (2007). Integrating roadmapping into technical planning. *Research Technology Management, 50*(6), 31-48.

Cuhls, K., de Vries, M., Li, H., & Li, L. (2015). Roadmapping: Comparing cases in China and Germany. *Technological Forecasting and Social Change, 101*, 238-250. doi:10.1016/j.techfore.2015.03.008

Dijkman, R. M., Dumas, M., & Ouyang, C. (2008). Semantics and analysis of business process models in BPMN. *Information and Software Technology, 50*(12), 1281-1294. doi:10.1016/j.infsof.2008.02.006

Dissel, M. C., Phaal, R., Farrukh, C. J., & Probert, D. R. (2009). VALUE ROADMAPPING. *Research-Technology Management, 52*(6), 45-53.

European Commission. (2003). Definition of Micro, Small and Medium sized enterprise adopted by the commission. *Official Journal of the European Union, 20-05-2003*(L. 124), 39-40.

European commission. (2015). Statistics on small and medium-sized enterprises Retrieved from http://ec.europa.eu/eurostat/statistics-explained/index.php/Statistics_on_small_and_medium-sized_enterprises

Fenwick, D., Daim, T. U., & Gerdsri, N. (2009). Value Driven Technology Road Mapping (VTRM) process integrating decision making and marketing tools: Case of Internet security technologies. *Technological Forecasting and Social Change, 76*(8), 1055-1077. doi:10.1016/j.techfore.2009.04.005

Foden, J., & Berends, H. (2010). Technology management at rolls-royce. *Research Technology Management, 53*(2), 33-42.

Gerdsri, N., Assakul, P., & Vatananan, R. S. (2010). An activity guideline for technology roadmapping implementation. *Technology Analysis and Strategic Management, 22*(2), 229-242. doi:10.1080/09537320903498553

Gerdsri, N., & Kocaoglu, D. F. (2003, 20-24 July 2003). *An analytical approach to building a technology development envelope (TDE) for roadmapping of emerging technologies: a case study of emerging electronic cooling technologies for computer servers.* Paper presented at the Management of Engineering and Technology, 2003. PICMET '03. Technology Management for Reshaping the World. Portland International Conference on.

Gindy, N., Morcos, M., Cerit, B., & Hodgson, A. (2008). Strategic technology alignment roadmapping STAR® aligning R & D investments with business needs. *International Journal of Computer Integrated Manufacturing, 21*(8), 957-970. doi:10.1080/09511920801927148

Groenveld, P. (1997). Roadmapping integrates business and technology. *Research-Technology Management, 40*(5), 48-55.

Grossman, D. S. (2004). Putting technology on the road. *Research Technology Management, 47*(2), 41-46.

Hammersley, M. (2001). On 'systematic' reviews of research literatures: A 'narrative' response to Evans & Benefeld. *British Educational Research Journal, 27*(5), 542-554.

Hansen, C., Daim, T., Ernst, H., & Herstatt, C. (2015). The future of rail automation: A scenario-based technology roadmap for the rail automation market. *Technological Forecasting and Social Change*. doi:10.1016/j.techfore.2015.12.017

Holmes, C., & Ferrill, M. (2005). The application of Operation and Technology Roadmapping to aid Singaporean SMEs identify and select emerging technologies. *Technological Forecasting and Social Change, 72*(3 SPEC. ISS.), 349-357. doi:10.1016/j.techfore.2004.08.010

Ilevbare, I. M., Probert, D., & Phaal, R. (2014). Towards risk-aware roadmapping: Influencing factors

and practical measures. *Technovation, 34*(8), 399-409. doi:10.1016/j.technovation.2014.05.006
Jun, S. P., Seo, J. H., & Son, J. K. (2013). A study of the SME Technology Roadmapping Program to strengthen the R&D planning capability of Korean SMEs. *Technological Forecasting and Social Change, 80*(5), 1002-1014. doi:10.1016/j.techfore.2012.10.022
Kappel, T. A. (2001). Perspectives on roadmaps: how organizations talk about the future. *Journal of Product Innovation Management, 18*(1), 39-50. doi:10.1111/1540-5885.1810039
Kennispark Twente. Retrieved from https://www.kennispark.nl/
Kostoff, R. N., Boylan, R., & Simons, G. R. (2004). Disruptive technology roadmaps. *Technological Forecasting and Social Change, 71*(1-2), 141-159. doi:10.1016/S0040-1625(03)00048-9
Kotter, J. P. (1995). LEADING CHANGE - WHY TRANSFORMATION EFFORTS FAIL. *Harvard Business Review, 73*(2), 59-67.
Lee, C., Kim, J., & Lee, S. (2016). Towards robust technology roadmapping: How to diagnose the vulnerability of organisational plans. *Technological Forecasting and Social Change, 111*, 164-175. doi:10.1016/j.techfore.2016.06.022
Lee, H., & Geum, Y. (2017). Development of the scenario-based technology roadmap considering layer heterogeneity: An approach using CIA and AHP. *Technological Forecasting and Social Change, 117*, 12-24. doi:10.1016/j.techfore.2017.01.016
Lee, J. H., Kim, H. I., & Phaal, R. (2012). An analysis of factors improving technology roadmap credibility: A communications theory assessment of roadmapping processes. *Technological Forecasting and Social Change, 79*(2), 263-280. doi:10.1016/j.techfore.2011.05.003
Lee, J. H., Phaal, R., & Lee, C. (2011). An empirical analysis of the determinants of technology roadmap utilization. *R and D Management, 41*(5), 485-508. doi:10.1111/j.1467-9310.2011.00657.x
Lee, S., & Park, Y. (2005). Customization of technology roadmaps according to roadmapping purposes: Overall process and detailed modules. *Technological Forecasting and Social Change, 72*(5), 567-583. doi:10.1016/j.techfore.2004.11.006
Lee, S., Yoon, B., Lee, C., & Park, J. (2009). Business planning based on technological capabilities: Patent analysis for technology-driven roadmapping. *Technological Forecasting and Social Change, 76*(6), 769-786. doi:10.1016/j.techfore.2009.01.003
Lindermann, N., Valcarcel, S., Schaarschmidt, M., & von Kortzfleisch, H. (2009). SME 2.0: Roadmap towards Web 2.0-Based Open Innovation in SME-Networks - A Case Study Based Research Framework. In G. Dhillon, B. C. Stahl, & R. Baskerville (Eds.), *Information Systems - Creativity and Innovation in Small and Medium-Sized Enterprises* (Vol. 301, pp. 28-41). Berlin: Springer-Verlag Berlin.
Mirbel, I., & Ralyte, J. (2006). Situational method engineering: combining assembly-based and roadmap-driven approaches. *Requirements Engineering, 11*(1), 58-78. doi:10.1007/s00766-005-0019-0
Munster, M. (2011). What does open innovation imply for high-tech SMEs? An empirical study and analysis on motives, challenges and consequences.
Navimipour, N. J., & Charband, Y. (2016). Knowledge sharing mechanisms and techniques in project teams: Literature review, classification, and current trends. *Computers in Human Behavior, 62*, 730-742. doi:10.1016/j.chb.2016.05.003
OECD Science. (2007). *OECD Science, Technology and Industry Scoreboard 2007*.
Oliveira, M. G., & Rozenfeld, H. (2010). Integrating technology roadmapping and portfolio management at the front-end of new product development. *Technological Forecasting and Social Change, 77*(8), 1339-1354. doi:10.1016/j.techfore.2010.07.015
Parida, V., Westerberg, M., & Frishammar, J. (2012). Inbound Open Innovation Activities in High-Tech SMEs: The Impact on Innovation Performance. *Journal of Small Business Management, 50*(2), 283-309. doi:10.1111/j.1540-627X.2012.00354.x
Pfeiffer, J. (1968). *New look at education; systems analysis in our schools and colleges*. New York: Odyssey Press.
Phaal, R., Farrukh, C. J. P., & Probert, D. R. (2004). Technology roadmapping - A planning framework for evolution and revolution. *Technological Forecasting and Social Change, 71*(1-2), 5-26. doi:10.1016/s0040-1625(03)00072-6
Phaal, R., Farrukh, C. J. P., & Probert, D. R. (2006). Technology management tools: concept, development and application. *Technovation, 26*(3), 336-344. doi:10.1016/j.technovation.2005.02.001
Phaal, R., & Muller, G. (2009). An architectural framework for roadmapping: Towards visual strategy. *Technological Forecasting and Social Change, 76*(1), 39-49. doi:10.1016/j.techfore.2008.03.018
Phaal, R., Routley, M., Athanassopoulou, N., & Probert, D. (2012). Charting exploitation strategies for emerging technology. *Research Technology Management, 55*(2), 34-42. doi:10.5437/08956308X5502021
Renault, V. (2014). Section 14. SWOT Analysis: Strengths, Weaknesses, Opportunities, and Threats. *Community assessment.* Retrieved from http://ctb.ku.edu/en/table-of-contents/assessment/assessing-community-needs-and-resources/swot-analysis/main
Rousseau, D. M., Manning, J., & Denyer, D. (2008). Evidence in Management and Organizational Science: Assembling the Field's Full Weight of Scientific Knowledge Through Syntheses. *Academy of Management Annals, 2*, 475-515. doi:10.1080/19416520802211651

Saritas, O., & Aylen, J. (2010). Using scenarios for roadmapping: The case of clean production. *Technological Forecasting and Social Change, 77*(7), 1061-1075. doi:10.1016/j.techfore.2010.03.003

Saritas, O., & Oner, M. A. (2004). Systemic analysis of UK foresight results Joint application of integrated management model and roadmapping. *Technological Forecasting and Social Change, 71*(1-2), 27-65. doi:10.1016/S0040-1625(03)00067-2

Siebelink, R., Halman, J. I. M., & Hofman, E. (2016). Scenario-Driven Roadmapping to cope with uncertainty: Its application in the construction industry. *Technological Forecasting and Social Change, 110*, 226-238. doi:https://doi.org/10.1016/j.techfore.2016.01.030

Strategos.com. Identifying growth opportunities. Retrieved from https://www.strategos.com/service/identifying-growth-opportunities/

Strategyzer.com. The Value Proposition Canvas. Retrieved from https://strategyzer.com/canvas/value-proposition-canvas

Vishnevskiy, K., Karasev, O., & Meissner, D. (2014). Integrated roadmaps and corporate Foresight as tools of innovation management: The case of Russian companies. *Technological Forecasting and Social Change*. doi:10.1016/j.techfore.2014.04.011

Vishnevskiy, K., Karasev, O., & Meissner, D. (2016). Integrated roadmaps for strategic management and planning. *Technological Forecasting and Social Change, 110*, 153-166. doi:10.1016/j.techfore.2015.10.020

Vojak, B. A., & Chambers, F. A. (2004). Roadmapping disruptive technical threats and opportunities in complex, technology-based subsystems: The SAILS methodology. *Technological Forecasting and Social Change, 71*(1–2), 121-139. doi:http://doi.org/10.1016/S0040-1625(03)00047-7

Wall, B., Jagdev, H., & Browne, J. (2005). An approach to developing an eBusiness roadmap. *Production Planning and Control, 16*(7), 701-715. doi:10.1080/09537280500290136

Walsh, S. T. (2004). Roadmapping a disruptive technology: A case study - The emerging microsystems and top-down nanosystems industry. *Technological Forecasting and Social Change, 71*(1-2), 161-185. doi:10.1016/j.techfore.2003.10.003

Wells, R., Phaal, R., Farrukh, C., & Probert, D. (2004). Technology roadmapping for a service organization. *Research-Technology Management, 47*(2), 46-51.

Willyard, C. H., & McClees, C. W. (1987). MOTOROLAS TECHNOLOGY ROADMAP PROCESS. *Research Management, 30*(5), 13-19.

Wright, T. (2014). How to write a good vision statement. Retrieved from https://www.executestrategy.net/blog/write-good-vision-statement/

Zhang, Y., Guo, Y., Wang, X., Zhu, D., & Porter, A. L. (2013). A hybrid visualisation model for technology roadmapping: Bibliometrics, qualitative methodology and empirical study. *Technology Analysis and Strategic Management, 25*(6), 707-724. doi:10.1080/09537325.2013.803064

Zhang, Y., Robinson, D. K. R., Porter, A. L., Zhu, D., Zhang, G., & Lu, J. (2016). Technology roadmapping for competitive technical intelligence. *Technological Forecasting and Social Change, 110*, 175-186. doi:10.1016/j.techfore.2015.11.029

Zhang, Y., Zhang, G., Chen, H., Porter, A. L., Zhu, D., & Lu, J. (2016). Topic analysis and forecasting for science, technology and innovation: Methodology with a case study focusing on big data research. *Technological Forecasting and Social Change, 105*, 179-191. doi:10.1016/j.techfore.2016.01.015

9. APPENDICES

9.1 Appendix A: Literature matrix

Articles/concept	Definition of roadmapping	Circumstances in which TRM is applied	Roadmapping techniques	Interesting findings
Abe, H., et al. (2009). "Integrating business modeling and roadmapping methods - The Innovation Support Technology (IST) approach." Technological Forecasting and Social Change 76(1): 80-90.	After Slywotzky, a business model (BM) is described as follows: the totality of howa company selects its customers, defines and differentiates its offerings, defines the tasks it will perform itself and those it will outsource, configures its resources, goes to market, creates utility for customers, and captures profit. It is the entire system for delivering utility to customers and earning a profit from that activity. We use BM to support engineers to envisage "what", "who" and "how" are conditioned for their innovation, and to draw "how much" cost and value are required for its financial model. Strategic roadmapping (SRM) is a well-known and commoditized method that comprises a time-based, multi-layered chart, enabling the various functions and perspectives to be aligned. On the other hand, BM is our original contribution and it was first reported in. The concept of the IST is based on the best use of the pros of BMand SRM. By integrating BM and SRM, the IST is a methodology that manages to integrate the two concepts of technology push and market pull in one and the same approach. While BM is a tool that focuses on technology push, SRM covers the concern of market pull.		IST: 3 steps. Step 1: Workshop 1. First determine: "As is model" - market, customers, business idea, etc. Then determine: "to be model" - vision, will from all involved. Identify gap between "as is" and "to be". Next you should make technological scenario. Product functions and technologies related to the product concept drawn with "my vision and my will" are pulled out from the METI-Strategic Technology Roadmap (METI-TRM) database and arranged for the purpose, and then a technological scenario is made. By this method the technological scenario can be easily obtained by use of the METI-TRM database, not by zero-base. Step 2: Workshop 2. Next, planning of the business scenario is made. Industrial value chain analysis, PEST (political, economic, sociological, technological) analysis, and business environment analysis by using five forces after M. Porter are executed as a start of the business modeling procedures [18–20]. Then we create profit modeling by utilizing Slywotzky's 22 "profit patterns" in business activities [6–8]. 1) The purpose of the business scenario plan is to design and to obtain the business target of the company in the future. 2) The company's business unit (hereafter BU) technology roadmap can be obtained by roadmapping of the product function and the enabling technology to achieve the business target in the future. Step 3: Workshop 3. Contents of the BU technology roadmap and discoveries through these roadmapping workshops are reflected in the business model in the future. The target customers, the value propositions, the supply method, and the profit model according to scenarios are confirmed before the business model is completed. Then, the business model and the company technology roadmap are integrated with the integrated strategic roadmap (ISRM).	
Ahlqvist, T., et al. (2012). "Systemic transformation, anticipatory culture, and knowledge spaces: Constructing organisational capacities in roadmapping projects at VTT Technical Research Centre of Finland." Technology Analysis and Strategic Management 24(8): 821-841.	We suggest that roadmapping is a felicitous method for fostering and steering systemic transformationcapacities.Thisisbecauseroadmapping,especiallyinitsstrategicform(seebelow),isan adaptive process-based methodology well suited for systemic contexts (see Ahlqvist, Valovirta, andLoikkanen2012):itsvisualformatenablesthetransparentformulationofvisionswithexplicit linkagesacrossthetemporalspectrum(present,mediumterm,andlongterm)androadmaplayers (suchasdrivers,markets,andenablingtechnologies).Inthesystemiccontext,roadmappingrefers toacontinuousandtransparentprocess,notasingleexercise,whichproducesahermeticchartof the future with a sealed vision.Therefore, the vision should be understood as temporarily locked target that is systematically verified and re-formulated, either based on an organisation's strategy clock or when a	1. to generate a common vision. 2. identify societal needs. 3. Articulate demand. 4. linking before said layers together. 5. identify single targets. 6. temporal sequences.	In the context of systemic transformation capacities, the generic process of roadmapping is coarsely the following: (1) constructing an initial roadmap with a future vision and required temporal axes (short term, medium term, and long term), (2) translating the critical parts of the roadmap into action points, and (3) revisiting the roadmap periodically, varying roughly from a few months to 2 years. In these checkpoints, the roadmap is assessed against the changed circumstances. Step 1 is done in three steps. A) Identification of relevant knowledge spaces. B) Specification of roadmap scope. C) Building managerial orientation to deal with the results.	Periodically revising the roadmap

	critical need, such as a change in the environment, emerges.			
Amer, M. and T. U. Daim (2010). "Application of technology roadmaps for renewable energy sector." Technological Forecasting and Social Change 77(8): 1355-1370.	Roadmaps forecast future market directions, technological developments, and help to make strategic decisions. Generally roadmaps are used to answer three fundamental questions: (a) Where are we going? i.e. what are our vision, mission, objectives, goals and targets etc. (b) Where are we now? i.e. present state of technology, products, markets etc., and (c) How can we get there? i.e. policy measures, action plans, R&D programs, long-term & short-term strategies etc	Roadmaps may be developed by aiming at customer requirements (market pull approach) or trying to exploit technological innovations which can result in new business opportunities (technology push approach).	Bray and Garcia's approach: Phase 1: preliminary activity • Satisfy essential conditions • Provide leadership/sponsorship • Define the scope and boundaries for the roadmap Phase 2:Tech roadmap development • Identify the "product" that will be the focus of the roadmap • Identify the critical system requirements and their targets • Specify major technology areas • Specify the technology drivers and their targets • Identify technology alternatives and their time lines • Recommend the technology alternatives that should be pursued. • Create the technology roadmap report Phase 3: follow-up activity • Critique and validate the roadmap • Develop an implementation plan	Theliteratureindicatesthatroadmappingcanbeintegratedwithothertech niquessuchas the Delphi method, portfolio methods, balanced scorecards, SWOT analysis, PEST analysis, Quality Function Deployment, innovation matrix, technology intelligence techniques, citation network analysis, patent analysis, and product development stage gates (Kostoff, Boylan, and Simons 2004; Phaal, Farrukh, and Probert 2005b; Groenveld2007; Kajikawa et al. 2008; Lee, Mogi, and Kim2009; Phaal and Muller 2009; Lamb, Daim, and Leavengood 2012).
Battistella, C., et al. (2015). "The Extended Map methodology: Technology roadmapping for SMES clusters." Journal of Engineering and Technology Management - JET-M 38: 1-23.	Technology Roadmapping draws a map of present and (possible) future technologies, products and markets, identifying alternative technological and market "roads" in terms of linkages among technologies, products and markets and organizational resources and objectives. The EM methodology aims to create a strategic technology roadmap at the industry level that contains pre-competitive information (Bruce and Fine, 2004) of collective interest on the opportunities for development of new products and services that require functionalities/innovative technologies and consider the main business parameters. The map is intended as a tool to support the group, and it provides each company structured information to support decision making and a basis for strategic choices.	SMEs working together. An Intermediary is installed for: In this context, the intermediary performs two main functions, both of which might be associated with the front-end of innovation (Lynn et al., 1996 ; Wolpert, 2002): the information scanning and gathering function and the communication function.	1. Kick-off: the kick-off is the launch of the initiative, the project definition and the study definition. 2. State of the art and trends. The first step explores the themes initially defined and identifies the state of the art and current industry trends (e.g., markets, value chain, products/services, and key technologies) within the scope of interest. 3. Definition of OPs. The study leads to the second step: the identification and definition of possible favourable opportunities that could be further examined. Once approved by the responsible of the team of champions, every opportunity identified and found interesting will be examined and analysed using the same approach described in the OP methodology. The resulting profiles of opportunities are further examined and evaluated before being assembled to compose a complete roadmap for the industry sector. 4. Mapping. Step 3 consists in elaboration (evaluation, selection and further study), characterization (definition, time positioning and linkages of elements of the map) and graphic visualization (elaboration of map graphics, processing of documents) of all the information collected and analyzed.	This exclusion may be due for example to a number of reasons (Arshed et al., 2012). First, many of the large organizations, which tend to be the typical adopters of roadmapping methods, do not want to engage SMEs or any other outside organization that could be a potential competitor (Lichtenthaler, 2008a ; Lichtenthaler, 2008b). They possess all the expertise and see little value in involvement with small and medium-sized enterprises. Second, knowledge sharing can encourage opportunistic behavior when there are asymmetries of knowledge and can influence businesses to rely less on the behavioral level if adverse effects occur too early, or occur in negative sharing experiences (Petrick and Echols, 2004). Third, typical technology roadmaps have been realized in practice to hold information for strategic use, rather than operational use (Savioz and Blum, 2002). These strategic approaches are often not useful for most small businesses because of the short time horizons SMEs reference and the prevalence of operational objectives. Finally, small and medium-sized enterprises have difficulties in implementing and supporting roadmapping due to a number of factors – time, cost and effort – associated with the maintenance of what can be considered a complex process (Yoon et al., 2008).

			5. Follow-up. The follow-up requires an enterprise to use the information obtained to support business decision making. This information, of a strategic nature, can enable the implementation of a subsequent new product development plan or a technology transfer process. Table 4 for more information	
Bildosola, I., et al. (2017). "TeknoRoadmap, an approach for depicting emerging technologies." Technological Forecasting and Social Change 117: 25-37.	Generally speaking, TRMs have a very varied use in both scientific and professional fields. Bray and Garcia (1998) underscore the major uses and benefits derived from technology roadmapping, and within the framework of technology forecasting they highlight that roadmapping provides a mechanism to help experts forecast S&T developments within targeted areas.	Should be applied to identify and fully grasp and emerging technology. So technology push.	The TKRM: Three layered approach: Technology, Application and Market Step 1: retrieving the data and refining the search. The first task is to generate a specific database consisting of scientific publications directly related to the technology being depicted. For the case of CC, the scientific databases from which the specific database was generated were Web of Science (WoS) and Scopus Step 2: Cleaning up the refined database. The second task involves the use of a text mining tool and some of its basic functionalities. Scientific publications obtained from the previous step have to be integrated in a single database and fuzzy matching has to be applied to specific fields within the documents: authors, affiliations and author's keywords. This process takes all the variations which express exactly the same concept (plural, acronyms, equivalent expressions, etc.) as a single word. Step 3: Generating the profile. The profile is divided in two parts: literature profile and research community profile; and the state of the research and its evolution. Step 4: Ontology generation Keyword reduction by taking the only the most frequent keywords. Then the research can be clustered and named. Step 5: Identification of sub-technologies Step 6: Identification of links See whether the identified sub-technologies actually have practical implications (applications) if so: it can be used. IF not: it can be developed. Step 7: Trend analysis Searching online for trends for both the short and the medium term future. Step 8: Expert assessment All the steps that the researcher have done will be checked by a group of experts in the field.	
Caetano, M. and D. C. Amaral (2011). "Roadmapping for technology push and partnership: A contribution for open innovation environments." Technovation 31(7): 320-335.	The technology roadmapping (TRM) is a method that helps organizations plan their technologies by describing the path to be followed in order to integrate a given technology into products and services.	Technology push method for open innovation environments	Stage 1: Market and Market partners Identify which markets the technology can be applied to, and prioritize those. Identify which partners fit to the strategy and prioritize those. Stage 2: Potential product concepts The objective of Stage II of MTP is to identify and prioritize concepts of possible products based on the market prioritized in Stage I. They are product concepts because so far there is no detailed description of their specifications, but only a preliminary description. Stage 3: technologies, technology and financial partners	A lot of specific on the steps can be found in chapter 5. Very detailed for technology push

			The purpose of Stage III of MTP is to identify and prioritize potential technologies to be developed from the product prioritized in the previous stage. This stage assists in the identification of possible technology (TPs) and financial (FPs) partners, who may be mobilized in the development of different technologies to be prioritized. Roadmap will have the following layers (Fig 6) 1. Market 2. Product 3. Core technology 4. Sub technologies 5. Resources (Market, technology and financial 6. Partners (collaborators and co-operators)	
Carayannis, E., et al. (2016). "Smart roadmapping for STI policy." Technological Forecasting and Social Change 110: 109-116.	Roadmapping is a broadly applied management instrument for developing and implementing company technology and innovation strategies. Roadmaps are a widespread instrument for company technology and innovation managers including analysis of technologies and products in light of R&D requirements, dynamics of technologies' main properties, possible market development and estimates of future demands for products and service	For STI's: Science, Technology and Innovation policy makers. Accordingly STI policy roadmap needs to fulfill three different functions: • diagnosis/modeling/intelligence • regional, governmental policy formulation support • implementation guideline	Smart roadmapping for STI's Preparation 1. Pre-roadmapping (identifying current policy on STI) 2. Deskresearch (literature review) 3. Pre-validation (expert panels & interviews) Analysis 4. Structuring and synthesising 5. Stakeholder analysis (SWOT etc) 6. Scenarios and framework conditions elaboration Validation 7. Validation	
Carvalho, M. M., et al. (2013). "An overview of the literature on technology roadmapping (TRM): Contributions and trends." Technological Forecasting and Social Change 80(7): 1418-1437.	Therefore, the word "roadmap" represents a summary of science and technology plans in the form of maps, and the roadmapping process is the development of this roadmap [5]. Although a roadmap can be presented in several forms, it usually includes a multilayer graphical representation of a plan that connects technology and products with market opportuniti	Include the right people There must be commitment from the client The technology roadmap conclusions must be implemented There should be a dissemination plan to capitalize and ensure increased participation There should paint a realistic picture of the nontechnical barriers There should provide broad recognition of competing technologies Senior management commitment Role of roadmap manager Competence of roadmap participants Stakeholder-driven Normalization and standardization Roadmap criteria Reliability	It is evident that despite the differences in the specific activities associated with the TRM initiatives described in different papers, there is a consensus about the three main phases that must be considered: preparation (when decisions are made); implementation (when initiatives are executed) and finalization, when the results of the process are consolidated and disseminated and major decisions are made about the continuation of the process.	There is a lack of evidence regarding the relationship between TRM and organizational outcomes. Table 6 shows a list of tools other authors used in the roadmapping process. Should be interesting for our map

		Relevance to future actions Cost Global data awareness Integrate TRM with existing management tools Finding ways to increase the efficiency and effectiveness of the roadmapping process Business unit (who is/are the customers?) Engineering discipline (material science<comma> power<comma> etc.) Market requirements (geography<comma> industry and application) Core competencies Technology timing Participation of administrative authorities and coordinators Customized solutions Internet-based groupware Graphical presentation tools Simulations Critical debate Brainstorming Idealized design		
Cheng, M. N., et al. (2016). "A scenario-based roadmapping method for strategic planning and forecasting: A case study in a testing, inspection and certification company." Technological Forecasting and Social Change 111: 44-62.	Technology roadmapping is one of the popular management tools for managing emerging and potential technologies in fields of technology planning and development. By leveraging the graphical visualization of a plan with a multiple layer and timeline, a technology roadmap is used to identify alternative technology development paths for achieving desired objectives. The roadmap is also used to make connections among all the factors (e.g. technology, product, services, resources) to better understand the relationship between market objectives and technology development based on its flexible layout which aligns with the timeline		Scenario-based roadmapping SBRM Phase 1: Prerequisite preparation - Initiate - Determine company needs for implementation of the activity - Define background of study, purpose and scope of the activity Phase 2: Scenario team formation - Identify participants - Conduct a kick-off meeting - Form the participants in three groups: scenario building team, scenario assessment team and decision team Phase 3: scenario building - Construct a scenario worksheet - Generate future scenarios Phase 4: Scenario assessment and selection - Check for validation - Assess each possible future scenario on six individual criteria - Select plausible scenarios for roadmapping Phase 5 scenario based roadmapping	Tips and tricks provided for scenario building

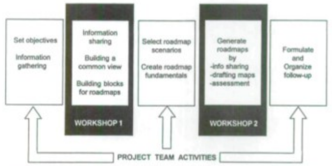
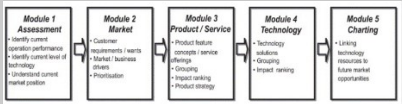
			- Generate a preliminary roadmap for all the plausible scenarios - Determine the quantity of inside-out scenario-based roadmaps - Generate a comprehensive roadmap based on the one that is selected.	
Cho, Y., et al. (2016). "An industrial technology roadmap for supporting public R&D planning." Technological Forecasting and Social Change 107: 1-12.	Roadmapping is implemented to develop a stronger awareness of how to serve potential and current markets with the right product features at the right time and to improve the cross-functional cooperation required for integrating technology, product and market drivers for new product and service creation in terms of customer requirements (Groenveld, 1997). A firm must generate an effective technology plan aligning with a business plan in order to identify and develop the technologies required to meet its customer's future needs.	Market pull	Industrial TRM 1. Preparation stage: At this stage, decision-makers discuss and come to a consensus regarding areas that TRMs are necessary in order to resolve current issues that the society faces. a.Select subjects of TRM. b. Identify major experts in each area.c. Determine decision criteria and clarify a roadmap procedure. d.Select a committee. e. Plan a cooperation with industry associations to lead roadmapping. f.Plan a workshop for roadmapping in each sector. 2. Roadmapping stage: This stage includes roadmapping activities associated with industrial TRMs. a. Confirm necessary information with respect to TRM. b. Open a workshop for roadmapping in each field. c. 50% of participants should come from industry. d. All interested groups (academia, research institute, consumer, and firm) should be involved. e. All participants must have expertise about the selected area so that they may contribute to the workshop. f. Identify megatrends/industry and market trends with SWOT analysis and value chain analysis. g. Identify the critical system requirements and their targets/identify capabilities and gaps. h. Link core technology with products to identify the product that will be the focus of the roadmap. i. Specify the technology drivers and their targets with technology tree technique. j. Analyze the IP trends associated with targeted technologies. k. Prioritize technology alternatives that should be pursued using portfolio analysis. l. Specify technology alternatives and their time lines. m. Create micro and macro roadmaps. n. Consolidate all roadmaps and set visions based on various scenarios. o. Sum up workshop reports. p. Establish subcommittee to prepare the first draft of TRM. q. Develop the first draft roadmap. r. Take a feedback after circulating the first draft roadmap. s. Consolidate TRM with additional evaluations and comments from industry. t. Establish and execute attainable plans.	Therefore, it is significant to note that industrial TRM must serve a strategic decision making tool to allocate R&D investment. Third, the industrial roadmapping process is distinctive in its deployment of Delphi, Technology Tree (TT), IP analysis, data mining, and portfolio analysis, in order to improve the effectiveness of strategic planning for the industry that encompasses market, technology, standards, infrastructure, regional innovation, international cooperation, and regulation aspects.
Cosner, R. R., et al. (2007). "Integrating roadmapping into technical planning." Research Technology Management 50(6): 31-48.	Properly done, roadmapping can identify gaps or contradictions in the planning process, and it can lead to finding new opportunities. However, evaluation of the value of the opportunities and their fit with the overall strategy of the company using portfolio management techniques is still required		The crucial first step in integrated technical planning is to establish the goals of the roadmapping process and the business value that is being sought. A phased set of escalating goals may be the best approach. Agreement on these goals is crucial to controlling unplanned growth in scope, which can doom the roadmapping process to failure. The second step is to determine the approach to be used in building the roadmaps. otherwise called the engagement model. Three approaches were identified in our research: 1) built by a central group, using information collected from across the enterprise; 2) buih in a series of workshops with different groups of stakeholders; 3) built by each contributing organization, working to enterprise guidelines. The best approach will depend on the company's culture and on the process used to provide resources for developing the roadmaps.	

			The third step is to establish the architecture of the roadmaps, that is, how the complete enterprise roadmap will be decomposed into component plans (i.e.. types of roadmaps). To a degree, this will depend on the overall goals, and the approach to be followed in developing the roadmaps. The process owner must determine the content and format for each discrete roadmap type. This architecture should be aligned with assignment of responsibilities in the selected engagement model. Roadmap development will be greatly facilitated by tailoring the architecture to the company's organization and culture.	
Cuhls, K., et al. (2015). "Roadmapping: Comparing cases in China and Germany." Technological Forecasting and Social Change 101: 238-250.	The terminology varies between China and Germany. This is not only due to the language. Even if we translate words or sentences into English as an intermediary language, the terms used imply different notions. The methodological terminology also differs: In China, the word "roadmapping" is used in a very broad sense to describe many different approaches that would tend to be called "foresight" in German/English. In German/English, one would definitely finish a roadmapping exercise by producing an actual "map". Therefore the layout of "roadmaps" often resembles real roads to the future, subway maps, circle radar maps, a simple arrow from the past to the future or other possibilities. In the Chinese cases, these maps are always linked with written reports, and the reports always conclude with very clear policy-making suggestions for the government. There are also a lot of differences in the meaning of the word "scenario" (internationally, not only Chinese — German). Therefore, it is necessary to explain what is meant by scenario (roadmapping) in each project before the real work starts.		In all cases, we find a differentiation of 1. the information-gathering methods and steps, 2. the "drawing the roadmap" in a single picture and 3. designing the output.	
Dissel, M. C., et al. (2009). "Value roadmapping." Research Technology Management 52(6): 45-53.	The roadmapping approach uses structured visual diagrams to support strategic dialogue, linking technology investment to business outcomes. It is being used in industiy, at company and sector levels, to support a variety of strategic goals (7,8.9).	Applied when the technology is at early stages. Technology Readiness level between 1 and 3. (total = 9) Mostly technology push, but also some market pull	VRM Preparation stage 1. Define strategic framework, vision, scenario Mapping 2. Map technology development and investment milestones 3. Define value streams 4. Map market and business trends and drivers Define 5. Map barriers and enablers Review 6. Review project plan and VRM Present 7. Visualization Maintain 8. VRM as a process	Figure 2

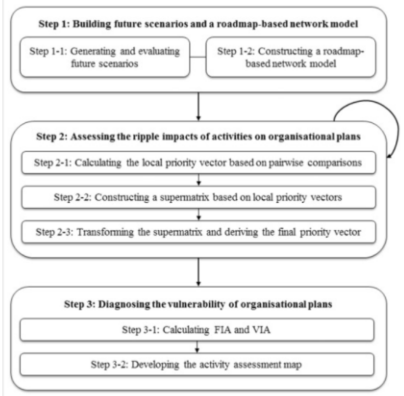
Fenwick, D., et al. (2009). "Value Driven Technology Road Mapping (VTRM) process integrating decision making and marketing tools: Case of Internet security technologies." Technological Forecasting and Social Change 76(8): 1055-1077.	TRM is used as strategic planning tool. The Value Road Map (VRM) [22] concept of assigning a value on products and services provides marketing tie-in to customer value drivers, and a quantifiable method to select emerging technologies for business benefit.		Following the VTRM process steps, an (A) Assessment, (B) Market Analysis, (C) Services availability, and (D) necessary Technologies, are evaluated to arrive at an (E) Roadmap which is created to link technology to future market opportunities. A) Assessment- SWOT + Five forces = evaluate the current market B) Market analysis – understand value proposition for customers and use it to identify market drivers. Prioritize the drivers and find the gaps of unfulfilled drivers. C) Services availability – Desirable features – form categories, rank them and paint a strategy (pairwise comparison method and hierarchical decision models). Identify service or product solution gaps that are actually viable D) Necessary technologies – technologies that are needed for the solutions should be listed, clustered, compared and ranked. This will help in identifying technology gaps; use Technology Development Envelope (TDE) E) Roadmap links – TDE can help to link all the technologies to the products, services and markets. So it is important to make three layers with - Driver gaps (market gaps) - Solution gaps (what is vialbe to solve) - Technology gaps (what is available and what needs to be developed) And link them together. The process of creating a Value-Driven Technology Roadmap (VTRM) begins with a current assessment of company's internal capabilities, as well as the external industry environment. The goal is a complete Technology Roadmap, hopefully with processes in place to update the roadmap when a significant change in the company or environment is quantified. Starting with the current assessment, the purpose of doing a SWOT analysis and Five Forces analysis is to create a foundation for a Value Proposition. The Value Proposition leads to the Value (Market) Drivers used to build the first (top) level of the Roadmap. The Features Matrix completes the Market Drivers level of the Roadmap. The Perceptual Map connects and compares the Drivers with the Solutions, and depicts the Gaps prevalent in the Solutions, which are added as the second level of the Roadmap. These Gaps identify new or improved Features needed in the Services. The Delphi Pairwise Comparison utilizes expert opinion regarding the suitability of potential Technologies in addressing the needed Features, and scores are awarded to each potential Technology in addressing the Factors needed for the Service features. An Analytic Hierarchy Process (AHP) is employed to evaluate performance of each prospective Technology when tested against external customer Criteria. The External attributes can change at each time period, which will affect the Object scoring of Technologies. In addition, emerging technologies may not be available until a later time period and must be scheduled to build or acquire to coincide with when the Technology is needed. The Technology Development Envelope (TDE) plots the scores from the AHP at each time period, and the highest scoring Technology is the best fit for the variables available at that time period to satisfy the Solutions (or Services) needed. Each Technology requires Resources to either build or acquire, and that information is added to the bottom level of the Roadmap. The Roadmap process must be iterative, so that when new data is available that might affect the roadmap, the TDE should be revisited to create a potentially new roadmap which incorporates the latest findings.	

			The practical application of the roadmapping process is eased considerably by a selection of appropriate tools, and the applicability overlap has a large impact on the confidence and reliability of the results	
Foden, J. and H. Berends (2010). "Technology management at rolls-royce." Research Technology Management 53(2): 33-42.	formulating strategies, selecting ideas, aligning to business and product requirements, and formulating technology proposals	Gregory, for example, proposes a framework consisting of five TM sub-processes: identification, selection, acquisition, exploitation and protection {4). Such frameworks should provide support along the complete technology life cycle. At the beginning of the life cycle, a technology exists within the organization merely as an idea or concept that could have a beneficial impact on the organization's operations. Awareness of these potential technologies can be acquired through the application of the first TM stage: Identification and Monitoring.	The proposed framework (Figure I) consists of six sub-processes, or stages, that are aligned to the technology life eyele: 1) identification and monitoring; 2) selection and approval; 3) development research; 4) acquisition and adaptation; 5) exploitation and review; and 6) protection. The first five of these processes represent sequential stages, although several feedback loops exist, the most important being between the first and last stages. These represent the replacement of aging technologies by newer radical solutions.	
Gerdsri, N., et al. (2010). "An activity guideline for technology roadmapping implementation." Technology Analysis and Strategic Management 22(2): 229-242.	Technology roadmapping is viewed by practitioners in the field as an innovative strategic planning tool to visualise and formulate the linkage between a business and technology strategy. A technology roadmap is a visual representation of the organisation's strategy		1. Initiation 2. Development 3. Integration Applied with change management. Came to the following action plan	Thus, the process depends on people and an individual contribution throughout the process is considered as one of the key success factors along with process and data (Gerdsri and Assakul 2007. This paper proposes an activity guideline for TRM implementation by referring to the change management approaches of Prosci's ADKAR (Hiatt 2006) and Kotter's eight steps (Kotter 1996).

			Action plan to support the TRM implementation process *Initiation* ✓ Understand the value of applying TRM in the organisation ✓ Build awareness of why TRM implementation is needed ✓ Discuss the detailed concept and the roll-out plan of TRM implementation ✓ Raise urgency of why TRM implementation is immediately necessary to all participating members ✓ Develop a vision, objective, and scope of TRM implementation for the organisation ✓ Gain acceptance and sponsorship from top-management ✓ Communicate the vision for the buy-in and support from key players ✓ Form a working group responsible for activities related to TRM implementation ✓ Provide the fundamental concept of TRM to all participants ✓ Prepare all participants to be ready to implement the TRM process ✓ Customise the generic TRM process to fit with the organisational setting *Development* ✓ Plan and organise a series of workshop sessions to develop a roadmap ✓ Allocate responsibilities to each individual in the group as well as set up ground rules for the group participation ✓ Maintain the momentum and energy from all participants throughout the TRM development process Action plan to support the TRM implementation process ✓ Remove barriers blocking each participant from carrying out the TRM activities ✓ Conduct debriefing and review sessions *Integration* ✓ Consolidate roadmaps into one master roadmap (if needed) ✓ Establish the procedures to review and revise a roadmap so that a roadmap can be kept alive ✓ Integrate TRM process into organisation's existing processes ✓ Transfer ownership of the process to the proper group of people	
Gindy, N., et al. (2008). "Strategic technology alignment roadmapping STAR® aligning R & D investments with business needs." International Journal of Computer Integrated Manufacturing 21(8): 957-970.	At the enterprise level, technology roadmapping is primarily a management tool to improve the enterprise's strategic technology planning processes by aligning technology acquisition to company strategic objectives derived from market and business drivers. In addition, the team-orientated technology roadmapping process also supports consensus building.	Alignment	1. Preliminary phase Aimed at developing a knowledge management framework for the data , information and knowledge generated during the STAR process 2. Technology requirements Purpose is evaluate and rank the technologies that are key to current and future success. Through requirements capture (info gathering), benchmarking, and technology watch. 3. Project creating and assessment phase	Requirements capture: AHP tool

Groenveld, P. (1997). "Roadmapping integrates business and technology." <u>Research Technology Management</u> 40(5).	This approach is characterized by the integration of technology, product and market/application, paying due attention to how requirements and opportunities change over time. Roadmapping is a process that contributes to the integration of business and technology and to the definition of technology strategy by displaying the interaction between products and technologies overtime, taking into account both short- and long-tenn product and technology aspects.	Limited information available	 *Figure 4.—Essential elements of the roadmap-building process are the establishment of a multidisciplinary project team that guides the process, and workshops that are organized to ensure integral involvement of, and input by, the organization.*	In the start-up phase, only one or two of the three parameters of product, technology and time can be considered simultaneously. This helps to structure the discussions and clarify which problems have to be addressed first. Tools such as QFD and the Innovation Matrix,, which stem from technology management practices, can be used to determine one or more of these parameters
Grossman, D. S. (2004). "Putting technology on the road." Research Technology Management 47(2): 41-46.	Technology planning tool used for linking advanced technology development timing to the product plan, visualizing objectives.	Goal was to make the technology plan visible, alignment was important (marketing had to be involved early on) but most important the roadmap provided a common framework for meaningful discussions between key stakeholders.	y-axis performance x-axis time	
Hansen, C., et al. (2015). "The future of rail automation: A scenario-based technology roadmap for the rail automation market." Technological Forecasting and Social Change.	A general objective of technology roadmapping approaches is to provide a structured way of forecasting the future developments of a market or industry and to review this prediction in an ongoing process.	Market pull approach	1. Preparation of qualitive technology roadmap Three layers: market, systems and products, technologies 2. Scenario identification for the qualitative roadmap Each driver – variable – possible future scenarios – finding the most propable one 3. Evaluation of relevance and sensitivity analysis on basis of quantitative roadmap 4. Graphical representation of the results	Market: literature research or expert workshop A way to calculate the best options
Holmes, C. and M. Ferrill (2005). "The application of Operation and Technology Roadmapping to aid Singaporean SMEs identify and select emerging technologies." Technological Forecasting and Social Change 72(3 SPEC. ISS.): 349-357.	Product/technology roadmaps are specifically company centric and seek to align decisions with trends, schedule product and/or service introductions and create a plan that integrates market and customer needs, product evolution and the introduction of new technology [7].		prioritisation 	
Ilevbare, I. M., et al. (2014). "Towards risk-aware roadmapping: Influencing factors and practical measures." Technovation 34(8): 399-409.	Roadmapping provides a structured approach to innovation and strategy and has become one of the most widely used management techniques for these purposes. It is increasingly being applied in industry due to its ability to deliver communication and consensus among decision stakeholders and provide a structured planning process.		1. Initiation and planning RISK: establish context for risk management 2. Input and analysis RISK: Risk assesment & treatment 3. Roadmap synthesis and output RISK: Risk reporting 4. Implementation of the roadmap RISK: monitor and review risks	Nice suggestion of a Generic roadmap
Jun, S. P., et al. (2013). "A study of the SME Technology Roadmapping Program to strengthen the R&D planning capability of Korean SMEs." Technological	By general definition, a "roadmap presents a method for pursuing the desired direction to achieve a specific goal" and the purpose of preparing a roadmap is to assist the organization in securing and utilizing the appropriate capabilities at the appropriate time in order to achieve its goals.	The provided roadmaps are market-oriented roadmaps focusing on future demand rather than focusing on technological trends, and is designed for mid-term planning (3~5 years) rather than short-term (2~3 years) or long-term (5~10 years) planning, since this	When examined from the perspective of roadmap building, the process of the Korean SME Technology Roadmapping Program consists of four stages. The first is the stage of building the roadmap at the market–product level. Activities conducted in this stage include internal and external environment analysis, analysis of customer needs through market research, linkage of key product success factors and product component functions/performance features, and conceptualization of candidate products. These activities enable participants to analyze the market and the internal and external environment of the company and thus identify the products suitable for the individual SME. Secondly, in the stage of building the roadmap at the product–	The midterm is interesting for SMEs. By contrast, Korea's program relied centrally on the analyses of specialists and technology and market research, and the core outcome included the provision of various information that can utilized in the

Forecasting and Social Change 80(5): 1002-1014.		corresponds to the usual timeframe of the business strategy plans used by companies.	technology level, a schematic diagram (parts diagram) of the component technologies of the product is created and the performance fulfilling technology (technology alternatives) for each product concept is selected, and the application time frame is determined. Thirdly, during the stage for building the integrated R&D roadmap, the respective roadmaps derived from the previous stages are integrated. Participants build an integrative roadmap linking market–product–technology and determine the implementation timetable and the development strategy for the required technology. The last stage is the stage in which the R&D strategy is established and the R&D plan is completed. In this stage, an R&D strategy is determined for the products targeted for development, and the R&D portfolio strategy is defined for these products, thereby completing the building of the roadmap	future in addition to the roadmap itself. This is why Korea's program required relatively large amounts of expenses and time, providing funding of around $20,000 per company and covering a maximum support time span of 3 months.
Kappel, T. A. (2001). "Perspectives on roadmaps: how organizations talk about the future." Journal of Product Innovation Management 18(1): 39-50.	Roadmaps can be used for forecasting and planning	The ascent of roadmapping has several implications, depending on one's perspective. For the foresight and futurist communities, it has become a legitimate opportunity to revitalize and advance the practice of technology forecasting. For corporate leaders roadmapping has acquired social legitimacy, and in some circles, resisting it is akin to being against reason itself. With early adopters, their personal success, enthusiasm, and the intuitive appeal of mapping have so far substituted for convincing evidence of its objective benefit. Conditions: The first and strongest finding in this area relates to organizational motive for roadmapping. The cases strongly indicated that roadmapping enjoyed more success in the presence of a recognized external threat. In sum we observed that "appealing to fear" works better to motivate roadmapping than "seeking opportunities to get ahead." Success appears more likely in product areas that: (1) are substantially important to the company and the participants (in terms revenue, profits, or reputation) to encourage the organization's most valuable people to spend considerable effort required by the process; (2) entail significant or long term investments in technology, justifying the effort to forecast market and product parameters beyond the next product release; and (3) involve a perceived threat from the marketplace.	The field data collection generated a substantial inventory of tactics used to initiate roadmapping in a given organization. The variety of approaches falls into two categories. Diffusion tactics, the first category, are intended to spread roadmapping throughout an entire firm. Behind the diffusion tactics is a belief that roadmapping belongs everywhere in the organization, or that by broadcasting it, roadmapping will be received and implemented in the right places and eventually become a way of life in the firm. Tactics - Education - Policy - Imitation A second category of approaches involves selective introduction, a one-to-one model more similar to a technology transfer. These tactics assume that roadmapping is not needed everywhere, it will not work everywhere, or the introduction effort should be concentrated in the most important areas of the business. Tactics - Intervention - Consulting - Catalyst - Personnel transfer	

Kostoff, R. N., et al. (2004). "Disruptive technology roadmaps." Technological Forecasting and Social Change 71(1-2): 141-159.		Technology push	1. Define the problem or opportunity to be adressed 2. Identify technology alternatives and associated experts 3. Use advanced information technology methods to collect the full literature 4. Combine literature and place it in a structured format. 5. Cluster and find alternatives 6. Experts will be invited to a workshop, brainstorm to find the best alternative 7. Two major solutions: technical and non-technical	1. Senior management commitment 2. Role of roadmap manager 3. Competence of participants 4. Stakeholder driven 5. Normalization and standardization 6. Roadmap criteria 7. Reliability 8. Relevance for future actions 9.
Lee, C., et al. (2016). "Towards robust technology roadmapping: How to diagnose the vulnerability of organisational plans." Technological Forecasting and Social Change 111: 164-175.	Technology roadmapping supports strategic and long-range planning by offering a structured means of exploring and communicating the dynamic relationships between markets, products, and technologies.	The proposed approach focuses on the vulnerability of organisational plans in achieving organisational objectives, in that (1) technology roadmapping is a tool to support strategic and long-range business planning; and (2) technology roadmapping links multiple perspectives, such as market, product, and technology.	 Fig. 2	It works for high-tech SMEs AHP
Lee, H. and Y. Geum (2017). "Development of the scenario-based technology roadmap considering layer heterogeneity: An approach using CIA and AHP." Technological Forecasting and Social Change 117: 12-24.	Quite naturally, scenarios have also taken a front seat in the development of the technology roadmap (TRM) which has been discussed as a prominent strategic planning tool. Therefore, these layers are related to the internal decision-making, i.e. what kinds of products we have to consider, and what kinds of technology we have to develop. Therefore, a scenario in the product layer and the technology layer is a decisive problem, which is controllable factor in the firm.	Both external (market pull) and internal approach (technology push)	1. Scenario building: Baseline approach with two plausible extremes 2. Identifying possible events and possible development plans: 3. Measuring the impact of the external environment: use CIA a. Use step 2 b. Estimate probability of each event (expert judgement) c. Cross impact estimated d. Matrix e. Monte carlo to identify the final probability 4. Develop a market layer 5. Measuring the impact of internal decision: AHP a. Create alternatives b. Evaluation criteria c. AHP model 6. Develop product and technology layer	Three-scenarios – two possible extremes
Lee, J. H., et al. (2012). "An analysis of factors improving technology roadmap credibility: A communications theory assessment of roadmapping processes." Technological Forecasting and Social Change 79(2): 263-280.	From a company's point of view, TRM represents a needs-driven technology planning process that identifies, selects, and develops technology alternatives to meet a series of product demands. These demands determine how the TRM in terms of a final output is produced.	one of the major expectations placed on technology roadmapping is that it will offer the information necessary for better decision-making. Further, they indicate that maps should meet this expectation by 1) identifying the gap between a key technology needed to meet a product performance goal and present technologies, and 2) identifying ways to leverage R&D investments through coordinating research activities either within a single company or among alliance members. Another benefit of TRM is that it	1. Planning 2. Insight collection 3. Insight processing 4. Interpretation/implementation	Focus on the communication value of roadmapping. In other words, there is no specific roadmapping methodology that can be commonly used by all companies in all industries. Hypothesis that they accepted: - The stronger a TRM development team's willingness to cooperate with TRM users, the more credible TRM becomes.

		may generate a framework to plan and coordinate technology or product development. TRMs are further useful in being able 1) to derive a consensus on the technologies that will be necessary to meet demand, and 2) to offer a mechanism for forecasting technology development in terms of product goals for the business		- The more a TRM development team is willing to reduce the uncertainty associated with TRM forecasts, the more credible a TRM becomes. - The more often the communication between a TRM development team and TRM users, the more credible a TRM becomes. - The more TRM users perceived TRM outputs as credible, the more TRM utilization increases. Hypthesis rejected: - The more the written channel is used as the main form of communication between the TRM development team and TRM users, the more credible a TRM becomes. - The more the face-to-face channel is used as the main form of communication between the TRM development team and TRM users, the more credible a TRM becomes.
Lee, J. H., et al. (2011). "An empirical analysis of the determinants of technology roadmap utilization." R and D Management 41(5): 485-508.	In short, the TRM is a rational methodology for seeking agreement on selecting technologies that will help achieve an organization's goals. It also serves as a framework used for adjusting technology development schedules.	A number of researchers have sought to specify the benefits of using TRMs. Garcia and Bray (1997), Kostoff and Schaller (2001), Phaal et al. (2004), Lopez-Ortega et al. (2006), and Groenveld (2007) claim that a roadmap can contribute to the development of a consensus among decision makers on the need for new technologies. It may also provide a decision mechanism for acting on intended innovations in target areas. Another benefit of TRMs lies in their informationbased decision support for investment in new technologies.		First, developing an appropriate software tool to support TRM was found to be more significant than any other factor in terms of impact on TRM utilization. Second, an effective roadmap process is an important factor in the utilization of TRM, highlighting the importance of implementing effective post-TRM management processes for roadmaps that respond to technological or business change (Phaal et al., 2004). Third, the degree of alignment of a TRM with company objectives can positively influence the likelihood of its being utilized, with a further positive mediating effect on R&D performance. Lastly, R&D performance can be improved by utilizing a TRM, while it also benefits from mapping's partial mediating effects for the other three independent factors.
Lee, S. and Y. Park (2005). "Customization of technology roadmaps according to roadmapping purposes: Overall process and detailed modules." Technological Forecasting and Social Change 72(5): 567-583.	Technology roadmap is one of the most widely used methods for supporting the strategic management of technology. At the industry level, it helps to forecast technological future trends based on either exploratory methods or normative approaches [1]; [2] ; [3]. At the corporate level, it provides a graphical means for exploring and communicating the relationships among markets, products, and technologies over time	To sum up, technology roadmaps have been used as a management tool for planning, forecasting, and administration. Recently, it is expanding its application areas toward new product development process [19], knowledge management [36], and even virtual innovations [21]. Furthermore, although traditional roadmapping approaches were limited to the sustaining technologies, roadmaps for disruptive technology are proposed [37] ; [38].		To respond to the existing needs, commercial roadmapping software systems are starting to appear [7]. For instance, Honeywell technology roadmapping utilizes Geneva Vision Strategiest software to digitally capture technology projects, components, subassemblies, and the timing of these developments to support products [19]. Modularization was adopted as the customization method, and so, after eight types of standardized roadmaps were suggested, customized roadmap templates were designed consisting of three modules: forecasting, planning, and administration. Furthermore, a web-based system having a customization function was developed to support the easy creation, dissemination, and upkeep of roadmap. With the customization function, a set of roadmaps, providing useful information

				to obtain a particular purpose, was created simply by selecting an application purpose and then meeting the input requirements which will be the basis of the roadmaps. Users do not need to worry about designing the appropriate roadmap formats and contents, which may be mostly beyond their capacity. In addition, the use of the customization function enables concentrated management of information.
Lee, S., et al. (2009). "Business planning based on technological capabilities: Patent analysis for technology-driven roadmapping." Technological Forecasting and Social Change 76(6): 769-786.	One of the tools that has been developed to address the issue is Technology Roadmap (TRM), which is known to be effective in connecting business and technology planning [4], where planning procedures mostly depend on the qualitative judgment of technical experts.	A TRM can present the co-evolution of technologies [5], can support technology management and planning [6] and also a offer a visual description showing the relationships between research projects and development projects and their objectives and requirements [7]. However, most existing TRM approaches tend to be constrained by market-oriented perspectives: such an approach regards TRM as the set of activities beginning with the perception of a market opportunity and ending with R&D requirements TECHNOLOGY PUSH	At the first stage — 'R&D planning' — R&D targets and schedules are determined, and as part of this stage it is essential to examine technology trends and competitors' activities. The Monitoring module is designed to discover relations between firms based on their technologies. It enables a firm to discover which other firms have been doing similar research and which are leading the industry. After potential R&D items have been selected, detailed development plans should be elaborated at the second — 'technology planning' — stage. Possible new technologies that could result from R&D are discussed, including such issues as how to acquire those technologies and when they might be expected to be realized. The Collaboration module shows relations between firms based on the knowledge flows in their patents, allowing a firm to consider their chance of technology realization by collaborating with others. Once technology planning is completed, the next step is 'product planning', to find new business opportunities based on the technologies that will become available, which is the core of the technology-driven roadmapping process. A single technology, though developed for a specific context, may turn out to be applicable in various industries with a minimum modification. The most important task at this stage is to discover such industries, which is the aim of the Diversification module. This module indicates the likelihood of technology applications in different industries using patent citation analysis, by taking the knowledge flows in patents as indicating technological flows, and assuming that industries with more technological flows may offer greater possibilities for technology applications [53]. Product planning is completed when an idea of all the possible products that might result as a consequence of applying the technology to different industries has been generated. However, the diversification module results reflect only the technological aspects of possible product development avenues, and do not consider competitor activities or general market conditions and tends. Hence, at the last stage — 'market planning,' — seeks to identify markets where other firms with similar technological assets are competing to understand the potential connections between products and markets. The Benchmarking module is then employed to find firms worth benchmarking, and in the light of these results, the firm can finally decide which market(s) to enter. Through these four stages, promising markets where a particular technology can be best applied can be finally identified. The detailed description of patent analysis follows in the next section.A	All modules are explained in the research. Very interesting for technology push

<table>
<tr>
<td>Oliveira, M. G. and H. Rozenfeld (2010). "Integrating technology roadmapping and portfolio management at the front-end of new product development." Technological Forecasting and Social Change 77(8): 1339-1354.</td>
<td>At the front-end, technology roadmapping can be used mainly for strategic planning, product planning, program planning and integration planning [15]. Some advantages of applying TRM are integrating innovation perspectives (market, product and technology), facilitation of intraorganizational communication and long-term planning</td>
<td></td>
<td>
<table>
<tr><th>Activity</th><th>Description</th></tr>
<tr><td>1. Definition of unit of analysis</td><td>Establishes the boundaries of the method's application in terms of business unit, market segment and product line.</td></tr>
<tr><td>2. Business strategy analysis</td><td>Identifies the business drivers that establish the directions and targets in the NPD process.</td></tr>
<tr><td>3. Market analysis</td><td>Defines the drivers that represent market needs and trends.</td></tr>
<tr><td>4. Product analysis</td><td>Determines the product features of the selected product line.</td></tr>
<tr><td>5. Technology analysis</td><td>Identifies technologies and evaluates their ability to deliver the product features.</td></tr>
<tr><td>6. Definition of product strategies</td><td>Formulates the product strategies by analyzing the information created in the preceding activities. Uses the generic roadmap to integrate business, market, product and technology information.</td></tr>
<tr><td>7. Proposal of NPD projects</td><td>Defines product concepts and projects that meet the product strategies.</td></tr>
<tr><td>8. Financial evaluation</td><td>Analyzes the financial aspects of projects to determine the financial return for the business. It includes traditional metrics such as: NPV, IRR, payback, and ROI.</td></tr>
<tr><td>9. Evaluation of probability of success</td><td>Evaluates the risks that may affect the development of the product project. It separates the risks into technical and commercial risks.</td></tr>
<tr><td>10. Evaluation of strategic alignment</td><td>Analyzes the alignment between the project and the business strategies according to specific criteria.</td></tr>
<tr><td>11. Project prioritization</td><td>Ranks the proposals of new product projects based on financial metrics, probability of success, and strategy alignment.</td></tr>
<tr><td>12. Project interrelationship analysis</td><td>Verifies four types of interrelationships among projects that may affect the project portfolio selection: technical, resource utilization, benefits, and timing.</td></tr>
<tr><td>13. Selection of NPD project portfolio</td><td>Selects NPD projects to be included in the ongoing product project portfolio by analyzing strategic alignment, value maximization, balancing and resource allocation.</td></tr>
</table>
</td>
<td></td>
</tr>
<tr>
<td>Phaal, R., et al. (2004). "Technology roadmapping - A planning framework for evolution and revolution." Technological Forecasting and Social Change 71(1-2): 5-26.</td>
<td>Technology roadmapping is a flexible technique that is widely used within industry to support strategic and long-range planning. The approach provides a structured (and often graphical) means for exploring and communicating the relationships between evolving and developing markets, products and technologies over time.</td>
<td>Market pull</td>
<td>The standard T-Plan process comprises four facilitated workshops. The first three focus on the three main layers of the roadmap (market/business, product/service and technology), with the final workshop bringing the themes together on a time-basis to construct the chart (see Fig. 6). The approach is driven by market and business requirements, which are used to identify and prioritize product and technology options (as shown in Fig. 1).

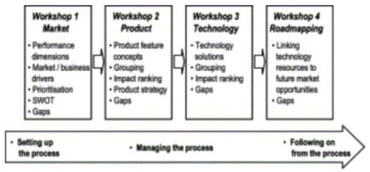


Fig. 6.
T-Plan: standard process steps [31].

The key benefit of the fast-start T-Plan approach, apart from the direct business benefits that arise from its application, is that the value of the method can be assessed quickly and economically. The learning that is gained by this initial application provides confidence about how to best take the process forward within the organization.

There are two key challenges to overcome if roadmapping is to be adopted widely within a company:

(i)

Keeping the roadmap alive: the full value of roadmapping can be gained only if the information that it contains is current and kept up-to-date as events unfold. In practice, this means updating</td>
<td>For the purposes of this paper the following definition is adopted, proposed by the European Institute of Technology and Innovation Management (EITIM):

Technology management addresses the effective identification, selection, acquisition, development, exploitation and protection of technologies (product, process and infrastructural) needed to achieve, maintain [and grow] a market position and business performance in accordance with the company's objectives [10].

This definition highlights two important technology management themes:

1.

Establishing and maintaining the linkages between technological resources and company objectives is of vital importance and represents a continuing challenge for many firms. This requires effective communication and knowledge management, supported by appropriate tools and processes. Of particular importance is the dialogue and understanding that needs to be established between the commercial and technological functions in the business.

2.

Effective technology management requires a number of management processes and the EITIM definition includes the five processes proposed by Gregory [11]: identification, selection, acquisition, exploitation and protection of technology. These processes are not always very visible in firms, and are typically distributed within other business processes, such as strategy, innovation and operations.

A recent survey of 2000 UK manufacturing firms [61] indicates that about 10% of companies (mostly large) have applied the technology</td>
</tr>
</table>

			the roadmap on a periodic basis, at least once a year, or perhaps linked to budget or strategy cycles. The initial first-cut roadmap produced by the T-Plan process must be captured, stored, communicated, researched and updated, which requires careful consideration of the process and systems needed to facilitate this. (ii) Roll-out: once the first roadmap is developed, it may be desirable to facilitate the adoption of the method in other parts of the organization. Essentially there are two approaches to rolling-out the method: • Top-down, where the requirement for roadmaps is prescribed by senior management—the particular format may or may not be specified. • Bottom-up ('organic'), where the benefits of using the method are communicated and support provided for application where a potential fit with a business issue/problem is identified	roadmapping approach, with approximately 80% of those companies either using the technique more than once, or on an ongoing basis.
Phaal, R., et al. (2006). "Technology management tools: Concept, development and application." Technovation 26(3): 336-344.				A list of tools that can be used in the final roadmap.
Phaal, R. and G. Muller (2009). "An architectural framework for roadmapping: Towards visual strategy." Technological Forecasting and Social Change 76(1): 39-49.	The condensed visual format of a roadmap is important, providing a 'one-page' high-level view of the system in question, incorporating all key perspectives in a form that supports the strategic dialogue necessary for developing consensus and aligning action, and identifying challenges, risks and tensions. The roadmap lens is comprised of two distinct layers: 1. An underlying information-based structure (the roadmap architecture) — how the information contained within the roadmap is organized, which represents the key elements of the system (layers and sub-layers of the roadmap), set against time. 2. An overlaying graphical layer, with format, style and color chosen to represent the roadmap structure and its contents for communication purposes. The multi-layered time-based format is posited as the most comprehensive and flexible format for developing roadmaps, although different graphical styles have been developed for summary and communication purposes [8].	which is crucial if the approach is to provide a framework for supporting effective dialogue and communication within and between organizations.		This initial planning and design work should be done by a small group of people ('process team'), liaising with other key stakeholders, as appropriate (for example, senior management, steering group, experts). The process team should be perceptive to change and opportunities, 'out-of-the-box' thinkers, visionary by nature. During the later phases of the development tensions caused by constraints will be added by broadening the involved stakeholder group. The development of good roadmaps requires the involvement of key stakeholders and groups, often representing very different perspectives'. At the highest level, roadmaps comprise three broad layers: 1. Trends and drivers 2. Products 3. Technology There are many possible ways of structuring the layers and sub-layers; there is no unique or necessarily best way of doing this, but achieving a good result is critical to the success of the activity. It is important to define the architecture to the right level of granularity. Too much detail can be a mistake (i.e. too many layers and sub-layers), as the architecture can be too complicated and may constrain participants' thinking. On the other hand, too little detail makes organizing information that is captured difficult.

<table>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr>
<td>Phaal, R., et al. (2012). "Charting exploitation strategies for emerging technology." Research Technology Management 55(2): 34-42.</td>
<td>Roadmapping methods provide a practical approach to supporting technology and innovation strategy, although their application to emerging technology is particularly challenging.

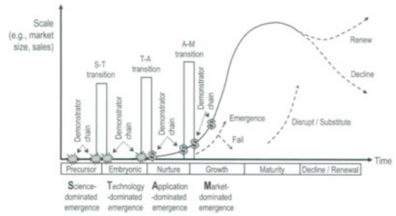
Emergence roadmapping (ERM) is a workshop method that supports rapid strategic appraisal of early-stage technologies. The approach, which is based on earlier work demonstrating patterns in the historical emergence of industries. The ERM method follows on from the value roadmapping (VRM) approach (Dissel et al. 2009), which enables value opportunities for emerging technology to be identified and prioritized..</td>
<td></td>
<td>

FIGURE 1. Phases and transitions of industrial emergence (adapted from Phaal et al. 2011, 221).

ERM focusses on the shift between the phases. Roadmapping technologies should always try to visualize the progress that has been booked for people to conintue working on the roadmap

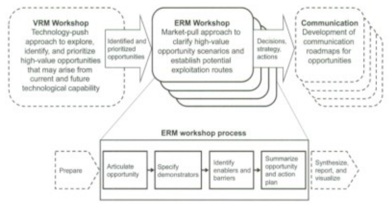


FIGURE 4. The emergence roadmapping (ERM) workshop process.</td>
<td>Emergence roadmapping can facilitate the decision-making progress for early-stage technologies by allowing workshop participants to rapidly map the potential commercial exploitation paths for a technology on the industrial emergence framework, tracing its potential trajectories through a series of demonstrator steps. The aims of the ERM workshop are

1. To clarify the innovation opportunity, in tenus of application, market, and technology; 2. To define steps toward the opportunity, mapping the demonstration chain; and 3. To identify key enablers and barriers as well as next actions to move toward the first demonstrator.</td>
</tr>
<tr>
<td>Saritas, O. and J. Aylen (2010). "Using scenarios for roadmapping: The case of clean production." Technological Forecasting and Social Change 77(7): 1061-1075.</td>
<td>Roadmap: The central idea was to chart future technological trends against potential market evolution. Since then roadmapping has been used in a variety of contexts, particularly in the industry at corporate level. Roadmaps communicate visions, attract resources from business and government, stimulate investigations and monitor progress

Roadmapping: The essence of roadmapping is asking three questions:

•

Where do we want to go?

•

What are the ways of getting there?

•</td>
<td>Market pull and technology push</td>
<td>A systematic roadmapping process consists of three main phases:

1.

Preliminary activity

- Scenarios cand determine plausible futures

2.

Development of the roadmap

- scenarios provide different ways to get to the plausible futures

3.

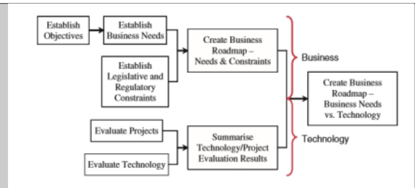
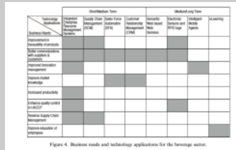
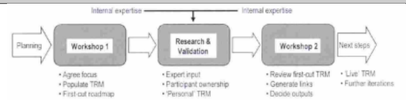
Follow-up activity

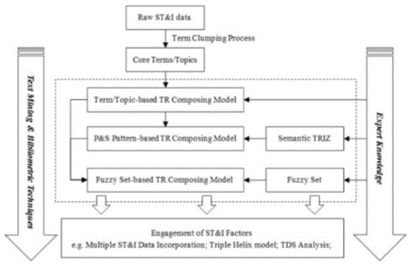
- Test robustness of the roadmap and plan ahead with scenarios</td>
<td>A real roadmap used by people to find their way.

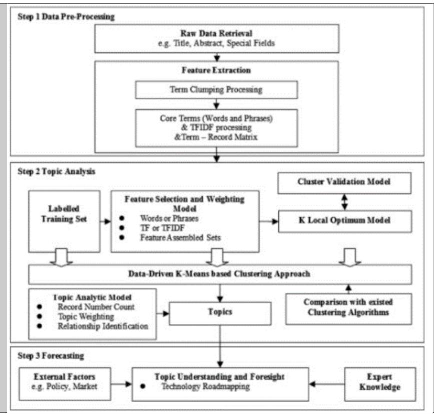
PESTAL = STEEPV</td>
</tr>
</table>

<table>
<tr><td></td><td>What should we do from now on?</td><td></td><td></td><td></td></tr>
<tr><td>Saritas, O. and M. A. Oner (2004). "Systemic analysis of UK foresight results Joint application of integrated management model and roadmapping." Technological Forecasting and Social Change 71(1-2): 27-65.</td><td>The roadmap is selected set of requirements, links and R&D projects that describes the state of technology development and potential transfer in a coherent area. It could be composed of a single requirement for a system linked to corresponding R&D projects, or it could encompass multiple requirements linked to numerous projects.</td><td>Roadmapping is the second methodology used in complementary stance with IMM to capture, visualize, manipulate and manage information to decrease complexity in foresight by constructing roadmaps</td><td>1. Delphi survey
2. Scenario
3. Expert panel who roadmap
4. Delpi questionair
5. Extended discussion</td><td>In the application of roadmapping to the UK foresight exercises, we employed graphical modeling system (GMS). Developed by U.S. Navy Research Center, GMS visually portrays requirements, capabilities, R&D projects in different development phases, relationships between R&D projects and requirements and integration among R&D projects [36]</td></tr>
<tr><td>Siebelink, R., et al. (2016). "Scenario-Driven Roadmapping to cope with uncertainty: Its application in the construction industry." Technological Forecasting and Social Change 110: 226-238.</td><td>A business roadmap is a visual representation of the evolution over
time of those markets that a company wants to serve in the future, the
products it wants to offer on these markets, and the technologies and
other capabilities that are necessary to make these products</td><td>Market pull</td><td>1. Prepare the workshops
2. Analyzing the current situation
Consider driving forces
List of current activities and markets
List of strengths and weaknesses
3. Exploring future business environments
Scenario planning (described in section 3.3)
4. Determining robust areas
List of likely implications
Focus areas determined
5. Developing business roadmap
6. Implementing the roadmap</td><td></td></tr>
<tr><td>Vishnevskiy, K., et al. (2014). "Integrated roadmaps and corporate Foresight as tools of innovation management: The case of Russian companies." Technological Forecasting and Social Change.</td><td></td><td>There are two main directions of roadmapping — the market pull and technology push approaches. The first considers market demand as the major driver of R&D [6]; [7]; [13]; [15] ; [16]. The latter starts with the most important technologies and tries to identify the market needs that could address the challenges arising from the use of the new technologies [7]; [17]; [18] ; [19].</td><td><table>
<tr><th>No.</th><th>Phase</th><th>No.</th><th>Stage</th><th>Results</th><th>Methods</th></tr>
<tr><td>1.</td><td>Preparation</td><td>1.1.</td><td>Creation of expert group</td><td>• Elaboration of requirement system for experts
• Revealing leading experts and organizations in the subject field
• Negotiations with experts about their participation</td><td>Bibliometrics, patent analysis, literature review</td></tr>
<tr><td>2.</td><td>Visioning</td><td>2.1.</td><td>Detection of trends and drivers for subject field</td><td>• Revelation of trends, drivers, barriers and limitations for the subject field</td><td>Interviews, expert panels, brainstorming</td></tr>
<tr><td></td><td></td><td>2.2.</td><td>Elaboration of future vision</td><td>• Socio-economic context
• Trends in S&T sphere
• List of expecting breakthroughs</td><td>Interviews, expert panels, brainstorming, wild cards</td></tr>
</table></td><td>a.
Corporate Foresight requires substantial investment by companies. This is a serious challenge since there is no ultimate evidence that the outcomes of corporate Foresight are valid and sustainable.
b.
Corporate Foresight and integrated roadmapping are assumed effective only when done regularly
c.
Corporations are often confronted with uncertainty by employees and recent skepticism about corporate Foresight.</td></tr>
</table>

			3. Analysis 3.1. Technology push analysis — • Analysis of research fronts • Promising S&T development directions for the subject field — Bibliometrics, patent analysis, benchmarking, interviews, expert panels 3.2. Market pull analysis — • List of promising market segments • Revelation of factors influencing market segments • Estimation of future markets dynamics — Scenarios, cross-impact analysis, interviews, expert panels 3.3. Estimation of competitive advantages for prospective product groups — • List of promising product groups including key product features and necessary technologies • Strengths and weaknesses, opportunities and threats for product groups • Degree of competition from alternative product groups — SWOT analysis, interviews, expert panels, benchmarking 4. Prioritizing 4.1. Creation of priorities system — System of priorities including product groups aimed at: • orientation on big and growing segments • competitive advantages comparing alternatives • S&T and production backlog — Brainstorming, benchmarking, expert panels 4.2. Validation of priorities system — Validated system of priorities with a participation of leading domestic and foreign experts — Seminars, expert panels	
Vishnevskiy, K., et al. (2016). "Integrated roadmaps for strategic management and planning." Technological Forecasting and Social Change 110: 153-166.	Roadmapping is a complex long-term planning instrument that allows for setting strategic goals and estimating the potential of new technologies, products, and services. Until recently, roadmapping was used mainly for strategic planning, either from a technological or a market research perspective. Roadmaps emphasized either technological development or satisfaction of market demands but rarely both. Consequently, roadmaps either excessively stress the technology side, which might lead to technically sophisticated solutions that lack applicability, or overstress customer needs, neglecting business competence-building	Either market-driven or technology-driven approaches	1. Pre-roadmapping: project domain and key priorities, using Delphi 2. Desk research: all available knowledge literature search, benchmarking, foresight centers. 3. Expert procedures 4. Creative analysis: use WiWi (wildcars and weak signals) 5. Interactive discussion	
Vojak, B. A. and F. A. Chambers (2004). "Roadmapping disruptive technical threats and opportunities in complex, technology-based subsystems: The SAILS methodology."	In spite of the relatively wide use of this tool, some variation exists among users regarding exactly what roadmaps and roadmapping entail. For example, former Motorola chairman Robert Galvin [10] has suggested that "A 'roadmap' is an extended look at the future of a chosen field of inquiry composed from the collective knowledge of the brightest drivers of change in that field …." Further, Groenveld [8], in his discussion of roadmapping at Philips Electronics, describes roadmapping as "… a process that contributes to the integration of business and technology and to the definition of technology strategy by displaying the interaction between products and technologies over time …."		Standards The process begins with the designer seeking to understand what the trends are for industry standardization at various levels of the value-added chain and how they impact product performance characteristics. Participation in the standards process is an excellent way to accomplish this. Off-line conversations and proposals can provide significant insight. Architecture The designer next moves to brainstorming various architecture options available at each value-added level within the supersystem. These first two steps set the stage for the rest of the analysis. Integration The burden on the designer here is to develop options for forward integration, backward integration, and lateral integration into the rest of the supersystem. It also involves putting oneself	We believe that the use of this methodology can benefit the expert in that it can assist in broadening the range of possibilities considered beyond the ordinary. Further, we believe it also can help the junior engineer in that it points the way to some fertile areas for identifying potential disruptions.

	Additionally, in their review of science and technology roadmaps, Kostoff and Schaller [1] indicate that "… the single word 'roadmap' has surfaced as a popular metaphor for planning S&T (science and technology) resources."		in the position of the designer of other portions of the supersystem and determining to what extent your product (or some portion of the function of your product) could be a target of their attack. This part of the analysis must be repeated for each standard and architecture option under consideration. In addition, various sequences and combinations of disintegration and reintegration must necessarily be considered. Often a blank paper approach to meeting the system or subsystem requirements is helpful. Linkages Perhaps the most difficult (and most rewarding) task is the identification of linkages between the functional performance of all portions of the product with the performance of all other elements of the supersystem. This part of the analysis also must be repeated for each standard and architecture option under consideration. Substitutions This step is challenging in that it requires the designer to seek out what he or she may currently not be aware of, competitive threats to a component of your product or some portion of the product that may radically replace that element. As much as with the other elements of the methodology, this requires a proactive scanning of the technical literature to know what is out there, as well as to evaluate the level of threat or opportunity it provides. The net must be cast very widely as the most disruptive substitutions can occur quickly through the adoption of a component or subsystem that has already been developed for a very different application.	
Wall, B., et al. (2005). "An approach to developing an eBusiness roadmap." Production Planning and Control 16(7): 701-715.	As a first step to developing any roadmap, one needs to establish the business imperatives and potential technologies—in addition to the managerial changes—that could be implemented to attain the business goals.		 Figure 1. Outline of roadmapping approach.	This list comprises of three basic types of technology: . Existing technology: This is generic and sector specific technology that already exists and is in use by some other players in the business sector. The technology being used by the leaders in the business sector is also identified in this section. . Planned technology: Again generic and specific technology that is planned for implementation in the business sector in the foreseeable future. . Visionary technology: This is the technology that has been imagined by the 'futurologists', the people with the long-term vision of what could potentially be available in the following 5 to 10 years. 
Wells, R., et al. (2004). "Technology roadmapping for a service organization." Research-Technology Management 47(2): 46-51.	Technology roadmapping (TRM) provides a method for ensuring that investments in technology are aligned with the development of new capabilities that are required to exploit future market opportunities. The TRM approach	A number of key benefits have been realized from using roadmapping within the Royal Mail, in the context of research planning: ■ *Mutual understanding:* The Logistics roadmap was used to help communicate the plan for the research theme with sponsors in the business. It was particularly useful for providing a shared view that took into account the business and research/technology drivers, enabling the Research Group to gain a better understanding of the most important external drivers for the business. Also, the roadmap helped the business to gain a better understanding of when research activity and technology developments are likely to be available and deployable. ■ *Focus and prioritization:* The roadmap helped to identify what the focus of the research activity should be, which areas of research were the highest priority for the business, and where there were gaps in the plan—i.e., new areas for research. ■ *Framework for expert knowledge:* The roadmaps have also been useful as a framework to understand where expert knowledge will be required in the future, and to help focus Research Group technology scanning activities, as shown in Figure 3 for the E-commerce theme.	 *Figure 4.—The Royal Mail roadmapping process supports the initiation of roadmapping activity in the organization, consisting of two workshops separated by a research and validation phase.*	

Zhang, Y., et al. (2013). "A hybrid visualisation model for technology roadmapping: Bibliometrics, qualitative methodology and empirical study." Technology Analysis and Strategic Management 25(6): 707-724.	As defined by Winebrake (2003), technology roadmapping is a future-based strategic planning device that outlines the goals, barriers and strategies necessary for achieving a given vision of technologicaladvancementandmarketpenetration		1. Objects definition: collect and process patents and literature reviews The model in Figure 3 combines bibliometrics and qualitative methodologies, and in this step we engage both technology analysts and experts.After the general literature review, technology analystsdefinethedraftsearchstrategyandgeneratethehigh-frequencytermsdatasetandcluster mapping via desktop text analysis software (VantagePoint). Experts identify and classify the subfields with the support of cluster mapping, summarise the basic terms'dataset and extend the terms'dataset(whichwescopewithintheidentifiedsubfields)basedontheirexperienc e.Finally,the draft terms' dataset is composed of high-frequency terms', basic terms' and the extended terms' datasets and then we refine the terms by comparison analysis with the participation of both technology analysts and experts. The usual search terms, derived from some general search strategies, only have single keywords or IPCs, while former search terms from former projects in this field have an integrated format with both of them.We finish the final discussions for refining search terms after several informal interviews and expert workshops. The more feedback and modifications are obtained, the better the results that can be expected. 2. Relationship definition We define the relationships between the objects by association rules that are based on 'term cooccurrence analysis'and PCA (principal components analysis) methods. On the one hand, term co-occurrence focuses on the pattern of terms occurring simultaneously in the records. If two terms occur together in the records more frequently than expected, a relationship is presumed to exist between them. 3. Technology roadmapping Wesummarisethestepsof'constructionoftechnologyroadmapping'inthefollowingt hreeparts: • Exploringtheclustersbyrelationship-basedobjects-associatedmappingandclassifyingobjects into related clusters; • Definingthephasesofthetechnologydevelopmentcyclebythetime-basedobjects-associated mapping, which is shown along the ordinate axis of technology roadmapping; • Locating the objects for technology roadmapping and then modifying the locations in an appropriate place.	
Zhang, Y., et al. (2016). "Technology roadmapping for competitive technical intelligence." Technological Forecasting and Social Change 110: 175-186.	Technology roadmapping (TR) is a future-oriented strategic planning device (Winebrake, 2004) that provides a structured approach to help identify relationships between existing and developing technologies, products, and markets, over time		 1. Term/topic based TR Cluster terms, find relationsships between them and use experts to consolidate those. 2. P&S pattern based TR SAO analysis. The P&S pattern-based TR composing model focuses on the questions: "Which problems are addressed, and when?" and "How the problem was solved (new techniques, materials, or something else), and when?" Comparing with the term/topic-based TR, this model helps discover linguistic features of technological components and emphasizes the logical relationships during the process of technology evolution. 3. Fuzze set based TR Numeric values for vague human concepts	

Zhang, Y., et al. (2016). "Topic analysis and forecasting for science, technology and innovation: Methodology with a case study focusing on big data research." Technological Forecasting and Social Change 105: 179-191.	TRM is defined as a future-oriented strategic planning approach to connect technologies, products, and markets over time			

9.2 Appendix B: SLR - Generic approach and technology strategy division: an overview

Contribution	Standard methodology (combination) vs own methodology	Market pull vs technology push
(Abe et al., 2009)	Own methodology (scenario)	Both
(Ahlqvist et al., 2012)	Generic approach	Market pull
(Amer & Daim, 2010)	Generic approach (Case study)	Both
(Battistella et al., 2015)	Generic approach (SMEs)	Market pull
(Bildosola et al., 2017)	Own methodology (Text mining)	Technology push
(Caetano & Amaral, 2011)	Generic approach (technology push)	Technology push
(Carayannis et al., 2016)	Generic approach (scenario)	Both
(Carvalho et al., 2013)	Generic approach (literature study)	Both
(Cheng et al., 2016)	Own methodology (scenario)	Market pull
(Cho et al., 2016)	Generic approach (for complete industries)	Market pull
(Cosner et al., 2007)	-	-
(Cuhls et al., 2015)	Generic approach (case study: germany vs china)	Both
(Dissel et al., 2009)	Generic approach (VRM)	Technology push
(Fenwick et al., 2009)	Own methodology (VRM)	Market pull
(Foden & Berends, 2010)	Own methodology	Technology push
(Gerdsri et al., 2010)	Generic approach (change management)	-
(Gindy et al., 2008)	Generic approach (alignment)	-
(Groenveld, 1997)	Own methodology (predecessor of generic approach)	-
(Grossman, 2004)	Generic approach (communication/discussion)	-
(Hansen et al., 2015)	Generic approach (scenario)	Market pull
(Holmes & Ferrill, 2005)	Generic approach (Singaporean SMEs)	Market pull
(Ilevbare et al., 2014)	Generic approach (risk)	Market pull
(Jun et al., 2013)	Generic approach (Korean SMEs)	Market pull
(Kappel, 2001)	Own Methodology	Both
(Kostoff et al., 2004)	Own methodology (disruptive technology)	Technology push
(C. Lee et al., 2016)	Own methodology	Both
(H. Lee & Geum, 2017)	Generic approach (scenario)	Both
(J. H. Lee et al., 2012)	Generi approach (communication value)	Both
(J. H. Lee et al., 2011)	-	-
(S. Lee & Park, 2005)	-	-
(S. Lee et al., 2009)	Own methodology (patent analysis)	Technology push
(Oliveira & Rozenfeld, 2010)	Standard methodology (portfolio management)	Market pull
(Phaal et al., 2004)	Generic approach	Market pull
(Phaal, Farrukh, & Probert, 2006)	-	-
(Phaal & Muller, 2009)	-	-
(Phaal et al., 2012)	Generic approach (demonstrator)	Both
(Saritas & Aylen, 2010)	Generic approach (scenarios)	Both
(Saritas & Oner, 2004)	Generic approach (IMM)	Market pull

(Siebelink et al., 2016)	Generic approach (scenario)	Market pull
(Vishnevskiy et al., 2014)	Generic approach	Both
(Vishnevskiy et al., 2016)	Generic apporach (planning)	Both
(Vojak & Chambers, 2004)	Own methodology	-
(Wall, Jagdev, & Browne, 2005)	Own methodology	--
(Walsh, 2004)	Generic apporach	Market pull
(Zhang et al., 2013)	Generic approach (biblio/patents)	Market pull
(Zhang, Robinson, et al., 2016)	Own methodology	-
(Zhang, Zhang, et al., 2016)	Own methodology	-