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Smart roadmapping for STI policy

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ABSTRACT

Roadmapping is a broadly applied management instrument for developing and implementing company technology and innovation strategies. During the last years this national science, technology and innovation (STI) policy makers have become aware of the potential roadmapping offers for strategic technology and innovation management and begun applying it in the context of STI policy and priority setting in this context especially. Still reality shows that roadmapping for STI policy purposes is by far more complex than company technology and innovation roadmapping.

The article therefore develops a structured, integrated and flexible approach to roadmapping for STI policy which we name "Smart Roadmapping for STI Policy", taking into account the complexity of STI policy as well as the need for and implications of a Targeted Open Innovation approach to STI policy and the resulting requirements to roadmaps. The proposed approach is designed to allow integration in the broader policy decision making and different level STI strategy implementation.

1. Introduction

The survival and prosperity of nations and societies alike is increasingly becoming dependent on the quality, scope, nature, dynamics, and adaptability of local and global concentrations and combinations of knowledge and the way these are interconnected and leveraged in the form of new and sustainable technology ventures. Often national system of innovation resemble more archipelagos of islands of excellence and less of a strategically integrated, multi-layered, multi-modal, and multi-nodal knowledge grid. Such fragmentation results in substantial added value that is not being captured and value-adding potential not being realized in the context of the national science, innovation and technology enterprise. This is further exacerbated by the nature of science, research and innovation being highly inter-connected and non-linear as well as increasingly cross-disciplinary. Private and public sector competitiveness and regional economic development strategies have increasingly focused on issues under the classification of innovation networks and knowledge clusters and the building of stronger resources, linkages and networks frequently themed as public–private partnerships. Such innovation modalities consist of a critical mass of local knowledge, expertise, personnel, and resources grouped together by related technologies and may include researchers, collaborators, competitors, partners, and other supply chain members within related technologies.

In response to these developments, many organizations now support and conduct roadmapping exercises. Developed and advertised by companies and consultants as a strategic process of handling the effect and response uncertainty of technology and social drivers of change, organizations are frequently called upon to integrate these exercises into their organizational and strategy processes.

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 (Albright and Kappel, 2003; Daim and Terry, 2008; Holmes and Ferrill, 2005; Lee et al., 2007, 2009a, 2009b; Kim et al., 2009). In essence, these roadmaps target mainly at products/markets or technologies. However, roadmapping practice shows that there is an insufficient consideration of future market requirements, customers'behavior and preferences and the consideration of the resource basis for satisfying market needs is lacking (Carayannis et al., 2015; Khripunova et al., 2014; Meissner, 2013; Vishnevskiy et al., 2015b).

In the last decade, the value of roadmaps was also recognized by science, technology and innovation (STI) policy decision makers at different levels. Roadmaps are oftentimes used to support the implementation of STI strategies which are developed by policy makers with the aim to maintain and/or improve the STI performance of whole countries and to develop the underlying STI infrastructure to prepare countries for

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the future (Gackstatter et al., 2014; Gokhberg, Meissner, 2013). However using roadmapping for STI policy is a very difficult and ambitious task, especially because it applies to both R&D and innovation practices and policies. Hence, the major challenge for roadmapping STI policies lies with the development of feasible policy actions and instruments, e.g. the translation into proposals for political practices but less with the integration of different methods for roadmap development (Dettmann et al., 2014; Mikova and Sokolova, 2014). Moreover, roadmaps for STI policy need to highlight the causalities and dependencies between different policy instruments at horizontal level and consider the vertical level, e.g. national (federal) policies in the context of regional policy ambitions and measures. Thus, the STI policy mix faces 2 main challenges in the design phase already: 1) alignment of STI policy instruments horizontally within the overall policy mix and 2) alignment vertically with regional policy instruments (Gokhberg et al., 2014). Overarching these two major challenges remains the implementation of policy instruments which is frequently causing additional efforts and complementary measures (Cervantes, Meissner, 2014; Meissner et al., 2013a, 2013b; Rodriguez and Paredes, 2015).

While maintaining and potentially reshaping the STI policy mix it's crucial to consider the path dependency and causality between different STI policy instruments and measures, e.g. undertaking ex-ante assessment of the potential impact of the measures not only on the national and institutional STI performance but also on the policy mix overall (Meissner and Sokolov, 2013). Accordingly, the composition of STI policy roadmaps requires stronger and more complex cross impact analysis of STI policy instruments in light of the STI policy mix (Kindras et al., 2014; Meissner, 2012, 2014). STI Policy roadmaps per se should aim at the development of the national STI system if initiated by national or regional governments, e.g. at the national or regional NIS as a whole instead of selected technologies/products or the like. This implies that the analysis of the respective STI policy mix only isn't sufficient, instead it needs to be complemented by analysis of actors responsible for policy instrument (Meissner, 2015a, Meissner, 2015b). Actors' responsibility includes development and also implementation of policy instrument (Drilhon, 1991; Proskuryakova et al., 2015).

Given this background the need arises to conceptualize the architecture and modalities of roadmaps for STI policy. The paper therefore considers the following research questions:

- Which features make STI policy roadmaps different from standard roadmaps?
- What is the impact of technology learning on roadmapping?
- How do STI policy roadmaps interact with STI policy?

The paper proceeds as follows. The first section drafts an approach towards developing STI policy roadmaps. Then we discuss the meaning of learning for roadmapping and conclude with a discussion of roadmaps for STI policy.

2. Smart roadmapping architectures and modalities

While it is widely acknowledged that this delivers value to strategic planning for corporations, national STI policy makers are challenged to elaborate solid basis of information which form the base of roadmaps, shape and forms of these to ease integration in the operational activities, e.g. the implementation and all related adaptive and absorptive capacities needed coupled with approaches to education and training for technology related learning. Smart roadmapping for STI policy incorporates macro, meso micro level data, information and knowledge analytics as well as higher order learning competences (learning, learning-to-learn and learning-to-learn-how-to-learn) to ensure best possible results in dealing with high levels of risk, uncertainty and complexity and in anticipating discontinuous innovations and leveraging technological disruptions to the technology lifecycle (Albright, 2006). It turns out that the implementation, hence the eventual impact of roadmaps, is determined by the commitment of actors affected by the roadmaps in any shape. Accordingly, there is an evident need to involve the respective number of stakeholders already in the roadmap development stage which is reasonable higher than for targeted small scale roadmaps as it's the case for industry applications (Vishnevskiy et al., 2015a). Moreover, in light of the broad range of STI policy instruments numerous policy relevant institutions are involved which are typically embedded in different institutional setups with diverging motivations and interests. The latter become crucial when it comes to implementing policy measures to achieve impact at national level still the challenge remains to identify the roadmap priorities and the competences needed to develop and implement them. Accordingly STI policy roadmap needs to fulfill three different functions:

- diagnosis/modeling/intelligence
- regional, governmental policy formulation support
- implementation guideline

The *diagnosis/modeling/intelligence function* of roadmaps provides a structured systematic analysis of the suitability and usefulness of the existing STI policy mix and its appropriateness to the special features and characteristics of the respective NIS. It also contributes a set of missions that will afterwards determine priority policy measures. The process of goals definition can be a case of setting mission-oriented priorities or they can be imposed externally. In addition, this function gives an indication about policy measures and initiatives developed and implemented by other countries. *Supporting the formulation* of policy is another function of roadmaps which results from the structures of roadmaps including milestones and related activities. Finally, action plans which complement roadmaps are helpful *guidelines for implementing* policy measures.

From this broad range of roadmap functions, it turns out that there is an obvious need to split policy roadmaps into more specialized dedicated roadmaps in order to make roadmaps feasible and implementable (Fig. 1).

In order to bringing the different dimensions and aspects together, three types of roadmaps for STI policy are proposed: 1) a roadmap clearly dedicated to the STI policy mix assessment and design (STIPMAD) which should establish a continuous policy mix assessment procedure; 2) a roadmap aiming at the actual policy instruments implementation and monitoring (PIIM) and 3) an overarching roadmap for supporting the STI policy mix management (STIPM). The latter integrates the core aspects resulting from STIPMAD and PIIM and sets milestones which give a clear guideline for policy mix management.

The STIPMAD roadmap is developed from a range of activities involving *stock taking* of existing policy instrument with relevance to the STI policy mix and respective initial assessment of the overall mix. Although the STI policy mix has been a frequently discussed and used term, it is not clearly defined and lacks a common understanding among politicians and academics. Furthermore, it can be assumed that the actual STI policy mix is composed differently in different countries where the special national characteristics and features are taken into account. Therefore, it's essential to include a stock taking exercise in the policy roadmapping and complement this with initial *assessment*. The assessment then also includes an evaluation of the path dependencies and the causalities between different STI policy instruments and an analysis of the complementarities of policy measures and legal frameworks in light of the policy mix. It also helps to evaluate and estimate the necessary and available resources (finance, human resources, infrastructure, etc.) for STI policy measures implementation.

Furthermore, it's appropriate to assess the meaning and importance of the STI policy mix in the light of national policy priorities overall (Cervantes and Meissner, 2014). Based on these initial activities, *Foresight* is done which results in possible development scenarios of the