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Scenario-driven roadmapping for technology foresight

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ABSTRACT

This paper presents a novel method for using scenarios for technology foresight. Technology foresight is a well-established discipline, practised with popular foresight methods such as roadmapping and scenario planning. Applying each foresight method reveals limitations in practice, some of which can be addressed by combining methods. Following calls for combining foresight methods, and past attempts to integrate scenario planning and technology roadmapping, we propose a novel method for their combination. The resulting method — 'scenario-driven roadmapping' differs in: i) using scenario planning first to identify plausible images of the general environment and then using the scenarios for technology roadmapping; and ii) taking advantage of 'flex points' – critical developments which would signal transitions along particular pathways – to create a 'radar' to support effective monitoring of the environment over time. This new combined method takes advantage of the strengths of both methods, while addressing their limitations. A case study vignette centred on the work of a special interest group for Radio Frequency IDentification (RFID) technology adoption in the English National Health Service is presented to illustrate and reflect upon the use in practice of the 'scenario-driven roadmapping' method. Participants were able to develop a detailed technology roadmap with clear 'flex points' helping to connect present circumstances with pathways towards future scenarios. We report on how participants engaged with the scenario-driven method and outcomes achieved were recorded.

1. Introduction

The evolution of technology and the search of the 'next big thing' is a continuous quest for organisations. Mapping the future of a technology is nowadays an established practice (Boe-Lillegraven and Monterde, 2015) adopted by all kinds of organisations to anticipate better new trends and forces, and their impact on the advancement of a technology. Many types and methods for technology foresight have been developed in the last three decades (Mishra et al., 2002). Of them all, technology roadmapping stands out as the most popular, being widely used to support the development of future technologies (Lee et al., 2013). Despite its potential and value, technology roadmapping has a number of limitations (Lee et al., 2011). Thus, we observe efforts to combine technology roadmapping with other foresight methods in order to minimise the effects of these limitations (Saritas and Aylen, 2010).

Scenario planning is another very popular foresight method, often used in technology strategy development (Tran and Daim, 2008). Various studies have closely linked scenario planning and technology roadmapping (Drew, 2006; Lee et al., 2007; Phaal et al., 2004; Tran and Daim, 2008; Yoon et al., 2008), and others even suggested blending the two methods (Saritas and Aylen, 2010; Strauss and Radnor, 2004). Combining the two methods does however require very careful consideration, as they are distinct in logic, scope, and the level within the organisation at which they are utilised (Strauss and Radnor, 2004).

Technology roadmapping often assumes a straight line projection or single scenario, and can become less useful in the face of change that is volatile, systemic and sudden (Strauss and Radnor, 2004), especially over longer periods of time. Wright et al. (2013a), in a previous special issue on scenario planning in this journal, commended the potential outcomes of combining scenario planning with other methods. There are calls (Phaal and Muller, 2009) for using roadmapping processes to accommodate the uncertainties associated with future forecasts and aspirations, and where appropriate to communicate these in the roadmap itself.

This paper presents 'scenario-driven roadmapping', a novel foresight method combining scenario planning and technology roadmapping. Combining selected elements of scenario planning with selected elements of technology roadmapping is not new. Our method however is more comprehensive and differs in: i) using firstly scenario planning to identify plausible images of the general environment and then apply the method of technology roadmapping; and ii) taking advantage of 'flex points' – critical developments which would signal transitions along particular pathways – to create a 'radar' to support effective monitoring of the environment. This

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method takes advantage of the strengths of each method, while addressing limitations identified in the literature.

In the rest of the paper, we review technology roadmapping and scenario planning, emphasising the various frameworks which describe the activities that should take place when using the method in practical settings, and discussing their inherit weaknesses and limitations as foresight methods. We develop a new method which addresses these limitations, to improve the practice of technology foresight. Finally, a fully developed application is reported, which provides a basis for reflecting on the utilisation of the new method.

2. Literature review

2.1. Technology foresight

The field of technology foresight has its roots in the industrial era and developed from the need for long range planning for defence (Linstone, 2011). A popular definition of technology foresight is given by Martin (1995 p. 142) as:

> "*Technology foresight is the process involved in systematically attempting to look into the longer-term future of science, technology, the economy and society with the aim of identifying the areas of strategic research and emerging generic technologies likely to yield the greatest economic and social benefits*".

Broadly, there are a number shortcomings to technology foresight. Practitioners are urged to increase the quality of their work in order to present instances of "success stories" and further the impact of foresight activities (Costanzo, 2004; Cuhls, 2003; DenHond and Groenewegen, 1996; Rohrbeck and Gemünden, 2011; Salo and Cuhls, 2003). Researchers are called upon to contribute further to methodological and conceptual advances in order to provide a clearer understanding of what foresight activities can and cannot deliver (Rohrbeck and Gemünden, 2011; Salo and Cuhls, 2003).

There are several efforts to categorise, organise and arrange foresight methods (Georghiou, 2008; Magruk, 2011; Porter et al., 2004; Saritas and Aylen, 2010). Saritas and Aylen (2010) organised foresight methods into groups of: i) understanding; ii) synthesis and models; iii) analysis and selection; and iv) transformation and v) actions. Magruk (2011) developed a classification of technology foresight techniques with 10 types based on a cluster analysis: consultative, creative, prescriptive, multi-criteria, radar, simulation, diagnostic, analytical, survey and strategic. Georghiou (2008) presented a 'Foresight Diamond' where the four tips of the diamond, not intended to be independent, are defined as 'expertise, creativity, evidence and interaction'. Examples of 'expertise' methods include: roadmapping, expert panels and interviews presented as qualitative methods. Examples of 'creativity' methods include wildcards, simulation and gaming presented as semi-quantitative groups. 'Evidence' methods are also defined as semi-quantitative, including methods such as modelling, scanning, extrapolation and literature reviews. 'Interactive' methods are defined as fully quantitative including voting and polling. According to Georghiou (2008), roadmapping is in the 'expertise' area of the diamond, while scenario planning spans the area between 'expertise' and 'creativity'. Porter et al. (2004) presented technology foresight as encompassing a broad menu of methods, clustered in thirteen 'families', and often involving a blend of quantitative and qualitative methods in order to compensate for weaknesses in any one method. Placing scenario planning and technology roadmapping used in combination into perspective within the broader menu of technology foresight methods available, scenario planning belongs to Porter et al.'s (2004) 'scenarios' family and technology roadmapping belongs to both the 'descriptive' and 'matrices' families.

2.2. Scenario planning

Scenario planning is one of the most popular foresight methods (Ramírez et al., 2015; Schwartz, 2008) as it provides a future-focused method, which allows for the systematic use of insights from experts across a field, and helps explore the joint impact of various uncertainties (Van der Heijden et al., 2002). Scenario planning is not about predicting the future; it is about preparing an organisation for a number of plausible futures (Varum and Melo, 2010). Scenario planning provides an opportunity to envision plausible future states and thus helps to generate strategies to reduce risks, to take advantage of opportunities and avoid potential threats (Ramírez and Selin, 2014). Schoemaker (1995) identifies a range of conditions related to environmental uncertainty for using scenario planning. Van der Heijden (2005) extends the application of scenario planning beyond strategy development, to include anticipation, sensemaking and organisational learning. While scenario planning is widely used for strategy development in organisations (Huss and Horton, 1987), there are many instances of its application in other contexts such as national/regional, industries or even specific technologies (see Van Notten et al., 2003; and Franco et al., 2013 for reviews).

Ringland (2002) explains that the practical difference between scenario planning and 'traditional' planning methods is the time frame. Scenario planning is about taking a view of the long term future in order to help with the planning activities at different time horizons, whereas traditional planning is either too narrowly focused on the present or is based on 'single point' forecasts of the future (Burt et al., 2006). The core idea behind scenario planning is the anticipation of the future in multiple plausible images. As scenario planning has evolved (Bradfield et al., 2005) variation in its use has grown, and three schools of scenario planning thought have emerged (Wright et al., 2013a). In this study, we follow the intuitive logic school which promotes a process of qualitative inquiry to interpret the cause and effect of uncertainties in order to envision several alternative images of the future (Amer et al., 2012).

2.2.1. The process of scenario planning

Within the intuitive logic school of scenario planning, most scenario planning interventions are designed in accordance with early contributions to the field (Schoemaker and van der Heidjen, 1992; Schoemaker, 1995; Bradfield et al., 2005). The first stage concerns 'setting the scene'. Defining the purpose of the exercise, developing an understanding of the current situation, setting a time horizon, selecting the appropriate participants and defining the need for the scenario planning process are common aspects of the first stage (Schwartz, 1991), which normally takes place as a preparatory activity (Chermack et al., 2005).

The second stage covers identifying the key driving forces, either via interviews of key stakeholders or within a workshop setting. Tapinos (2012) showed that, although there is some variation in practice, the driving forces that shape the future should concern the general environment following PEST or one its derivatives (Burt et al., 2006). This stage can take place within a workshop setting with a wide ranging brainstorming session (O'Brien, 2004), though for larger interventions Van der Heijden (2005) proposes preparing a series of key questions to be used within interviews.

The third stage involves ranking driving forces by the level of uncertainty and impact. Van der Heijden et al. (2002) proposed the use of a two axis diagram to evaluate the relative importance and level of uncertainty for each factor in a qualitative, discussion-based approach. This diagram is used to cluster the driving forces identified in the previous stage in order to select the most important uncertainties. It has also been suggested (O'Brien, 2004) that the potential maximum and minimum values of each of the selected uncertainties should be considered.

The fourth stage encompasses selecting central themes and developing scenarios, using various techniques depending on the contextual setting of the exercise. The guiding principle is to develop plausible scenarios (Ramírez and Selin, 2014). It is evident that there is a lot of flexibility into how this stage is realised. Firstly, there is significant variation between different studies regarding how many scenarios should be identified; Amer et al.'s (2012) review found that the recommended number of scenarios to be developed varied from 2 to 8. Secondly, there are inductive and deductive methods to identify the scenarios' themes. The inductive approach is based on building the scenarios around uncertainties (see O'Brien (2004);

Schnaars (1987)). The deductive approach, which is more widely used, is based on pairing two uncertainties, from those selected in the previous stage, to create four alternative scenarios (Schwartz, 1991). Phadnis et al. (2014) point out that, despite the popularity of this method, there is very little description in the literature on how to select the uncertainties for the two axis. Ramírez and Wilkinson (2014) explain that there are different ways of using the deductive approach, debating whether the potential maximum and minimum value of ranges, identified in the previous stage, should be used for developing scenario themes.

Having determined the themes and number of scenarios, the scenarios themselves need to be developed. O′Brien and colleagues provide helpful guidance (O'Brien, 2004; O′Brien et al., 2007), and recommend assigning the value of each factor (based on the ranges identified in the third stage) for each scenario theme. The final element of this stage is to write the scenarios in a narrative form.

Tapinos (2012) suggested that the 'traditional' scenario planning process of the intuitive logic school could be divided into two phases: i) scenario development which finishes at the development of narratives; and ii) planning concerns the use of scenarios to develop strategy. It is recognised that guidance on the use of scenarios is an underdeveloped area (O′Brien and Meadows, 2013; Phadnis et al., 2014). In the field of strategy, there are a few prescriptive suggestions on how scenarios can be used for strategizing (Schoemaker, 1995; O'Brien, 2004; Godet, 2005; Tapinos, 2012). In other fields, the use of scenarios is even less developed (Hughes, 2013; Rickards et al., 2014). Scenario planning has been applied for the investigation of the future of a technology (Tran and Daim, 2008). There are those who do not explicitly cite the intuitive logic school, nevertheless they use its core ideas (such as Sager, 2001) and there are those who use variants of the intuitive logic school (Bierwisch et al., 2015). These articles first develop scenarios for the future and then foresee the future of technology within each scenario.

2.3. Technology roadmapping

Contemporary roadmapping was first used by Motorola in the 1970s to facilitate effective alignment between technology and product development. It has since been exploited at national, sector and company levels. It is applicable to a wide range of issues including capability planning, programme planning and knowledge asset planning (Phaal et al., 2004). Kostoff and Schaller (2001) described the main benefit of roadmapping as the provision of information to help make better technology investment decisions.

There is a multitude of approaches to technology roadmapping, with no commonly held definition. Several authors recommend adopting the most appropriate features of each approach for a given technology roadmapping exercise (Kappel, 2001; Kostoff and Schaller, 2001; Petrick and Echols, 2004; Phaal et al., 2004). There are also many classifications of these various approaches to roadmapping, based on several dimensions including purpose of the exercise, context of use, focal unit of analysis, method and source of data capture, and the format for presenting findings. Garcia and Bray (1997) contrasted product technology roadmapping, emerging technology roadmapping and issue-oriented roadmapping. Albright and Schaller (1998) identified four types: i) science and technology roadmapping; ii) industry technology roadmapping; iii) corporate or product-technology roadmapping; and iv) product/portfolio management roadmapping. More recently, Phaal et al. (2009) argued that the classification of technology roadmapping is dependent on the purpose of the planning activity in question and on their visual formats. The same authors explained that there are eight types of purpose: product, service/capability, strategic, long-range, knowledge asset, program, process planning and integration, and four classifications of visual formats: multiple layers (encompassing bars and tables), single layers (encompassing bars, tables and graphs), pictorial (encompassing flow charts) and text formats.

2.3.1. The process and underlying architecture of technology roadmapping

The process of creating a technology roadmap and the underlying architecture are discussed with the aim of identifying a generic framework. A basic model of technology roadmapping developed by Garcia and Bray (1997) is presented below:

Phase 1. Preliminary activity
1. Satisfy essential conditions.
2. Provide leadership/sponsorship.
3. Define the scope and boundaries for the technology roadmap.

Phase 2. Development of the technology roadmap
1. Identify the product that will be the focus of the roadmap.
2. Identify the critical system requirements and their targets.
3. Specify the major technology areas.
4. Specify the technology drivers and their targets.
5. Identify technology alternatives and their time lines.
6. Recommend the technology alternatives that should be pursued.
7. Create the technology roadmap report.

Phase 3. Follow-up activity.

Gerdsri et al. (2009) also propose a three-phase process. Stage 1 is the initiation stage aiming to prepare an organisation for the technology roadmapping process. Stage 2 is the development stage and aims to produce the roadmap by engaging the right people, gathering the necessary information, and conducting a step-by-step analysis through workshops. Stage 3 is the integration stage, which aims to integrate the technology roadmapping process into on-going business planning activities so that a roadmap can be constantly reviewed and updated in a timely manner.

Phaal and Muller (2009) (see Fig. 1) accommodate the flexibility and customisable nature of technology roadmapping by establishing an architectural framework which can be tailored to suit the setting of a given technology roadmapping exercise through 'timeframes' and 'layers'. Timeframes (typically the horizontal axis) may include the past, short-, medium- and long-term perspectives, as well as aspirations/vision. Layers and sublayers (typically the vertical axis) are represented by a systems-based hierarchical taxonomy, organised into three broad layers. The top layer relates to the trends and drivers that govern the overall goals or purpose associated with the roadmapping activity, including external market and industry trends and drivers (social, technological, environmental, economic, political and infrastructural), and internal business trends and drivers, milestones, objectives and constraints. The middle layer generally relates to the tangible systems that need to be developed to respond to the trends and drivers represented in the top layer. Frequently this directly concerns the evolution of products (functions, features and performance), but the middle layer can also represent the development of services, infrastructure or other

	Past	Year 1	Year 3	Year 10	Vision
External Market/Uncertainties					
Internal Business Strategy					
Product/Service/Strategy					
Technology					
Resources					

Fig. 1. Scenario Matrix 1.

mechanisms for integrating technology, capabilities, knowledge and resources. The bottom layer relates to the resources that need to be marshalled to develop the required products, services and systems, including knowledge-based resources, such as technology, skills and competences and other resources such as finance, partnerships and facilities.

Saritas and Aylen (2010) present three shortcomings of technology roadmapping: roadmaps are normative, rather than exploratory; they encourage linear and isolated thinking; and dissemination is difficult — only experts can understand the output, especially if it is couched in technical terms. Further shortcomings of technology roadmapping are identified by Phaal and Muller (2009) who highlight the many different forms that roadmapping can take, and argue that the form must be tailored to the needs of an organisation, which can generate more questions than answers initially.

The outcome of the various reviews and studies reported above is a multiplicity of methods and the common recommendation is that the most appropriate features and steps from various methods should be combined and customised to each setting. Despite the recognised drawbacks, technology roadmap remains a popular technology foresight technique. It is argued that, often, the process of technology roadmapping is more valuable than the roadmap itself due to the communication and consensus generated within the organisation or stakeholders in the setting (Kappel, 2001; Kostoff and Schaller, 2001; Petrick and Echols, 2004; Phaal et al., 2004).

2.4. Scenarios and technology roadmapping

To address the limitations of technology foresight with scenario planning or roadmapping several authors have suggested integrating these two methods. There is a growing number of publications advocating the combination of elements of scenario planning with elements of technology roadmapping as summarised in Table 1. In reviewing these articles, we acknowledge that all these studies are a step forward for technological foresight as they enhance roadmapping with some elements of scenario planning. We noted however three important limitations and derived specific propositions to address each one:

Limitation 1. *partial use of scenario development method and lack of exploratory futuring.*

As discussed in the previous section, technology roadmapping is heavily criticised (Phaal et al., 2005; Phaal and Muller, 2009; Abe et al., 2009) when used on its own, as it promotes a linear projection of the future. To address this limitation, all the methods reviewed in Table 1 have incorporated scenario planning as a part of the technology roadmapping process, in an attempt to bring the macro perspective of scenario planning into the micro-focused view of technology roadmaps. However, the previous methods do not take full advantage of scenario planning's benefits. Abe et al. (2009) and Kajikawa et al. (2011), for example consider the generation of uncertainties to be scenario planning. In addition, considering scenario planning as an intermediate element of technology roadmaps does not give sufficient emphasis to focusing on the long term future, nor does it lead to the development of exploratory scenarios of the future. For example, Strauss and Radnor (2004) suggest a concurrent development to roadmaps and scenarios, while Pagani (2009) uses scenario planning as cross impact analysis for the roadmaps. Another example is Saritas and Aylen's (2010) scenarios data presented on clean production which focuses on uncertainties and factors rather than fully developed scenarios. In all these cases there is no other step for exploratory futuring at the general external environment level before engaging with the development of the technology roadmaps.

Proposition 1. *perform scenario planning first, using all stages of the scenario development process.*

To overcome the normative character of technology roadmaps (Saritas and Aylen, 2010; Carvalho et al., 2013) which are not engaged with multiple plausible images of the future, we propose a more exploratory method which starts with scenario planning, making full use of all the stages of scenario development (Chermack, 2004a, 2004b). The roadmap is then developed based on the resulting scenarios.

Limitation 2. *insufficient guidance on how to build and integrate the scenarios within the technology foresight intervention.*

We have noted that, apart from methods which do not present a process for implementation (Phaal and Muller, 2009), some of the existing methods (Passey et al., 2006; Kajikawa et al., 2011; Saritas and Aylen, 2010) that combine technology roadmaps and scenario planning do not provide adequate explanation as to how scenarios should be built and be integrated with the roadmaps. As the last column of our summary Table 1 indicates, several of the methods (Passey et al., 2006; Abe et al., 2009; Gindy et al., 2008) have been customised for the needs of a specific intervention/industrial context.

Proposition 2. *provide clear and comprehensive description of the overall process, whose stages should not be context dependent.*

We propose that the combination of scenario planning and technology roadmapping follows the full process of intuitive logic models in order for the participants to: i) enhance their understanding of the future; ii) challenge their perceptions and strategic thinking; and iii) improving the quality of the decisions made (Wright et al., 2013b). The description on the resulting 'scenario-based roadmapping' method is generic but comprehensive, with certain choices that users face clearly highlighted.

Limitation 3. *short life span of foresight.*

Often, insights arising from roadmaps have a short life span (Phaal et al., 2005). Roadmaps tend to be produced as part of away-days or workshop interventions; they receive little attention after the event, and consequently they have limited impact in practice (Mietzner and Reger, 2005), especially in highly volatile and uncertain contexts. Yoon et al. (2008) highlight that regular updates of roadmaps are resource demanding and wearisome for participants. Moreover, it has been suggested (Abe et al., 2009; Carvalho et al., 2013) that technology roadmaps are difficult to use beyond the workshops where they were developed as they require regular revisiting to ensure the content and direction includes events or factors that were not in the original version. Our review of existing methods combining technology roadmaps and scenario planning showed that, apart from Strauss and Radnor (2004), no other method explicitly addresses how to make the roadmaps useful in the longer term.

Proposition 3. *include a mechanism for engaging with a technology roadmap after the intervention at which it was produced.*

To improve the usability of the technology roadmaps, a mechanism is needed to help managers connect the insights from an intervention with subsequent environmental developments. Strauss and Radnor (2004) developed 'flex points' for linking roadmaps and scenarios. We adopt their tool within scenario-based roadmapping, providing a type of strategic radar of the future (Schoemaker et al., 2013) to sense continuously emergent change in the environment (Day and Schoemaker, 2005; Haeckel, 2004).

To sum up, although previous attempts to combine technology roadmapping and scenario planning were a clear step forward, there are three limitations which, together, suggest a need and an opportunity for further development of the field. The scenario-driven roadmapping method set out in this paper specifically addresses each of these limitations. Next, an overview of the scenario-driven roadmapping method is provided and the three propositions presented above are elaborated to explain how our proposed method addresses the key limitations of past efforts to combine scenario planning and technology roadmapping. In part two of Section 3, each stage of the method is described in detail.

Table 1
Review of existing combined technology roadmapping and scenario planning methods and applications.

Name of method/author	Purpose	Process steps	Motivation	Limitations
Strauss and Radnor (2004)	A series of analyses to enable dynamic recognition of precisely where and how organisations are vulnerable to change.	15 step iterative process integrating the Scenario Planning Process as steps into a largely technology roadmapping based process.	More robust and dynamic product technology architectures designed to fit a range of quite different scenarios inclusive of 'flex points'.	This conceptual process does not explain fully how scenario planning is integrated with roadmapping. Also, scenario planning is taking place concurrently with roadmapping.
Pagani (2009)	For use in the 3G mobile TV industry.	Strategic thinking used in combination of scenario planning and technology roadmapping. Technology roadmapping activities as a foundation, then cross impact analysis scenario development. The outputs of these steps is then populated into a strategic thinking framework.	The limitations of technology roadmapping in assuming a straight line projection. The application in the 3G mobile service industry	This method is strongly linked to the context of application. Partial use of the scenario planning process for cross impact analysis.
Phaal et al. (2005)	Scenario planning can aid in understanding the uncertainty associated with the long-term aspect of roadmap.	Proposed integration of scenario planning to support the longer term aspects of roadmapping.	A conceptual recommendation to alleviate some of the limitations of deploying technology roadmapping as defined by existing literature at the time.	The procedure of the combination is not presented.
Passey et al. (2006)	Combining roadmapping with product concept visioning & scenario building to push boundaries of roadmapping for innovation in consumer electronic product concepts.	Customization of roadmaps to reflect purpose/setting	Identified specific roles an organisation could create to continue and drive further development unique to consumer electronic product concepts.	The process is customised to consumer electronic product concepts; the framework created is specific to the context of its application. Partial use of the scenario planning process.
Phaal and Muller (2009)	Presenting an architectural framework for technology road mapping	Describing how other forecasting techniques are complimentary to roadmapping but not discussing a process as such.	Other techniques being complimentary to technology roadmapping. In particular scenario planning aiding to understand uncertainties associated with futures.	This is a rather conceptual contribution which does not present the actual method.
Abe et al. (2009)	To create new business value and draw up a more reliable operational plan for the engineering and research sectors in Japan.	1st stage of scenario planning used to gain an understanding of the uncertainties in a given field. A combination of technology roadmapping and other business modelling techniques including aspects of scenario building.	To produce more persuasive business execution plans by integrating roadmapping with the business modelling methods and scenario planning to add an understanding of the macro environment.	Partial use of the scenario planning method. This process is highly customised to the engineering and R & D sectors in Japan and as a result not easily applicable to other settings/countries.
Gindy et al. (2008)	To enable companies to align their technology acquisition programmes to meet their business objectives.	Scenario Planning identified as a useful adjunct to national, international and industrial level roadmapping.	Commentary on how the current method utilised (STAR) would benefit from scenario planning by including consideration of extreme futures.	Scenario is treated as contingency planning with emphasis on extreme events.
Kajikawa et al. (2011)	Integrating risk analysis and scenario planning into technology roadmapping for the Japanese energy sector.	Proposing risk analysis and scenario planning as new components of the roadmapping process.	Limited functions of current technology roadmaps because of uncertainties embedded in the road map pathway not fully explored and lack of detailed narratives of the future(s).	Partial application of scenario planning, focusing on identifying uncertainties.
Saritas and Aylen (2010)	In the context of the clean production industry roadmaps are developed for specific technologies and scenarios are used to guide understanding of factors over the long term.	Scenarios and roadmap development together from the beginning	To develop a foresight method which utilises the pathway development strengths of technology roadmapping as well as the multiple future nature of scenario planning.	Lack of specificity on how scenarios and roadmaps are integrated.

3. Scenario-driven technology roadmapping: a conceptual method

3.1. Addressing past limitations

There is a tendency to use the terms: methods, models, frameworks and tools interchangeably. This paper focuses in the development of a method as the "*sequence of activities which aim at the development of specific results*" (Winter et al., 2009). Since visualisation is a powerful means of conveying ideas (Eppler and Burkhard, 2007) and making knowledge useful (Kress and van Leeuwen (1996), the process for developing scenario-driven roadmaps is presented in a clear sequence of activities, organised in two phases with eight stages, and represented schematically in Fig. 2.

There are two phases in the new method: i) intuitive logic scenario development; and ii) technology roadmapping based on the scenarios developed from phase one. Phase 2 includes identification of 'flex points' as a mechanism to connect developments in the external environment with the scenarios and the roadmaps. The two phases are strongly integrated as the scenarios, produced at the end of first phase, are the envisioned future used for the development of the roadmap and the identification of the 'flex points' in the second phase.

The first phase follows all the steps for developing scenarios and so takes advantage of the forward looking character of scenario planning and its consideration of the multiple images of the future (Chermack et al., 2005). A full, intuitive logics scenario planning process identifies uncertainties prior to developing detailed (Wright and Cairns, 2011), plausible scenarios. In scenario-driven roadmapping, foresight of the future should start with scenarios which explore the general environment affecting the technology. As discussed above scenario planning consists of scenarios development and strategy development based on scenarios (Tapinos, 2012; Wright et al., 2013b); this is the key break point in the use of scenario planning within the new method. As Chermack (2004a, 2004b, 2005) highlights it is essential that when scenario planning is utilised the intervention allows for 'learning' and development of 'mental maps' before 'decisions' are made. Thus, fully developed scenarios allow the participants of a technology roadmapping process to consider multiple futures when populating the roadmap. The new method therefore develops both multiple plausible scenarios and a detailed, complementary roadmap.

As part of phase two, the scenario-driven roadmapping method includes 'flex points' (Strauss and Radnor, 2004) to help relate potential developments over time in the general environment identified by the participants, to the roadmap they develop. 'Flex points' serve as critical indicators of key changes in the environment which would flag a transition in the likely technology trajectory towards one scenario or other. 'Flex points' allow for adjustments to be made in plans to fit a range of different scenarios (Strauss and Radnor, 2004). This becomes the basis for a flexible roadmap that would help indicate whether one of the scenarios is being realised over time, or which of the driving forces considered are more dominant over time. Ultimately, with the inclusion of 'flex points', we create a post-intervention 'compass' to monitor the environment similar to Schoemaker et al.'s (2013) 'strategic radars'. Through use of the 'flex point' approach, we seek to make the foresight developed during the workshop an integral part of everyday management; scenarios are not just 'free-floating' depictions of the future but are related to the present by prospective events. 'Flex points' provide a framework, or cues, for monitoring developments and critically assessing them with respect to the scenarios. 'Flex points' developed after a scenario planning exercise would take advantage of all the benefits of scenario thinking (Wright and Cairns, 2011). By first developing scenarios, as a distinct initial step, cognitive bias (Meissner and Wulf, 2013) in the identification of the 'flex points' can be minimized, and so improve the overall decision making (Chermack, 2005). The first layer of technology roadmapping is to establish an understanding of the

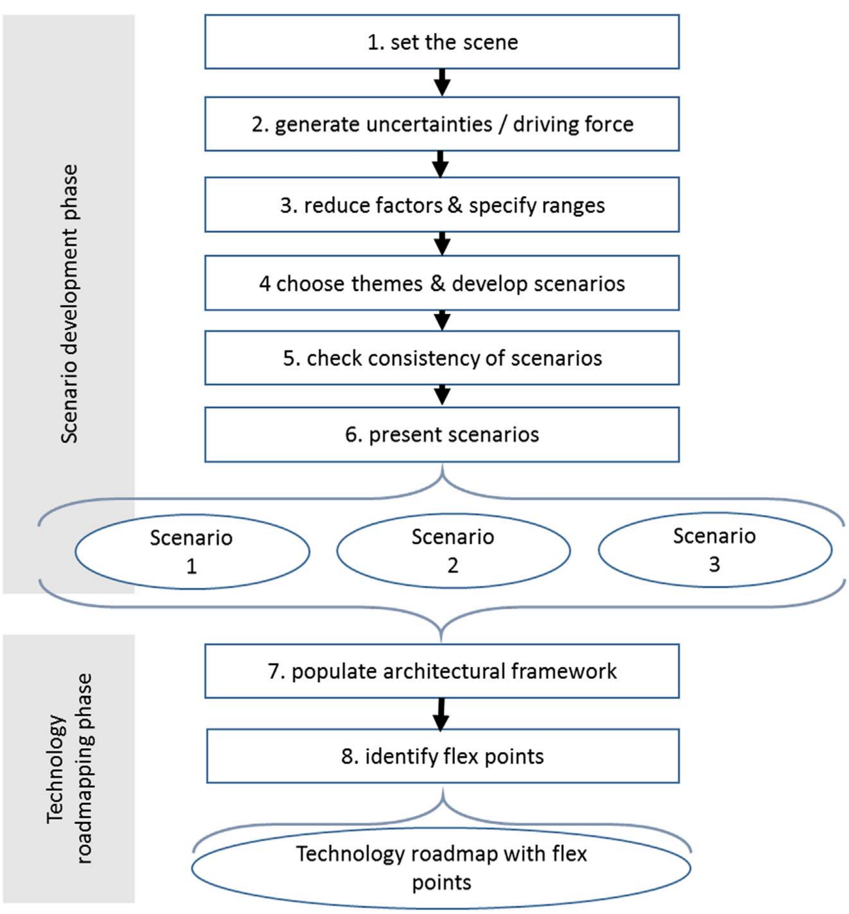

Fig. 2. Scenario Matrix 2.

external, general environment in which the organisation operates by assessing the trends, drivers and uncertainties that are important to the organisation. In this combined method, this information is already available as the outputs from the second and third stages of the scenario planning process, so time is saved in populating the first layer of the roadmap.

3.2. The eight stages of scenario-driven roadmapping

Analytically, the *first stage* of scenario-driven technology roadmapping is about setting the scene. This involves clarifying the purpose of the intervention (Ramírez and Wilkinson, 2014) by understanding the real need for this futuring study. It is important to establish the planning horizon for the scenarios. This stage can take place within a workshop, which should nevertheless be founded on some preparatory work (Van der Heijden, 2005) including interviews with the main stakeholders and, if possible, external actors with specialised knowledge.

In the *second* stage, the identification of key driving forces should follow scenario planning conventions (Wright and Cairns, 2011; O'Brien, 2004) using a PEST derivative to identify driving forces across the most important categories of the general environment.

In order to identify the key uncertainties for the development of the scenarios, in the *third* stage, in line with most 'intuitive logic' scenario development processes (Van der Heijden et al., 2002), we propose the use of the 'uncertainty/impact' matrix. If, in stage *four*, a deductive approach to scenario development is to be followed, then within stage three the potential lower and maximum values of each of the uncertainties would also be identified as advocated by O′Brien and colleagues (O'Brien, 2004; and O′Brien et al., 2007). In the stage of choosing the scenario themes (*fourth stage*), it is proposed that a first version of the scenarios is developed by identifying the potential value of each uncertainty within each scenario.

In the *fifth stage*, the consistency of the scenarios can be checked using cross impact analysis. According to Huss and Horton (1987), the orientation (positive/negative) and the strength (weak to strong) of the relationship between the uncertainties are examined, and then the consistency of values assigned in the previous stage are checked. If, in the *third stage*, an inductive approach is adopted then the *fourth and fifth stages* are unnecessary (see Ramírez and Wilkinson, 2014 for further information on the inductive approach).

The *sixth* stage of the scenario development phase consists of creating narratives of the future for each of the scenarios. There is plethora of options on how to express scenarios with narratives (Baungaard and Rasmussen, 2005; Ogilvy, 2011). We favour Baungaard and Rasmussen's (2005) advice to select the method that will resonate best with the users of the scenarios.

The *seventh* stage of the scenario-driven roadmapping process commences when the participants have familiarised themselves with the uncertainties of the future and alternative plausible scenarios developed in the previous stage. In this stage, participants switch to roadmapping related activities. For the construction of the technology roadmap, Phaal and Muller's (2009) five part framework (see Fig. 1) of external market/environment, internal business strategy, products/services, technology and resources, each part of which is considered over several time horizons, is used. The first part of the framework, the external market/environment factors, is provided by the outputs of scenario development exercise, and these therefore serve as the key link between the two phases. Within the scenario driven roadmapping method, participants engage in a systematic strategic conversation (Roubelat, 2007; van der Heijden, 1996) which prepares them more effectively for considering the future of a technology as explored in the roadmap (Phaal et al., 2004).

Stages two to six capture the driving forces and consider plausible images based on environmental uncertainties. The remaining three elements of Phaal and Muller's framework are populated through further discussions. Whereas technology roadmapping relies on deriving just a list of 'trends and drivers', a distinct benefit of scenario-driven roadmapping is that it offers a more detailed and systematic approach to make sense of the future based on the specific scenarios developed. The last activity (*stage eight*) is to identify the 'flex points', by considering potential key developments in the general environment at different periods up till the horizon set for the scenarios (Strauss and Radnor, 2004).

The scenario-driven roadmapping method proposes that only one technology roadmap be built for all scenarios, rather than a roadmap for each scenario. The rationale for this choice is that we do not treat the scenarios as probable outcomes/forecasts of the future but as plausible images which are used to enhance the ability of those involved to make sense of the future (Ramírez and Selin, 2014; Burt et al., 2006; Roubelat, 2007), appreciating the wider variety of driving forces and uncertainties that can create alternative future images.

Provided that the techniques align with intuitive logic perspective on scenario planning (Bradfield et al., 2005), there are several options for engaging stakeholders in scenario-driven roadmapping from workshops, through interviews, and even to online platforms. As with previous methods, there is scope for adapting the approach. Nevertheless, we acknowledge that participatory workshops support the development of shared mental models, improve sensemaking and enhance organisational learning (Chermack, 2005), and promote better connections between stages and thus better integration within the overall process.

In combining two foresight methods, this conceptual method mitigates the limitations of each approach when used separately, and integrates both the exploratory character of scenario planning and the normative orientation of technology roadmapping. The new conceptual method is based on an exploration of the general external environment and can potentially be used without company specific information. Thus it can be used in settings where collaboration across organisational boundaries is required, for example supply chain redesign, policy development networks or industries where technology foresight requires engagement from multiple stakeholders. On the other hand, if used by a single organisation, it can integrate foresight of the environment with technological foresight in order to provide the platform for an organisation to develop long term strategies.

In addition, our proposed method can be applied to both developing and emerging technologies. Thus, we consider that its application will be useful in settings where decision makers have to examine the challenges in the external environment in parallel with the anticipated benefits of an emerging technology whose adoption is faced with uncertainty.

4. Case vignette: scenario-driven technology roadmapping for RFID technology adoption in the NHS

4.1. Background

To develop our understanding of the practical application of the scenario-driven technology roadmapping process, and to critically reflect upon its implementation, we applied the method in a case study intervention with the GS1 Healthcare User Group (HUG). The GS1 HUG was established in 2009 by the United Kingdom's Department of Health to drive the adoption of Radio Frequency IDentification (RFID) technologies by co-ordinated effort across the English healthcare system. RFID technology has proven potential in healthcare settings in the areas of patient safety, reduction of errors, process efficiency, inventory management, tracking of mobile devices and information sharing throughout supply chains (Lee and Shim, 2007; Macario et al., 2006; Sheng et al., 2008; Tu et al., 2009; Tzeng et al., 2008; Varshney, 2007). There is a strong network effect with RFID which is central to its effectiveness and impact in healthcare management and supply management in healthcare settings. Take-up remains however very limited in scale and scope. Within the English NHS, there are many reasons for this, including localised decision making and limited funding, and a controversial history of major IT projects leading to a reluctance to invest in centralised projects (Robertson et al., 2010).

The primary function of the HUG is to promote RFID in operational areas of the NHS where the benefits of adopting the technology have been proven. A key aim of the GS1UK HUG is to ensure that the supporting systems have common data standards to enable information sharing between the individual RFID systems and (NHS) monitoring/performance management bodies.

HUG members were drawn from across the sector and include NHS, Department of Health, and standards experts, and representatives from the commercial healthcare products sector (devices, pharmaceuticals, etc.). As a standards body, GS1UK is closely connected to RFID technology providers, and other members of the HUG also link onwards to their respective communities. Though very knowledgeable and in a position to influence developments in RFID in the health sector over time, the HUG does not have a mandate nor funding to direct change. Rather its role is to shape, coordinate and orchestrate developments, and to facilitate system-wide learning from local initiatives. HUG members were therefore very interested in developing a long-term view of potential system level developments that would arise from highly distributed decision making across the many public and commercial actors in the health service network, in combination with external drivers in technology, healthcare demand and provision and public policy.

The whole intervention lasted 16 months. The scenario-driven roadmapping method was centred on three half-day workshops combined with multiple interviews before, after and between workshops. Participants came from a variety of organisations including four technology suppliers and three public sector institutions. The first author of this article conducted the interviews and facilitated the workshops. The co-authors attended as observers, taking notes, supporting data analysis, and critical evaluation of the method. Initial interviews were conducted with key stakeholders, to develop an in-depth understanding of the main drivers and inhibitors of the RFID technology adoption in the English NHS. Further contextual knowledge to support the facilitator's role was acquired through an extensive review of policy and academic literature on RFID adoption in healthcare nationally and internationally, and RFID in supply chain management in other sectors.

4.2. Scenario-driven technology roadmap development process

The intervention followed the conceptual method as described in Section 4.2. In the first stage, the participants were asked three questions that helped them realise the weaknesses of their current planning methods and the need for a futuring exercise: i) '*determine (roughly) the point in the future where existing knowledge cannot help us analyse the environment*'; ii) '*how far into the future are resources being committed?*'; and iii) '*when does the environment become uncertain?*'. Through a series of conversations, it was agreed that the appropriate purpose for the scenarios was: '*the future of RFID adoption in the context of the wider NHS*' and the planning horizon should be 15 years.

Using interviews for the second stage, 37 driving forces were identified, across the four categories of a PEST analysis (see Table 2). As it can be seen in Table 2, although a good number of forces was mentioned from each category of PEST, socio-cultural and technological forces were the most numerous. Next, a workshop was held with most of the participants at which, after a wider discussion of all the driving forces identified, the participants were asked to rank each of them on a 1 to 10 scale for importance and uncertainty. To avoid spending time to calculating scores (see Tapinos, 2013), we developed a basic online application, using google documents and excel to produce immediate results. The top twelve uncertainties, as ranked by the participants' scores are provided in Table 3. In the same workshop, the uncertainties' ranges were discussed and whenever it was difficult to select a figure for potential minimum and maximum, additional research was conducted after the workshop to fill in any missing figures.

The *fourth* stage took place in a series of workshops, in which the deductive approach for building the scenarios was followed, as described in Section 4.2. Five 2 × 2 matrices were built in the workshops, corresponding to 20 different scenarios (see Figs. 3–7 in Appendix A). In order to reduce the number of scenarios, the facilitator led discussions on how the world and the industry would look in each of the scenarios developed. At the end of each workshop the participants had to select one to take forward based on criteria of '*what seems more interesting, challenging, and worth exploring further*'. In the end, three scenarios were selected to be fully explored:

i) *IT has not saved NHS* (low level of capital budget to adapt new technologies/low level of quality online patient records);
ii) *the National Programme for IT worked* (high level of global technology regulations/high level of data standards across healthcare);
iii) *Great IT, poor public health* (high level of capital budget to adopt new technologies/low health of the population)

As advised in the literature (O'Brien et al., 2007), special care was taken to ensure that the three scenarios would be independent of each other. The narratives, though, were developed separately by the facilitator after the workshops. Scenarios were presented in a format derived from iHealth Insider (see Figs. 8–10), an online industry magazine with which all participants are familiar. The facilitator emailed the narratives to the participants as a means of preparing for the next stage.

A further series of workshops took place in the final phase, stages seven and eight as depicted in Fig. 2. Initially, the participants were encouraged to discuss scenarios and particularly their implications for society, industry and their organisations. Participants then explored the contents of the technology roadmap for the four categories of Internal Business Strategy, Products/Services/Systems, Technology and Resources, at four time intervals: years 1, 3, 10 and vision. The final stage was to identify 'flex points', which was done by discussing potential developments that would have a major impact on the evolution of the RFID technology. In total five 'flex points' were identified (see Table 5).

4.3. Reflections on the use of the scenario-driven technology roadmap method

Following Cairns et al. (2016), at each stage of the process, we captured both data to develop the scenarios and roadmapping, and participants' responses to and reflections on the process. In this section, we present reflections on the use of the scenario-driven technology roadmap following the sequence of activities undertaken. Early on there was some initial resistance to the 15-year planning horizon, as the rate of technology development is so rapid. One of the participants made a typical point: "*It is difficult to see past our current contracts of 1 to 3 years*". Nevertheless, when participants subsequently got involved in identifying driving forces they recognised the value of considering longer time horizons.

The stages and outputs that generated the most reflective discussion were stage 3 (reduce factors and specify ranges) and stage 6 (present scenarios). At the end of stage 3, the participants expressed surprise that they had managed to reach a mutually acceptable list of the most uncertain and important factors, despite being from different organisations with varying interests, expertise and views on the purpose of the scenarios and on the technology adoption in the NHS. One of the interviewees commented: "*it is so interesting to see everyone's identified uncertainties. We have not mapped out these as a User Group before*". The same interviewee commented that the scenario planning exercise gave a different perspective in discussions of the future of RFID technology.

The participants liked the scenarios being expressed in narratives and the medium chosen (iHealth insider format) made them very realistic. The participants commented positively on the plausibility of all scenarios and how useful they were for their activities and purpose of the HUG. As one of the participants noted during the presentation of the

Table 2
Driving forces for the future of RFID technology adoption in the NHS.

Political	Economic	Socio-cultural	Technological
Level of rationed healthcare	Level of availability of energy resources	Migration of people from different parts of the world	Level of quality online patient records
Stability of world peace	Level of privatization of healthcare	Level of population growth	Virtualization of healthcare
Biological effects of nuclear war	Security in assets (housing)	People take more interest in their healthcare: visibility, self-prescription etc.	Quicker paradigm shifts (e.g., information in books and knowledge to information on the internet)
Religious uprising	Level of privatization	Understanding of RFID amongst the general public	Healthcare records stored on person
Sharing of public health information	Level of security of major technology providers	Comfort with technology of the general public	Impact of cyber attacks
Level of importance placed on global data standards	Fluctuations in exchange rate.	Level of care expected	Level of capability of RFID technology
Level of global technology regulations	Level of capital budget to adopt new technologies for NHS hospitals	Comfort of having healthcare records online	Level of shared data standards
Change of lead political party		Level of reliance on tele-health	Level of quality patient records
		Health of the population in terms of obesity, mental health, aging issues	Change in coding structure
			Greater availability of RFID technologies due to increased competition
			Level of sharing of established processes from other industries e.g. warehouse management, pharmaceutical supply chains
			Global adoption of the same data standards across healthcare
			Fluctuations in technology regulation

Table 3
uncertainties selected for the future of the RFID technology adoption in the NHS.

Uncertainty	PEST category
Level of rationed healthcare	Political
Level of 'capital' budget to adopt new technologies for NHS hospitals	Economic
Health of the population in terms of obesity, mental health, aging issues	Socio-cultural
Level of availability of energy resources	Economic
Level of quality online patient records	Technological
Level of privatization of healthcare services	Political
Migration of people from different parts of the world	Socio-cultural
Level of global technology regulations	Technological
Level of care expected	Socio-cultural
Cyber attacks	Technological
Global adoption of the same data standards across healthcare	Technological
Fluctuations in technology regulation	Technological

scenarios, "*this scenario seems very much like the way it might go but we hadn't thought about it over the longer time frames we are discussing now*". However, participants also expressed some concerns: upon the presentations of the narratives the participants commented that they felt that the scenarios "*were floating*", and they asked "*where do we go from here?*". These concerns were addressed in the second phase of the intervention centred on roadmapping.

The second phase began with a general discussion of the scenarios produced in phase one. The participants had received the narratives in advance, and so had the opportunity to reflect on the scenarios' implications for the future of the technology, industry and their own organisations. For the development of the technology roadmap, following Fig. 2, we asked the participants to discuss what kind of strategies the HUG should develop in the four different planning horizons (years 1, 3, 10 and vision) to better align with each of the futures described in the scenarios.

RFID technology is a family of inter-related products, and RFID systems have multiple applications in healthcare. Therefore, in this case, the use of scenario-driven roadmapping concerns technology foresight for the deployment of RFID applications across the healthcare system, rather than the adoption of a single product. According to Lee and Park's (2005) roadmap topology, this is a 'technology portfolio map': the foresight developed for RFID technology in healthcare is more a portfolio of applications in given settings, rather than setting out a development plan for an individual product. So, in Fig. 2, the rows which concern 'Products/Services/Systems' and 'Technology' capture the general applications of RFID technology in healthcare and the input of the participants indicating that the NHS is anticipated to move towards '*paperless operations*' and '*automated processes*', while at the same time there is the anticipation that '*home monitoring*' is a key area for the deployment of RFID.

In discussing inputs for the '10 years' and 'Vision' aspects of the roadmap, one senior NHS manager commented '*if RFID technologies can be integrated into home monitoring devices, then much of the data required to monitor patients would not need to be collected within the hospital environment which will lead to cost savings and comfort*'. This was complemented by an example of a potential specific use of RFID technology made by one of the technology suppliers "*instead of taking the blood pressure, temperature, heart rate and environment factors like natural light and humidity separately, they would be all measured with one RFID enabled device*".

Even though the purpose of the intervention was to develop technology foresight and a technology roadmap for RFID technology across the NHS, participants naturally tended to focus their thinking on what

Fig. 8. Narrative for scenario "IT has not saved the NHS".

their own organisations should do, as illustrated by this quote from a HUG member from the private sector: "*I can see how the business planning is not relevant to my organisation but the resources section is very insightful […] the resources tells us what kind of expertise we would need for the future*". Interpreting uncertainty and producing foresight tends to be strongly linked to perceived scope for, and planning of, action. Stage 7, in which the roadmap was populated, was critical in integrating phases one and two of the scenario driven roadmapping method, as the participants engaged in discussions on the implications of the scenarios for the NHS, in terms of products, services and systems.

Subsequently, the participants discussed future technological needs within each scenario. A typical comment, from a pharmaceutical appliance company participant, referred to the technology element of roadmapping: "[it] *gives an insight to the kind of technology that the NHS may be using the future and it gives us an indicator of which technologies we need to develop*". Similarly, a senior manager from the NHS added: "*for example to the scenario with the screening programmes are really successful the technology for the screening programmes needs to be cheap and widely available, […] easy to use that nurses can use it and not only doctors*". These quotes are examples of many comments made by participants which, taken together, provide strong evidence of effective integration between the two phases — scenario development and technology roadmapping. Through their discussions and given the time they had between stages to reflect on outputs, we observed how the scenarios influenced their thinking, underpinning their developing arguments about the future of RFID in the NHS and their own organisation's role within that.

As HUG members, workshop participants commented both as representatives of their respective employing organisations and as sector experts with a system-wide perspective. This dual perspective was

Fig. 9. Narrative for scenario “If the National Programme for IT worked!”.

important and actively exploited. For each element of the technology roadmap a separate discussion was conducted for the different planning horizons (see Table 4). This part of the process was much praised by participants as it helped them create mental models of the pathways to each scenario. Related to this point, one of the participants from the NHS observed: “*for me, if centralised funding does not occur in the next 5 years, for the screening programmes, then NHS trusts would have to pay it by themselves which means that not everyone would be able to have it and therefore this scenario is unlikely to happen*”.

The identification of ‘flex points’ – an important and innovative aspect of scenario-driven roadmapping – started from posing the basic question: ‘*what would need to happen for each scenario to take place?*’. In the discussions which followed, we noted participants' references to key factors that would signal environmental developments in the direction of each of the scenarios (see Table 5). These ‘flex points’ are significant changes or events between the present and 15 years into the future. At the end of the process, we contrasted the ‘flex points’ with the uncertainties identified in stage 2. We observed that the ‘flex points’ were closely aligned to the driving forces of the scenarios. This is further evidence that the different stages of the scenario-driven roadmapping process and their outputs were effectively integrated. Comparing drivers (stage 2) and ‘flex points’ (stage 8) provides a useful check for internal consistency over the duration of the intervention, which is particularly valuable in cases like ours where the whole process takes several months. Conversely, inconsistencies would help to flag significant shifts in participants' understanding of their context and expectations of the future, for follow-up as part of the intervention.

The final interaction with study participants took place approximately 12 months after scenario development. At this meeting, the longer term relevance and impact of the scenarios on their respective

Fig. 10. Narrative for scenario: "Great IT, poor public health".

organisations was discussed. Some participants commented that, following their experience in the RFID intervention, they had brought the language of scenario planning into their organisations: they started discussing longer term planning; there were strategic conversations around future uncertainties; the three scenarios influenced their thinking about the future. For example, one of the leading figures from the HUG said: "*terms like planning horizons and external uncertainties were not in their planning conversations or any conversations about what the future would look like […] those are now helping us to consider wider elements [of influence]*". In addition, the discussion regarding 'home monitoring' (see Fig. 2) applications sparked a conversation regarding the standardization of technology and the costs of monitoring applications for patients at home. Two important comments were made, firstly as indicated by an NHS manager "*the* 'Mandate IT standards by DoH' *is an essential development for the industry*", while a manager from a technology supplier company indicated that everything depends on "*centralised funding* [for NHS]" (the first 'flex point') and "*provision of central funding for IT projects*" (the third 'flex point').

The technology roadmapping stages also proved valuable; participants said this phase helped them better understand the potential impact of each scenario on RFID adoption. One of the NHS managers admitted that "*when you showed us the scenarios I was not sure how to use them […] the discussion for the roadmap made a lot of sense to me*". In particular, they found that the identification and discussion of 'flex points' made them reflect on the scenarios more deeply, and consider potential pathways towards each scenario. One of the participants from the private sector highlighted that "*everybody is so busy with their work* [too much so to frequently revisit the roadmaps] *but I can see how these* [the 'flex points'] *can make you think about the scenarios and the future regularly, particularly with the recent changes* [referring to Health and

Table 4
Technology roadmap for RFID adoption in the NHS.

External	Year 1	Year 3	Year 10	Vision Scenarios
Internal business strategy	DoH/NHS England gains mandating rights and takes the lead Working with large, successful customer information organisations (i.e. IBM) Define what the NHS is actually responsible for? I.e. public health, physiotherapy. Satellite public health issues. Policy level change	Health assessment and screening programs to be a priority for the NHS agenda Qualified persons making decisions Planning for the healthcare system over a longer term than the current election cycle	Rationing/sharing a budget for each person of healthcare costs Centralisation enabled on decisions of all aspects of the healthcare system. Local requests can be assessed by DoH	A singular decision making process Mandated IT standards by DoH
Products/services/ systems	Relevant stakeholders informed of centralised system change. Roadmaps produced to bring clarity for the path to centralisation	Pre-emptive screening for major diseases Delicate balance in broad brush/highly targeted screening Central systems available with multiple interfaces depending on type of person/organisations using the system Centrally developed database for identification of products and shared standards between proprietary systems	Pre-emptive screening for major diseases Centrally governed systems. Migration systems for paper Policy level change implemented by systems Working with stakeholders on technology and information standards	Getting away from any paper processing Product identification/information management systems shared by the healthcare industry
Technology		Home monitoring Further papers for stakeholders of specifics of technology. Central systems available with multiple interfaces depending on type of person/organisations using the system	Home monitoring	Home monitoring Visibility to the general public of episodes of care i.e. audit tools Technology products and systems guided by the (reactive development of systems)
Resources	Subject matter expertise, not clinical leads dealing with other aspects such as information standards Technology capability assessment projects Applied product development research	Industry led tech project but with health service collaboration Contracts with multi-purpose interface system providers. Working level staff involved with the design of the system. Decision making staff decide which staff members require access to which interface.	Industry led tech but with health service collaboration	Industry led tech but with health service collaboration Working with similar stakeholders to today but with more use groups

Table 5
'Flex points' for RFID adoption in the NHS.

'Flex points'	Time frame (years)
If centralised funding does not occur	0-5
If health screening programs are not implemented	0-10
The provision of Central funding for IT projects	0-5
If health screening programs are implemented too late	10-50
If decision makers are not adequate for the job	0-5

Social Care Act, affecting home care]". Thus, the technology roadmap workshops were critical to help participants to make better sense of the scenarios.

Overall, within the period of our engagement with the HUG, the evidence from this intervention demonstrates that the implementation of the new method of scenario-driven technology roadmapping was effective. The process allowed participants to develop and make use of three scenarios as platforms to develop a technology roadmap with integrated 'flex points' for RFID in the NHS. The eight stages of the method are highly complementary and mutually reinforcing. The systematic and highly participative development and use of scenarios led the participants to reflect carefully on the driving forces for the future and realise how these could create plausible alternative scenarios. Making sense of how the future of the RFID technology in the NHS could unfold helped them to think of how to position their organisations for the future. Roadmapping activities led to making sense of the future via the scenarios. The scenarios and roadmap support their joint, system-level strategizing and their work within their employing organisations.

5. Conclusions

This paper introduces scenario-driven roadmapping, a method that blends scenario planning for the development of alternative plausible future states at the general level with technology roadmapping for the development of strategies for specific technologies. The review of previous efforts to combine scenario planning and technology roadmapping reveals three key limitations, for each of which we propose a response. These propositions are integral to the design of scenario-driven roadmapping. In previous combinations, the use of scenario planning activities was limited, typically being used to develop insights into key uncertainties and environmental drivers rather than full scenarios, to inform a technology roadmapping exercise. Technology roadmapping was the dominant part of the foresight exercise, with the primary purpose being to produce a roadmap, rather than scenarios. This approach is valuable. It is directed at mitigating one of the drawbacks of 'pure' technology roadmapping in that the inclusion of future uncertainties enable the roadmap developers to use a longer timescale.

Also, the review showed that some of these combinations were (necessarily) highly customised to the setting, therefore severely limiting scope for application to other settings. Saritas and Aylen's (2010) application is more detailed than most. The level of detail and complexity of the relationship between scenario planning and technology roadmapping is much greater in Saritas and Aylen's approach than ours. This reflects the different goals and perspectives of the two illustrative interventions, with one aimed at producing detailed roadmapping to direct research priorities and funding, and the other to provide a common platform for sensemaking (Ramírez and Wilkinson, 2014) and coordination which gives equal weight to the scenario planning and roadmapping phases and outputs.

Effective integration of the first and second phases of scenario-driven roadmapping is an essential aspect of the design. Within the eight stage process, there are several mechanisms to ensure close integration. The process takes place in multiple meetings over several months. Participants revisit the scenarios, first individually then in a group discussion as the first step in the roadmapping phase. Identifying 'flex-points' helps participants reconnect to the scenarios. We see 'flex points' as critical (changes in) conditions or events which signal an important transition point and radical change within, or a shift between, trajectories towards scenarios (or even, potentially, the redundancy of the current scenarios). Such 'flex points' may be externally determined and imposed upon the system, but may also be shaped or influenced from within the system either in a directed or more emergent fashion (e.g. step changes in local investment patterns; see Table 5). Furthermore, the responses to change are not a singular strategy as implied by Strauss and Radnor's definitions (see Table 4). Participants' reflections show they appreciated the discussions about 'flex points'; when we met them 12 months after the intervention, they discussed how these had been integrated into their strategic thinking.

The scenario-driven roadmapping method presented in this article seeks to address the calls in the literature (Porter et al., 2004) for multi-method approaches which complement each other. According to Magruk's (2011) ten classes of technology foresight methods, our method falls in the 'strategic' class as, through its application, participants develop an '*evidence-based cognitive*' understanding (ibid) about the future of the technology under examination. Also, considering Saritas and Aylen's (2010) classification for foresight methods, the method developed and tested in this paper spans across four of its categories. 'Understanding' is achieved with scenario planning activities, while the remaining stages of scenario-driven roadmapping map onto 'synthesis and modelling' of the perceptions on the external environment in order to 'analyse and select' the scenarios that help organisational and managerial decision making. Moreover the roadmapping elements of the model provide the opportunity for 'transformation and action'. Finally, in comparison to Georghiou's (2008) diamond our method is one of the few in the field that combines 'expertise' and 'creativity'.

Applying this method in a case study foresight intervention, we observed that it offers a number of distinct advantages. It establishes that scenario planning can be used in interorganisational settings. Its combination with technology roadmapping however extends scenario planning's applicability to policy oriented interventions (Cairns et al., 2013). Furthermore, the integration of 'flex points' extends insights developed through technology roadmapping allowing for a flexible roadmap which could serve as a strategic 'radar' that can be used long after workshops are completed, making the foresight exercise a part of managerial decision making (Sarpong et al., 2013).

We acknowledge that our method has been applied to only one case with particular contextual characteristics. We call for more researchers and practitioners to engage with technology foresight by starting with a comprehensive approach to scenario development and then using roadmapping. Its value to the group of RFID experts participating in the intervention reported here suggests that it would be particularly worth exploring the application of scenario-driven roadmapping in other settings where participants represent multiple constituencies, organisations, sectors and disciplines but share a common interest in the adoption of an innovative technology.

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Appendix A

Level of Privatization of Services / Health of the Population	
LOW/HIGH	HIGH/HIGH
- Less use of national standards	- Privatization creates a System based on business need not care based need
LOW/LOW	HIGH/LOW
- Private healthcare is not better - Timely Services	- Government not popular due to dismantling the NHS - Privatized too quickly

Fig. 3. Scenario Matrix 3.

Level of Capital Budget to adapt new Technologies / Level of quality Online Patient records	
LOW/HIGH	HIGH/HIGH
Redirection of existing resources where there is patient ownership of health records Money is an incentive for adoption Islands of information/system quality but still disjointed Lots of data but very little useful information Quality data is only in pockets	More individual ownership Healthcare provided on basis of lifestyle choices Well trained population Electronic records problem solved Greater capability of what you can do with the information gathered
LOW/LOW	HIGH/LOW
Only privately paying patients receive high levels of healthcare Government not popular at all but not plausible	Information gathering more towards what manufacturers/distributors want Information collected for the facilitation of business Healthcare becomes no longer free at the point of use Poor system management due to lack of mandating

Fig. 4. Scenario Matrix 4.

Level of Care Expected / Level of Privatization of Healthcare Services	
LOW/HIGH	HIGH/HIGH
Expectation increasing with better healthcare as in history = Healthcare improves=expectations improve End of life care to be better	Expectations remains high What people want now Limitations on health tourists
LOW/LOW	HIGH/LOW
Implausible	Health services there to make a profit and not care driven. Still has the NHS name, may well be provided by the private sector but paid for by the NHS. Expectation still very high

Fig. 5. Scenario Matrix 5.

Uncertainties to be Combined: Level of Capital Budget to adopt new technology/Health of the population	
LOW/HIGH	HIGH/HIGH
Prevention Schemes to adapt new technology Screening for quality life issues not just end of life issues Faster intervention Assisted Suicide technology if patient health records exist to a high enough level of detail Wellbeing educational programs Incentivized healthcare programs	More technology driven health assessment Interactive care of aging population Monitoring of health Prevention Schemes to adapt new technology Screening for quality life issues not just end of life issues Faster intervention
LOW/LOW	HIGH/LOW
Greater amount of deaths at a younger age Greater need for healthcare for those who are alive Reactive as opposed to proactive healthcare Higher stress levels Greater susceptibility to postcode lottery Downward spiral; risk of increased substance abuse	Class divides Talent skills divide Health is pushed but sports Active lifestyle Low cost sporting activities Competitive pricing for healthy food Supply and demand of healthy food Personal responsibility Taxes on processed food

Fig. 6. Phaal and Muller's (2009) technology roadmapping framework.

Uncertainties to be Combined: Level of global technology regulations/Global adoption of the same data standards across healthcare	
LOW/HIGH	HIGH/HIGH
Continental data standards with no alignment to exploit the shared data standards Legislation restricts technology data standards Industry lead adoption of one data standardization system Language barriers for usage of healthcare practitioners	Traceability of products in healthcare Electronically enabled traceability accountability Greater visibility over multiple systems and platforms Standard information available High quality master data product information
LOW/LOW	HIGH/LOW
No standard information requirements Restricted flow of information Stifles innovation	Regional adoption Data migration issues Sub optimal use of technology Costly workarounds for industry Knock on cost of potential treatments Lack of innovation Lack of speed to market Lack of traceability accountability visibility

Fig. 7. Stages and outputs of scenario-driven roadmapping.

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