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The role of the duraBASt research facility in an innovation ecosystem: An innovation management portfolio analysis

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Abstract

In order to facilitate innovation in the road construction sector the German Federal Highway Research Institute (BASt) has set up in 2017 an external demonstration, investigation and reference area, the duraBASt. Investigation fields and demonstrators enable realistic tests on a scale of 1:1. The aim of this unique research facility is to significantly shorten the time required from the idea of an innovation to its standard application. The duraBASt also fills the gap between small scale research in a laboratory and the very complex process of setting up a test track on the road network. In order to improve the future selection of research projects on the duraBASt an innovation management portfolio analysis was conducted to analyse the research projects that were completed on the duraBASt. This paper shows the results of this analysis and provides recommendation how research projects can be evaluated on their innovation characteristics.

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1. Background

Innovations in the road construction sector are key to tackling the major challenges that the transport infrastructure sector is currently facing. Current issues include, among others, traffic efficiency, road safety, environmental protection, climate change mitigation and effective energy conservation (BMVBS, 2013). Innovations in the road infrastructure, a public good, offer the potential of a "double dividend". Effective controlling of innovation activities generates positive economic and macroeconomic effects (employment, growth, competitiveness) as well as positive ecological and social effects (environmental protection, energy efficiency, improved working conditions). However, innovation dynamics in the road construction sector are limited and a systematic approach in evaluating and steering innovations is lacking. It is criticized by all actors within the sector that often decades pass before new solutions are tested and finally standardised. Especially in a sector such as road construction, which is highly regulated and characterised by a monopsonistic market structure, there is a latent danger that the innovation ecosystem will continue to stagnate and chances for trying out innovations will be missed.

2. Fostering an innovation ecosystem in the road construction sector: duraBASt

In order to facilitate innovation in the road construction sector the German Federal Highway Research Institute (BASt) has set up in 2017 an external demonstration, investigation and reference area, the duraBASt. Investigation fields and demonstrators enable realistic tests on a scale of 1:1. New construction material mixtures, building methods or building processes are tested for their durability through processes like accelerated pavement testing. The aim of this unique research facility is to significantly shorten the time required from the idea of an innovation to its standard application. The duraBASt also fills the gap between small scale research in a laboratory and the very complex process of setting up a test track on the road network.

During the period 2017-2018 the first tranche of eight research and innovation projects[†] were successfully completed: HEALROAD, SEDa, Sealing of drill core extraction points, OPB - Porous Concrete, Precast Concrete Parts, OPA - Porous Asphalt, Inno-Pave and OBAS - optimized screed with a material transfer system for chippings. The research activities were thoroughly evaluated on the technical feasibility (for example, Wacker and Jansen, 2018) and for some projects an economic evaluation (e.g. life-cycle-cost analysis) was conducted (Wacker, Panwinkler and Hoeller, 2019). However, none of the projects that were completed on the duraBASt were assessed nor evaluated according to criteria to measure their innovation characteristics and their position in the innovation ecosystem of the duraBASt.

The duraBASt research facility is now entering into the second tranche of research and innovation projects. Based on the successful initial research and innovation projects the request for using the duraBASt research facility has increased significantly, which means that a more thorough evaluation process for admitting research and innovation projects onto the limited space of the test facility needs to be conducted. Key to the selection process would be to identify research and innovation projects with high potential to innovate, but to keep a balance between projects with different technology readiness levels (TRL). Further, the selection process should avoid false positives (a project that appears to be innovative, but at the end turns out that it isn't) and false negatives (a project that is not allowed on the research facility because it doesn't appear innovative, but at the end is highly innovative).

3. Aim of this paper

The strategic aim of this paper is to:

- Present an overview of duraBASt research projects that will be analysed according to their innovation characteristics;
- Select a suitable "Innovation Management Technique and Tool" to conduct an ex-post evaluation of completed research projects;
- Identify suitable criteria to assess and evaluate innovations characteristics of the eight duraBASt research projects;

[†] Detailed information about the duraBASt research and innovation projects can be found on www.durabast.de.

- Derive from the results recommendations and future research needs for the selection of future innovation and research projects on the duraBASt.
- Define innovation from the perspective of the duraBASt research facility and position the duraBASt in an innovation ecosystem;
- Provide generalisable recommendations for the assessment and evaluation of innovations in the road construction sector.

4. First tranche of duraBASt research and innovation projects 2017 -2019

The following eight research and innovation projects will be analysed in this paper according to their innovation characteristics:

i) HEALROAD - Induction heating asphalt mixes to increase road durability and reduce maintenance costs and disruptions

The HEALROAD project was designed to extend the lifetime of wearing courses by using asphalt materials that can self-heal by means of electromagnetic induction. Besides conventional components that can be found in asphalt – for example filler, aggregates and bitumen – the HEALROAD mixture contains also conductive components that can be rapidly heated by induction, reducing the viscosity of the surrounding bitumen and boosting it through cracks. As a result, damage produced in the mastic that bonds the aggregate particles is healed and the service life of the road is extended.

ii) SEDa - Testing of multifunctional road-building materials and composites

The SEDa research project aims to investigate the potential of road pavements as an energy source. The focus and innovation of the project is both on the potential of the thermal energy stored in the road by solar radiation to generate electricity and on the increased durability of the road construction by dissipating heat. New materials and composites that combine advantageous heat transport properties with the existing requirements for mechanical behaviour are needed to make optimum use of the solar radiation spectrum. To this end, new multifunctional composite materials for the development of new collector variants are to be investigated.

iii) OPB - Porous Concrete

In addition to increasing durability and efficiency, concrete road construction tests in recent years have focused in particular on environmental aspects. A major factor here is noise control. Against this background, a noise-reducing concrete road surface has been developed and tested at BASt in cooperation with Gütegemeinschaft Verkehrsflächen aus Beton e.V. (GVB) and other partners from the industry. Porous concrete is concrete with a continuously porous structure which can be used for concreting the top layer (approx. 5 to 7 cm thick) on top of an already hardened first layer.

iv) Professional sealing of drill core extraction points

BASt has awarded an external research project to the Bergische Universität Wuppertal for the professional sealing of drill core extraction points. As part of the research project, a wide variety of mix variants were initially investigated and evaluated in the laboratory as backfill material for drill core removal points. The evaluations (of the results of the various tests) led to the selection of two mix variants, which were used on duraBASt as backfill material.

v) Precast concrete parts

Shortening construction times and increasing the durability of road pavements are paramount to guaranteeing the availability and durability of road infrastructure in the long term. Precast concrete elements demonstrate substantial benefits in this respect, such as high quality due to prefabricated manufacturing and possible multifunctionality (for example by integrating sewer manholes or lighting systems). Furthermore, compared to conventional concrete or asphalt methods, they can largely be installed irrespective of the weather.

vi) OPA - Testing of a modified mix design of porous asphalt

Porous asphalt surface layers are used in Germany to reduce Tyre/Road-Noise directly at the source of origin the road surface. The mixture contains coarse aggregates > 2 mm, filler and polymer-modified bitumen as binder without the addition of fine aggregates. This results in a high void content for a good acoustic effectiveness and guarantees the required acoustic durability of the layer. From the construction point of view problems like reduced stability and lack of process control could occur. A group of experts of the German Asphalt Association suggested a modified mix design after carrying out a study in the laboratory. This changed mix design with the addition of five percent of fine aggregates was tested on the duraBASt.

vii) Inno-Pave - New materials and innovative production and installation technologies
The current production of asphalt roads is subject to considerable environmental influences that can cause large variations in quality. These have a decisive influence on the service life and the performance characteristics of the road. In addition, every new construction and maintenance measure requires time, which must be minimized due to the associated traffic congestion. In the Inno-Pave project, a multi-layer road surface layer that can be produced under constant conditions was realized using polymer-based and textile materials. The basic research approach was the use of polymer-based materials in combination with textile reinforcement structures. The durability and performance characteristics and in particular the acoustic properties of traditional noise-reducing road surface layers – for example porous asphalt – should be significantly exceeded. The aim was to achieve a permanent noise reducing effect with an extended structural engineering service life.

viii) OBAS - Optimizing the surface design of asphalt pavements
During the paving process of asphalt surface layers chippings are applied to enhance the initial skid resistance. Usually the chippings are applied by rollers and integrated into the layer during compaction. At that rather late point in time the integration of the chippings could be unsatisfactory. In addition the applied rate of material could vary depending on the technique used, or the applied material overlaps due to the limited width of the roller drums. The OBAS project designed a new type of paver screed which applies the chippings in the paver and integrates them into the hot non-compacted asphalt by the screed.

5. Innovation management techniques and tools

Hidalgo and Albors (2008) provide a detailed overview of innovation management techniques (IMT) that organisation apply to manage innovation in a knowledge-driven economy. Like many National Road Research Laboratries[‡], the BASt, which traditionally has a strong technical focus, regularly applies a number of IMTs, but without actively referring to these activities as IMTs or referring to innovation management. It also has to be recognised that current literature on IMTs mainly focus on the needs of the private sector and product development, rather than the public sector, which has very specific needs that often cannot be quantified as easily as in the private sector.

Judging the needs for the duraBASt research facility in optimising the identification and assessment of innovation potential for research projects whilst keeping the right balance between project categories (e.g. technical focus, budget, Technological Readiness Level), it becomes clear that ‘project appraisal’ and ‘project portfolio management’ seem suitable IMTs to assess past research projects and develop a selection process for future projects.

Lerch and Spieth (2012) provide detailed overview of current issues for innovation project portfolio management (IPPM). A widely accepted definition of IPPM is provided by Cooper et al (1999):
“*Portfolio management is a dynamic decision process, whereby a business’ list of active new product (and R&D) projects is constantly updated and revised. In this process, new projects are evaluated, selected and prioritised; existing projects may be accelerated, killed, or de-prioritised; and resources are allocated and reallocated to the active projects.”* (Cooper et al. 1999, p.335”)

It is clear that this definition is a suitable starting point for developing a definition for IPPM in the context of the duraBASt research facility, but it has its limitations. For example, the duraBASt is not about product development, but about providing validation and acceptance to innovations in the road construction sector that could be endorsed by standardisation bodies. As this is pre-competitive research, financial return is often not a selection criterion at all.

[‡] For a detailed overview of European road research laboratories: http://www.fehrl.org/about-us/members

The core advantage of an IPPM is that it enables the clear visualisation of complex innovation criteria. These portfolio visualisations are often set up using two dimensions, but each dimension can comprise several criteria. The limitation of an IPPM is that it only represents a snapshot of the current portfolio setup, but it does not illustrate the dynamic process in selecting the initial innovations or the next steps in the innovation process. Hence, it is essential that several portfolios are created representing different time steps in order to make a before and after comparison possible.

6. Evaluating and assessing innovation

A strict guideline on how research projects should become innovative is not the aim of this evaluation process and it is even questionable whether this is actually possible. Instead, it is about being able to better capture the probability of success and specific innovation characteristic in the course of the innovation process. Several aspects relative to innovation need to be captured rather than technical aspects that are evaluated by established test methods. Therefore, a holistic view of the context conditions for road construction innovations forms the basis for the development of an evaluation and assessment system for the portfolio analysis of duraBASt research projects.

There is a wide literature on approaches on assessing innovations. However, many assessment tools are not suitable for the public sector research needs, which surround the duraBASt. Most assessment of innovation has a strong private sector focus. This is picked-up by Vries, Bekkers and Tummers (2016), where they clearly show that the public sector (and the road construction sector) has a sector specific perspective on common innovation themes: (1) definition of innovation, (2) innovation types, (3) goals of innovation, (4) antecendents of innovation and (5) outcomes of innovation.

The individual research projects on the duraBASt need to be seen in a wider innovation ecosystem (Durst and Poutane, 2013) and their success needs to be understood in the evaluation of an entire ecosystem by involving actors beyond organisational boundaries and understand wider concerns. The evaluation needs to provide evidence that the portfolio performance correlates positively with the performance of the duraBASt research facility and the innovations needs of the road construction sector. Of high importance is that the evaluation should be designed according to the needs of the end users, i.e. the research engineers working on the duraBASt. This means that in their limited time budget the research engineers should be able to conduct the evaluation without causing additional work. Therefore, it needs to be ensured that no other data is collected other than already collected as part of the technical evaluation and that the qualitative expertise of the research engineers should be valued.
Based on a literature review the following criteria were identified as potential criteria for a portfolio analysis:

- *TRL*
- *Funder /Research budget*
- *Application potential*
- *Innovation uncertainty (Jalonen, 2012); Technical uncertainty and market uncertainty*
- *Innovation type*
- *Follow-up activities*
- *Ecosystem success factors*
- *Incremental vs. disruptive change*

After the initial selection process the following indicators were removed from the list:

i) Technology Readiness Levels (TRL): It is clear that all projects that were conducted on the duraBASt were scoped in the levels 5-6 (Component validation in relevant environment; Fully integrated pilot (prototype) tested in a relevant environment).However, the role of the duraBASt or the BASt is not to follow an innovation until the end of the scale. Hence, this criterion only has a limited meaningfulness in understanding the exact role of the duraBASt in the innovation process to move an innovation from one TRL level to the next. As noted by Mankins (2009) the current TRL approach does not allow assessment of anticipated research and development uncertainty. Especially the reduction of uncertainty can be seen as a major added value from conducting research and innovation activities on the duraBASt.

ii) Ecosystem success factors: An innovation ecosystem (Durst and Poutanen, 2013) is a complex description that requires significant further work to actually describe the role of the BASt in an ecosystem. This is too ambitious at this stage, especially because data on the innovation ecosystem for the road construction sector is currently missing.

iii) Innovation type: Suitable innovation categories to describe research projects on the duraBASt currently do not exist. The results of the portfolio analysis can help to develop useful innovation categories for the future.

The following evaluation criteria for the duraBASt innovation portfolio were selected after consultation with the duraBASt research engineers based on their applicability, ease of use and ability to measure the performance of the duraBASt research facility:

i) Funder and research budget: These criteria describe the size of the research budget and the funder of the research. From these criteria it is possible to identify causality between the financial context conditions and innovation characteristics of the research projects. Following range classifications are determined for this criteria: “Above 2M€”, “Above 1M€” and “Below 1M€”.

ii) Application potential: This criterion provides an indication of the expected scale of application possibilities within the road construction sector and the potential market size when the innovation is successfully introduced. The range of application possibilities and market size provides also an indication of how many stakeholders are affected by the innovation. Following classifications are determined for this criterion: Small (limited range of application possibilities on the network and small market size), Medium (a wide range of application possibilities on the network and a medium market size) and Large (a very wide range of application across most of the network and a large market size).

iii) Incremental or disruptive innovation: This criterion distinguishes innovations with regard to the potential changes they will bring after introduction to the organisational and technical set-up of the road construction sector. Incremental changes are those that encourage the status quo, whereas radical changes are those characterised by processes of reorientation wherein patterns of consistency are fundamentally reordered (Tushman and Romanelli, 1985). Following classifications are determined for this criterion: Incremental (small modification to existing and practices), Medium (significant change to existing practices) and Radical (complete restructuring of existing practices).

iv) Innovation uncertainty for technology and market: Innovation is a process that is fraught with uncertainty. This criterion describes the scale of uncertainty until the innovation is successfully introduced. Uncertainty results from the fact that, on the one hand, events in the future do not follow the course of past events, and, on the other, knowledge of the future is always incomplete. From a set of commonly used factors causing uncertainty (Jalonen, 2011), technological and market uncertainty were identified as the most relevant in the context of the duraBASt as they inhibit clear decision making to facilitate a structured innovation path. Following classifications are determined for this criterion: Low (technological: there are only minor technical challenges to successful introduction of the innovation; market: the market under current regulatory environment is willing to apply the innovation as soon as all technological issues are solved), Medium (technological: there is a high number of technological challenges that require significant amount of resources in order to be solved; market: the market under current regulatory environment is hesitant for a wide scale introduction of the innovation) and High (technological: it is unclear whether technological challenges will be overcome; market: the market under the current regulatory environment is unlikely to introduce the innovation).

v) Follow-up activities: A research project on the duraBASt affects the level of uncertainty about the next step in the innovation path of an innovation. The criterion describes the next step after the research project was successfully completed on the duraBASt. Following classifications are determined for this criterion: “Market uptake” (the innovation path is completed), “Continued research” (further research on the duraBASt or elsewhere was initiated), “Standartisation process initiated” (regulatory barriers are being removed to facilitate the implementation of the innovation) and “No follow-up” (the innovation process was halted).

7. Methodology

The eight research and innovation projects that were successfully completed during the period 2017 – 2018 were evaluated according to the above criteria. Criteria iv) "Innovation uncertainty for technology and market" was conducted as a before and after analysis to illustrate the change in uncertainty levels when a research project is successfully completed at the duraBASt. This change in uncertainty level is shown as an indication of the trend in which the uncertainty level has changed.

The data for the evaluation was collected from the BASt research engineers who managed the research project on the duraBASt. Criteria i), ii) and v) are based on their factual assessment, whereas their input for criteria iii) and iv) on their professional, but subjective, judgment as no reliable data currently exists for criteria such as uncertainty. For data privacy and confidentiality reasons the results of the evaluation for each project were anonymised.

8. Results

The anonymised results of the evaluation of the eight research and innovation projects are presented in table 1.

9. Innovation Management Portfolio Analysis

The results of the evaluation were transferred into an IPPM template that categorised the research project (before) according to their uncertainty level (technology and market) and expected innovation change (incremental, medium, radical).

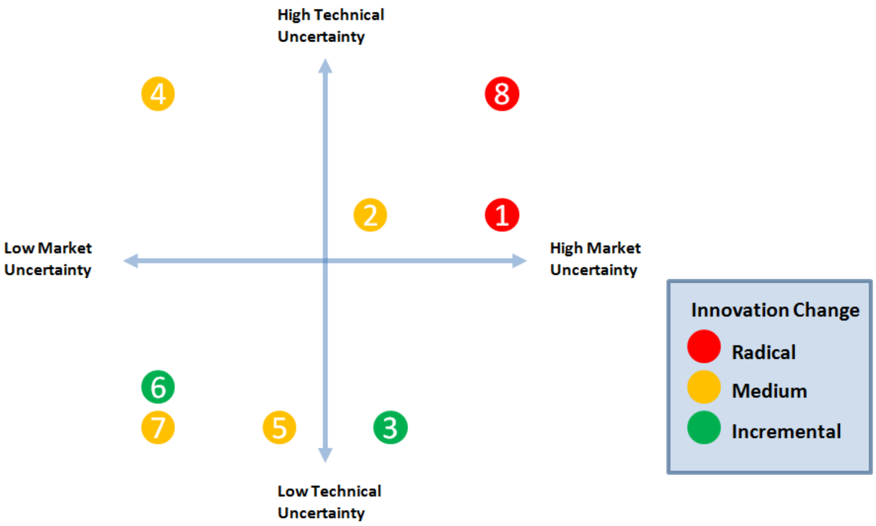

Figure 1: Innovation Portfolio duraBASt before the start of the research projects

From the innovation portfolio it is clear to see that the first tranche of selected research projects cover a wide spread of different uncertainty levels and innovation changes. This balanced approach illustrates the diverse role the duraBASt can take on the one hand as a demonstration site (e.g. projects 3,5,6 and7) for innovations that are close to market uptake or the initiation into standardisation and ,on the other, a research facility with projects that have high uncertainty levels (e.g. projects 1,4 and 8) with continued research needs. Further, the duraBASt projects address almost equally both technical and market uncertainties. This balanced approach can especially be important in the initiation phase of the research facility in order to illustrate the diverse range of projects that can be conducted on the facility.

Table 1: Evaluation of research projects based on five criteria.

Nr.	**Budget**	**Application Potential**	**Innovation Change**	**Technical Uncertainty (before)**	**Market Uncertainty (before)**		**Technical Uncertainty (after)**	**Market Uncertainty (after)**	**Follow-up**
1	Below 1M€	Small	Radical	Medium	High	**duraBASt**	(•) no change	(•) no change	Continued research
2	Above 1M€	Medium	Medium	Medium	Medium		(↙) reduction	(↙) reduction	Continued research
3	Below 1M€	Medium	Incremental	Low	Medium		(•) no change	(←) strong reduction	Standartisation process initiated
4	Above 1M€	Large	Medium	High	Low		(↗) increase	(•) no change	No follow-up
5	Above 1M€	Medium	Medium	Low	Medium		(↙) reduction	(↙) reduction	Market uptake / Standartisation process initiated
6	Below 1M€	Large	Incremental	Low	Low		(↙) reduction	(•) no change	Continued research / Standartisation process initiated
7	Above 1M€	Medium	Medium	Low	Low		(↙) reduction	(↙) reduction	Market uptake
8	Above 2M€	Medium	Radical	High	High		(↑) strong increase	(↗) increase	Continued research

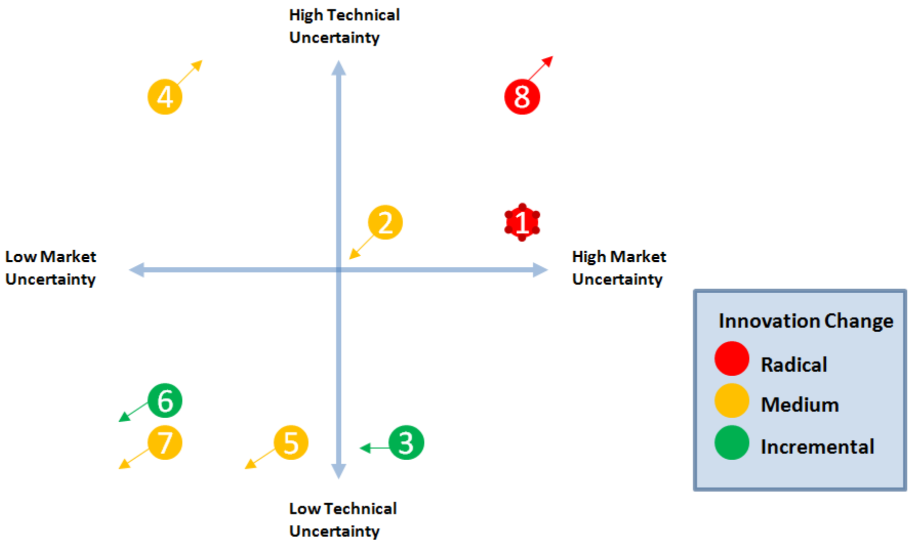

Figure 2: Innovation Portfolio duraBASt after completion of the research projects

The before and after analysis of the uncertainty levels illustrates that for projects 2, 3, 5, 6 and 7 the uncertainty levels have decreased thanks to the research activities conducted on the duraBASt. As can be seen from table 1, the decrease in uncertainty has lead for all projects with a decrease in uncertainty, apart from Nr.3, to a clear path towards “Market uptake” and/or “Standartisation process initiated”.

Projects 5, 6 and 7 have started out with low uncertainty levels. It this case the duraBASt acted as a demonstration platform to reduce remaining uncertainties to a minimum and create acceptance within the stakeholder ecosystem for that particular innovation. The ease of accessibility of the duraBASt for many stakeholders and decision makers within the innovation ecosystem of the road construction sector is a major added value for the demonstration activities on the duraBASt.

The uncertainty levels for projects 4 and 8 increased after the completion of the projects on the duraBASt. In the case of project 4 the increased uncertainty levels lead to the halt of further research activities. Here the duraBASt arbitrated a decision in the wider researcher community about the merit and feasibility of this particular innovation. For project 8 the increased uncertainty levels lead to a re-evaluation resulting in continued research in a lower TRL.

For project 1, the research activities on the duraBASt did not change the uncertainty level of the innovation, thus confirming that further research activities at the same level are required.

10. Conclusion and Outlook

In the course of the research it became apparent that the role of the duraBASt in the wider ecosystem is very specific and that the actual innovation ecosystem for the road construction sector in Germany or Europe can be described, at least from within the innovation management literature, as a widely uncharted territory. However, within this yet to be mapped innovation ecosystem, this paper has shown that the duraBASt takes a role in changing or reinforcing the path innovations take to navigate to their next destination along the innovation process towards implementation, further research or termination. The focus of the IPPM on uncertainty has proven a suitable and user-friendly criterion to provide an initial description of the key function the duraBASt plays in the innovation process.

However, it has to be acknowledged that the results have limitations due to the limited number of projects in the evaluation. Including further research projects from the second tranche of duraBASt research projects and potentially even research projects from wider test environments (e.g. laboratory, public road testing) could further strengthen the description of the innovation ecosystem and the role of the duraBASt. Further, the role of the IPPM could be strengthened when it is combined with additional IMTs such as, a stage-gate review approach (e.g. Cooper, 1990) where the duraBASt could potentially be considered as a gate between phases. In this way the rational analysis of the entire innovation path of an innovation could be supported.

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References

BMVBS, 2013. Roads in the 21st Century: Innovative Road Construction in Germany. Ministry of Transport, Building and Urban Development Press.

Cooper, R.G., Edgett, S.J., Kleinschmidt, E.J., 1999. New product portfolio management: practices and performances. Journal of Product Innovation Management. Vol. 16, pp.333-351.

Cooper, R.G., 1990, Stage-Gate Systems – a New Tool for Managing New Products. Business Horizons, 33, 3 (1990), 44-54.

De Vries, H., Bekkers, V., Tummers, L., 2016. Innovation in the public sector: a systematic review and future research agenda. Public Administration Vol. 94, No.1, 2016 (146-166).

Durst, S., Poutanen, P., 2013. Success factors of innovation ecosystems – Initial insights from a literature review. In R. Smeds & O. Irrmann (eds.) CO-CREATE 2013: The Boundary-Crossing Conference on Co-Design in Innovation (pp. 27-38). Aalto University Publication series SCIENCE + TECHNOLOGY 15/2013.

Hidalgo, A., Albors, J., 2008. Innovation management techniques and tools: a review from theory and practice. R&D Management, Wiley Online Library.

Jalonen, H., 2012. The uncertainty of innovation: A systematic review of the literature. Journal of Management Research, 2012, Vol. 4, No. 1: E12.

Lerch, M., Spieth, P., 2012. Innovation Project Portfolio Management: a meta-analysis, Int. J. Product Development, Vol.16, No. 1, pp. 77-94.

Mankins, J., 2009. Technology readiness assessments: A retrospective, Acta Astronautica, 65 (2009) 1216-1223.

Tushman, M.L. and Romanelli, E. 1985. Organizational evolution: a metamorphosis model of convergence and reorientation. In L. L. Cummings, & B. M. Staw (Eds.), Research in Organizational Behavior, vol. 7 (pp. 171–222). Greenwich, CT: JAI Press.

Wacker, B., Jansen, D., 2018. Toolbox for APT program monitoring at BASt and optimized data handling on new test facility duraBASt. TRB 2018 Annual Meeting, Paper number 18-03935.

Wacker, B., 2015. Accelerated Pavement Testing Program with the Mobile Load Simulator MLS10 – Temperature Analysis, 6th International Conference 'Bituminous Mixtures and Pavements'.

Wacker, B., Panwinkler, T., Hoeller, S., 2019. Assessment of road construction innovation on duraBASt. Proceedings 26th World Road Congress. PIARC.