Smart roadmapping for STI policy

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A B S T R A C T
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.

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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 systems 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., 2015). 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...
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 dependen-
cies between different policy instruments at horizontal level and con-
sider 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 assess-
ment 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 pol-
cy 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 re-
gegional governments, e.g. at the national or regional NIS as a whole in-
stead 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
(Drillon, 1991; Proskuryakova et al., 2015).

Given this background the need arises to conceptualize the architec-
ture and modalities of roadmaps for STI policy. The paper therefore con-
siders 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 capaci-
ties needed coupled with approaches to education and training for tech-
nology 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 antic-
pating discontinuous innovations and leveraging technological disrup-
tions 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. Ac-
cordingly, there is an evident need to involve the respective number of
stakeholders already in the roadmap development stage which is rea-
sonal 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 insti-
tutional 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 im-
plement them. Accordingly STI policy roadmap needs to fulfill three dif-
frent 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 struc-
tures of roadmaps including milestones and related activities. Final-
ly, 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 dedicat-
ed 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 clear-
ly 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 in-
volving stock taking of existing policy instrument with relevance to the
STI policy mix and respective initial assessment of the overall mix. Al-
though 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 ac-
count. 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 frame-
works in light of the policy mix. It also helps to evaluate and estimate
the necessary and available resources (finance, human resources, infra-
structure, 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, Fore-
sight is done which results in possible development scenarios of the
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