This paper was presented at The XXVI ISPIM Conference – Shaping the Frontiers of Innovation Management, Budapest, Hungary on 14-17 June 2015. The publication is available to ISPIM members at www.ispim.org.

Systematic selection of suitable Open Innovation methods

Matthias R. Guertler*

Institute of Product Development, Technische Universität München,
Boltzmannstraße 15, 85748 Garching, Germany
E-mail: guertler@pe.mw.tum.de

Constantin von Saucken

Institute of Product Development, Technische Universität München,
Boltzmannstraße 15, 85748 Garching, Germany
E-mail: saucken@pe.mw.tum.de

Anna-Teresa Tesch

Institute of Product Development, Technische Universität München,
Boltzmannstraße 15, 85748 Garching, Germany

Thomas Damerau

Fraunhofer-Institut für Produktionsanlagen und Konstruktionstechnik
IPK, Pascalstraße 8-9, 10587 Berlin, Germany
E-mail: thomas.damerau@ipk.fraunhofer.de

Udo Lindemann

Institute of Product Development, Technische Universität München,
Boltzmannstraße 15, 85748 Garching, Germany
E-mail: lindemann@pe.mw.tum.de
* Corresponding author

Abstract: The performance of Open Innovation (OI) is closely linked to the selection of suitable OI-methods, such as idea-contests, toolkits or cross-industry-innovations. It directly influences the quantity and quality of gained knowledge as well as appropriate incentives. As studies showed, selecting suitable OI-methods is still a challenge for companies, especially when unexperienced with OI. This paper presents a matrix-based approach for characterising and mapping a company's OI-situation (boundary conditions and OI-goals) and potential OI-partners to suitable OI-methods. The matrix approach was implemented in a software tool to allow a semi-automated ranking of suitable OI-methods. It also supports the identification of most suitable OI-partner-method combinations if different alternatives are available. The matrix approach acts as a decision support, leaving the final decision to the planners of the OI-project. An initial evaluation of the matrix approach in the context of two industry projects was successful.

Keywords: Open Innovation; Open Innovation methods; project planning, decision making.

1 Introduction

This paper addresses the selection process of suitable Open Innovation collaboration methods within an outside-in Open Innovation (OI) project. By opening up their innovation process, companies develop innovations in cooperation with different external partners, such as suppliers, universities or customers (Chesbrough 2003), (Chesbrough and Bogers 2014), (Dahlander and Gann 2010), (Huizingh 2010). For the collaboration itself, different OI-methods are available, e.g. R&D cooperation, idea/tion contests (Sloane 2011), Lead-User workshops (von Hippel 2005), etc. The correct choice of suitable OI-methods is crucial for the success and performance of an OI-project. OI-methods do not only influence the quantity and quality of the exchanged knowledge and resulting outcome of the OI-projects. They also define the boundary conditions for possible incentives and risk management measures. For instance, if aiming at general ideas from customers for potential new products, an idea contest might be the OI-method of choice. While a Lead User workshop might be better suitable for developing detailed solution concepts for combustion engine valves. This also illustrates another challenge: it is not only sufficient to derive OI-methods for a specific OI-situation, it is also necessary to identify OI-methods, which fit to selected OI-partners as well.

Despite or maybe due to this relevance, studies showed that companies still face challenges when planning OI-projects and selecting suitable OI-methods, e.g. (Guertler et al. 2014c), (Huizingh 2010), (van de Vrande et al. 2009). Especially OI-unexperienced companies (as well as academic teams) face these challenges since the planning of OI-projects is mainly experience based so far. Methodical support is limited: whether it is too abstract for practical use by missing a detailed decision process (Lakhani et al. 2012), or it focusses on specific OI-methods, e.g. intermediaries or idea contests (Diener and Piller 2010), (Piller and Ihl 2009). Though some authors, such as (Rothe et al. 2014), already suggest systematic approaches for selecting suitable OI-methods, they often only consider a limited set of decision criteria which does not allow a holistic consideration of all relevant boundary conditions.

Thus, this paper presents a matrix-based approach for ranking and deriving suitable outside-in OI-methods for a given OI-situation and set of potential OI-partners. The bases are three characteristics-profiles of OI-situation, OI-partners and OI-methods. The evaluation was conducted in the context of two industry projects.

Within this publication, we define a **characteristic** as a combination of an **attribute** (e.g. size of company) and a regarding **value** (e.g. SME).

2 Research Design

The presented work is based on the **Design Research Methodology (DRM)** (Blessing and Chakrabarti 2009) and is located in the Prescriptive Study (PS). It develops a methodology to overcome the previously mentioned problems/gaps identified in the Descriptive Study 1 (DS1). The resulting research questions were:

- How can suitable OI-methods for a given OI-situation and OI-partners be identified?
- How can suitable combinations of OI-methods and OI-partners be identified?
- How can characteristics of OI-situation, OI-partners and OI-methods be mapped?

Figure 1 illustrates the underlying research design. Based on an industrial requirement analysis regarding an OI-method selection tool, we evaluated existing approaches. This revealed suitable partial approaches but no existing holistic approach, which fulfils all requirements. Thus, we developed three sets of characteristics with ca. three values each to characterise an OI-situation (Guertler et al. 2014a), OI-partners and OI-methods (von Saucken et al. 2015). This was based on a literature review and subsequent workshops with academia and industry. By this, we ensured that characteristics are distinctive, understandable and measureable. In the next step, we identified general links between the attributes of the three domains. A simple example might be the link between the project budgets (OI-situation), the number or size of the OI-partners/-group (OI-partners) and the recommended number of method users (OI-method). After identifying the general links, links between the specific attribute-values were analysed, e.g. a limited OI-project duration is connected with a low application time of an OI-method. By modelling the characteristics and the values' links in Microsoft Excel, we developed a semi-automated selection tool for OI-method. The Excel structure also allows modifications of characteristic dependencies and future adding of new OI-methods. The mapping/linking of characteristics and properties was evaluated in a workshop in academia including a sensitivity and plausibility analysis. To ensure industrial applicability, the selection method and tool were evaluated in the context of two OI-projects with two German SMEs from the field of machinery and plant engineering.

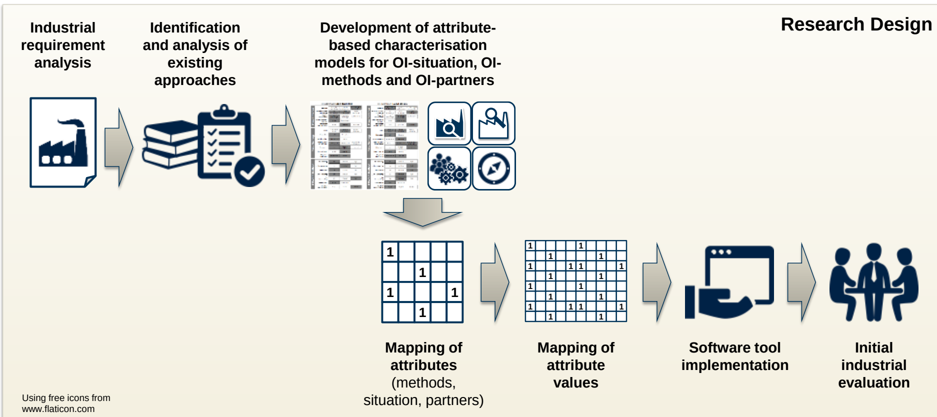

Figure 1 **Research Design**

3 State of the Art

The following section presents an overview of the research context and existing approaches from literature, which were adapted and used within this publication.

Situative Open Innovation (SOI)

Based on the previously described industrial demands (Guertler et al. 2014c), Guertler and Lindemann (2013) developed a methodology to support OI-teams from industry and academia by systematically and successfully planning OI-projects. Figure 2 gives an overview of the five phases. The outer ring of SOI (1 to 4) represents the "rough" planning, which gets detailed in SOI 5. Though it looks linear, iterations are allowed and necessary if context factors or others change. G1 to G4 are adapted stage gates (Cooper 2001) to ensure purposeful iterations.

The methodology's name "Situative Open Innovation" stresses its goal to systematically analyse a company's specific OI-situation, constrains and goals of the OI-project (SOI 1), to identify and select suitable OI-partners (SOI 2) and OI-methods (SOI 3). Based on this, regarding performance measures, controlling concepts and risk management strategies are derived (SOI 4). All planning elements get detailed in SOI 5 including e.g. the specific start and end date of an OI-method or the heights of financial incentives. For more information, please refer to (Guertler et al. 2015), based on (Guertler and Lindemann 2013).

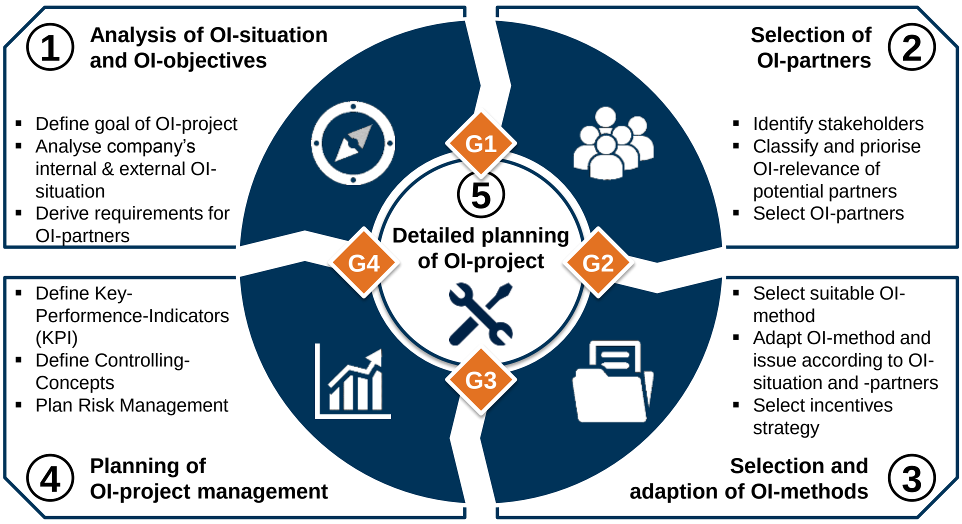

Figure 2 Situative Open Innovation for systematically planning OI-projects (Guertler et al. 2015)

Open Innovation (OI) methods

OI provides different OI-methods to collaborate with external partners. In the following, we present a set of 12 outside-in OI-methods, which are considered within this publication.

- **Idea/tion contest** (Walcher 2007): A task is published to the public, inviting partners to submit related ideas in a specific timeframe. Partners can also rate and comment on other ideas, and use them for own ideas. The best ideas are rewarded in the end.
- **Idea/tion platform** (Kaplan and Haenlein 2010): In contrary to an idea contest, idea platforms are usually not bound to a specific timeframe and allow a continuous and self-initiated submission of ideas by (external) partners.

- **(Problem) Broadcasting** (Diener and Piller 2010): Similar to idea contest and platform, a task is published to public or a specific pool of problem solvers. However, usually an interaction among partners is not supported.
- **Community for OI** (Blohm 2013): It is an informal association of partners, who are interested or affected by a specific topic or product. Its origin can be self-induced or induced by a company. They provide insights in user needs, ideas, solutions, etc.
- **Netnography** (Belz and Baumbach 2010): Based on an existing community, Netnography systematically analyses current discussion topics and user-interactions. This allows the identification of relevant needs of the community and initial solution ideas as well as active and experienced users.
- **Lead-User approach** (von Hippel 2005): Lead-User show relevant needs long before the majority of other users. They also hold the motivation and expertise to contribute to a regarding solution. Hence, their identification offers competitive advantages.
- **Immersive Product Improvement (IPI)** (Kirschner et al. 2011): It provides a structured feedback channel to product users. Those can mark positive and negative aspects within a graphical representation of the product. In addition, they can evaluate existing feedback and submit own ideas for potential improvements.
- **Toolkits for user innovation (early phases)** (Piller et al. 2004): They can be understood as very limited CAD tools, which allow partners to create and play with own designs of their “perfect” product. The underlying trial-and-error approach supports the identification of primary implicit needs (so called “sticky knowledge”).
- **Toolkits for user co-design (late phases)** (Reichwald and Piller 2006): In a later innovation phase, toolkits can also be used in the context of mass customisation.
- **Cross-Industry Innovation (CII)** (Enkel and Gassmann 2010): The identification and adaption of established concepts from other industries, allows radical innovations, and reduces the risk of failures and thus the time to market.
- **University cooperation** (Fabrizio 2006): It allows the collaboration with researchers and also students as well as access to current research topics, new approaches and a pool of young creative people.
- **OI-intermediary** (Diener and Piller 2009): As a combination of consultant and service provider, an OI-intermediary support OI-unexperienced companies planning, conducting and exploiting an OI-project.

Systematic characterisation of methods

To allow a systematic assessment and selection of OI-methods, these need to be characterised in a sufficient way. Based on different approaches of general method models, such as (Birkhofer et al. 2002), (Lindemann 2009), (Ponn 2007) and (WiPro 2015), von Saucken et al. (2015) developed an OI-specific method model. It is divided into two sections: (1) a descriptive section, containing necessary input, output and procedure; and (2) a method profile, systematically characterising the specific OI-method. As illustrated in Figure 3, the OI-method profiles are subdivided into three subsections, which describe the focused OI-partners, task settings and effort of each OI-method. This allows an easy comparison of different OI-methods, as demonstrated for the two OI-methods idea contest and Lead-User approach.

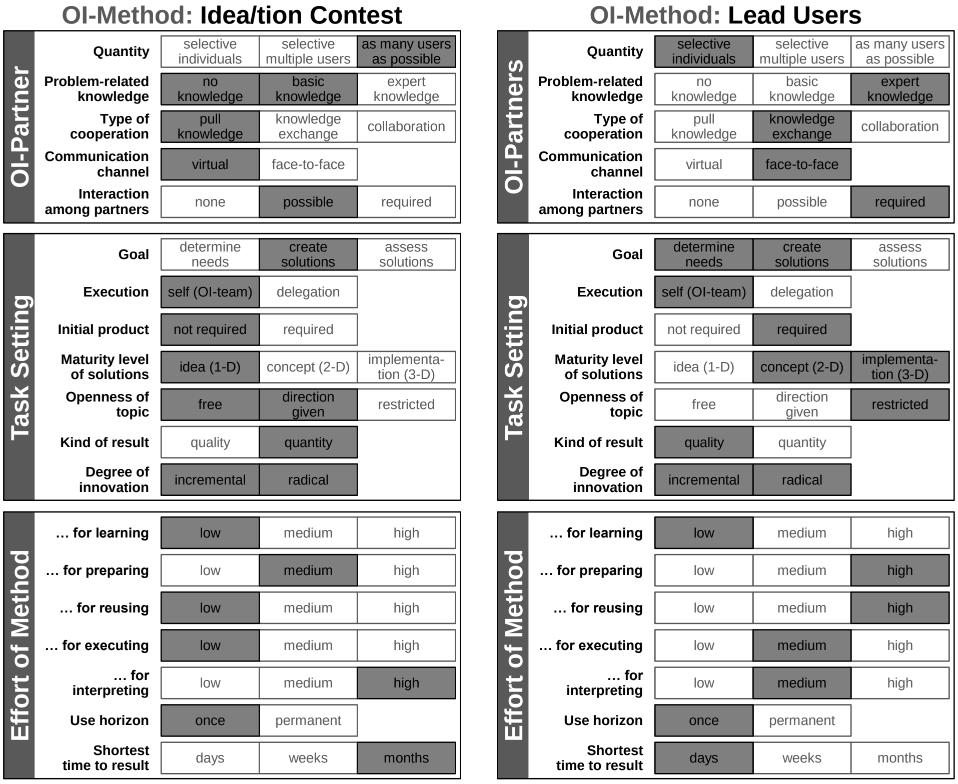

Figure 3 OI-method profiles, based on (von Saucken et al. 2015)

Existing method selection approaches

Literature provides different existing approaches for selecting suitable methods. In the following, we give a brief overview of established ones.

A well-established approach in product development is the selection of methods based on **method models/profiles**, such as (Birkhofer et al. 2002), (Lindemann 2009) and (Ponn 2007). Based on an analysis of the regarding situation, the characteristics of different methods are discursively compared with relevant situation factors. This usually includes the assessment of necessary input of a method, expected output, user requirements, general conditions, necessary working aids and hints for an application (Birkhofer et al. 2002). However, the selection is strongly based on the expertise of the project team’s members.

A similar approach is a **portfolio-based selection**, such as (Lakhani et al. 2012) from the field of OI. They characterise OI-methods regarding the task decomposition and the distribution of problem solving knowledge, and locate them in a resulting portfolio. This allows a rough selection of OI-methods. However, a detailed decision process is not supported.

A general approach from various disciplines are **decision trees**, such as (Safavian and Landgrebe 1990). They are based on the definition of differentiating criteria, which are ranked regarding their relevance in the application context, e.g. methods for internal or external use, and focussing on product or process improvements. The most relevant decision criteria represents the trunk of the tree, and the regarding criteria values set the main branches. Each branch contains the decision criteria of the next level, spanning further branches, etc. The resulting methods are represented as leaves of the branches. Though the selection process is intuitive, it is only useful for a small set of criteria. The number of paths through the tree is the product of the number of values of all criteria. Hence, its complexity increases with the number of criteria.

Rothe et al. (2014) present a **table-based approach**. Using a method model and a simple matrix form, they rate the influence of each method attribute on each OI-method (scale from very negative (-2) to very positive (2)). As illustrated in Figure 4, the data input is entered via the weightings of the different attributes: 0, the attribute is not relevant for the OI-project; 1, the attribute is relevant; and 2, the attribute is very important and acts as a KO-criterion. Besides these situative KO-criteria, also general KO-criteria are defined, which determine the suitability of an OI-method: e.g. the openness of an idea contest would be a KO-criterion, if a patentable solution is aimed for. However, the selection approach considers only a small number of OI-methods and only method attributes, but no situation or partner attributes.

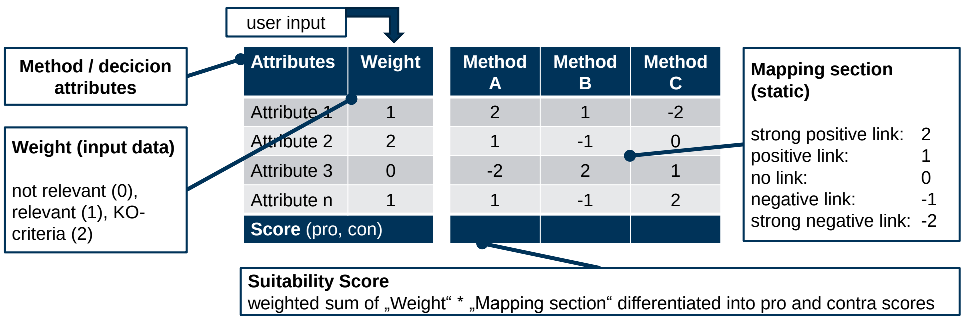

Figure 4 Table-based method selection approach, based on (Rothe et al. 2014)

WiPro platform

Based on the experience from different research project at RWTH Aachen, the online platform www.innovationsmethoden.info was designed (WiPro 2015). It contains 115 innovation methods, which are characterised by seven rudimentary attributes. They are the base for filtering suitable methods. However, the low number of input attributes does not allow a differentiated assessment of suitable methods, which results in a missing method ranking. In addition, only a small number of four OI-methods is considered.

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4 Matrix-based mapping attributes of OI-situation, partners and methods

Based on a workshop with three industry partners, we analysed their wishes and requirements regarding an OI-method selection tool. The main requirements are:

- R 1: Supporting the selection decision
- R 2: Ranking OI-methods regarding their situation and partner suitability
- R 3: Ensuring transparency of the ranking process
- R 4: Showing advantages and disadvantages of each OI-method
- R 5: Allowing a future enhancement by further OI-methods
- R 6: Ensuring an intuitive use of the resulting tool
- R 7: Using standard or freeware software to avoid acquiring special software
- R 8: Using a lean approach with as small handling effort as possible

To fulfil these requirements, we chose a matrix-based approach, as illustrated in Figure 5. It uses attribute vectors for characterising OI-situation and OI-partners. They are multiplied with **Domain Mapping Matrices (DMM)** (Maurer 2007), which contain the general dependencies between OI-situation, OI-partners and OI-methods. Subsequently, they are multiplied with the vector representations of the OI-method profiles to derive a suitability score of each OI-method. This segmentation into DMMs and OI-method-profile vectors allows the adding of new OI-methods. In the following, we will briefly explain the development of the regarding DMMs.

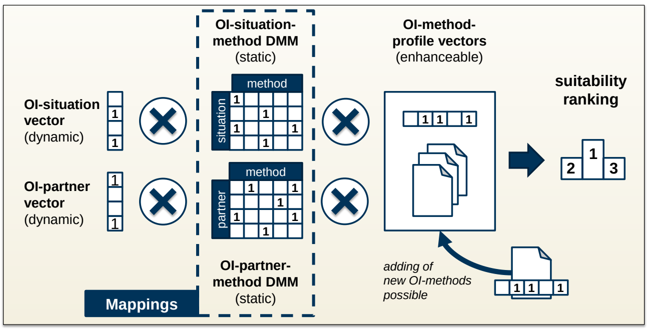

Figure 5 Adaptable mapping approach by using DMMs and OI-method-profiles

Mapping attributes

We used a two-step approach, as depicted in Figure 6. First, only attributes were mapped to identify relevant links. These links were then detailed by mapping attribute values.

In the beginning, we pre-filtered an enhanced version of the OI-situation attribute list, presented in (Guertler et al. 2014a). By this, we excluded all attributes without a measureable scale and not direct relation to OI-methods, such as size of company or industry. In total 52 attributes were considered. Using a scale from 0 (no link) to 3 (strong link), five members of the project team independently assessed potential links between the attributes of OI-situation (52), OI-partners (14) and OI-methods (19) in two DMMs – in total 1254 potential links (= (52+14)*19). By summing up the single values, the resulting scale reached from 0 to 15. In the following, we set the minimum link-strength limit to 9. By this, the cumulated sum of link-strength of 9 and higher represent 10.5 % of all possible links. These links were then detailed on an attribute-value level. For verification reasons, we also analysed links with a strength of 7 and 8, which confirmed the determined limit. The attribute mapping limited the number of attributes to 36.

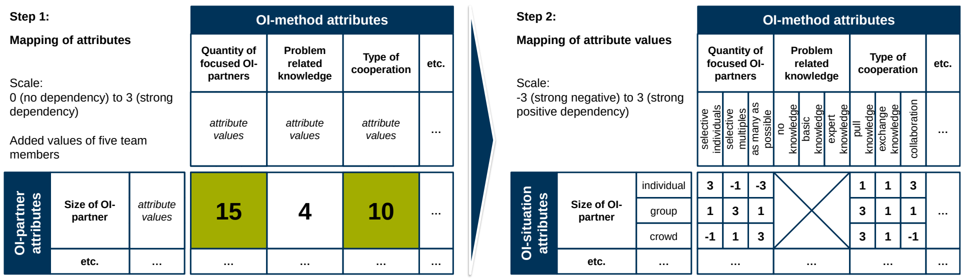

Figure 6 Two-step mapping: firstly attributes (l.) and secondly attribute values (r.)

Mapping attribute values

Based on the attribute DMMs, we mapped the specific attribute-values, as depicted in Figure 6. On average, each attribute has three values. Since only fields of the attribute-DMMs with values higher than 9 were further analysed, within the attribute-value-DMMs 378 matrix fields (= 3*126) were analysed. Three members of the project team assessed the attribute-value links, by using a 7-step scale from “-3” (very strong negative correlation), via 0 (no correlation) to “3” (very strong positive correlation). This detailed analysis also revealed links, which had a relevant high value in the attribute mapping, but a mapping on the base of attribute-values was not possible. These attributes were excluded in the following. Hence, the final number of considered attributes is 27. Figure 7 and Figure 8 depict the regarding OI-partner and OI-situation attributes.

ID	Attribute	Description	Possible values
General partner criteria			
1.1	**Affiliation to company**	How is the potential OI-partner affiliated to the company?	department-internal, comapny-internal, network-internal, external
1.2	**Size of OI-partner**	Characterises if the OI-partners is a specific person or company, a group or a large crowd	Individual, group, crowd
1.3	**Locality**	Where is the OI-partner located?	Same place, same region, same country, same continent, international
Strategic criteria			
2.1	**Interest in product/project**	What interest does the OI-partner have in the product or the OI-project?	none, low, medium, high
2.2	**Attitude to product/project**	What attitude does the OI-partner havetowards the product or the OI-project?	positive, neutral, negative
2.3	**Type of OI-partner**	Is the OI-partner a B2B company or a B2C private partner?	B2B, B2C
2.4	**Cooperative capabilities**	How is the OI-partner's capability to cooperate with the OI-team or other OI-partners?	none, low, medium, high
2.5	**Influence on product/project**	Which influence or power does the OI-partner have onto the product or OI-project?	none, low, medium, high
Technical criteria			
3.1	**Product experience**	Is the OI-partner familiar with the product (object of interest), which shall be innovated in the OI-project?	no experience, occasional use, regular use, expert
3.2	**Expected knowledge maturity**	Which type of knowledge maturity is expected from the OI-partner?	needs, solution ideas, solution concepts, prototypes, feedback
3.3	**Expected capabilities of abstraction**	How are the expected capabilities of the OI-partner to structure and solve the project task on an abstract level?	low, medium, high

Figure 7 OI-partner attributes within the tool

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ID	Attribute	Description	Possible values	MV
Company characteristics				
1.4.1	Company strategy	Company strategy influences the goal and boundary conditions of OI-project as well as of the entire innovation process	Prioritisation of: - Technology leadership - Quality leadership - Cost leadership	9
1.4.3	External strategic dependencies	Strategic dependencies to external actors can influence and constrain an OI-project, e.g. dependencies of suppliers or customers.	yes, no	9
1.5.6	R&D collaborations	Existing (external) R&D collaborations indicate experience with collaboration in general and with specific actors in particular as well as potential dependencies (actors play active role)	Customer, suppliers, universities, crowd, etc.	10
1.8.2	Durability of straegic decisions	Indicator for planning and investment certainty for the OI-project, more detailled than "Corporate Management"	< 0.5 year, < 2 year, 2-10 years, > 10 years	12
1.6.1	*Degree of globalisation*	*How are the company's activities spread? Indicates R&D and market potentials as well as potential dependencies*	*Local, national, Europe, international*	*6*
1.6.4	Number of active countries with sales	In how many countries does the company have sales departments?	<5-step scale>	7
1.7.1	*Innovativeness*	*How does the OI-team assess the general innovativeness of the company's employees?*	*N/A*	*8*
Company's environmental characteristics				
2.3.2	Customer type	Indicator for potential effort of acquiring OI-actors, collaboration boundary conditions (e.g. NDA) and incentive strategies.	B2C, B2B	10
2.3.3	Customer access	Does the company have direct contact to the users or indirectly via trade intermediaries, customers of customers, etc.? Indicator for acqusition effort, knowledge about customer needs, etc.	direct, indirect	12
2.3.4	Customer contact	Are there special web-platforms for selling the company's products? Indicator for interaction possibilities with customers	yes, no	12
2.5.1	Cycle duration	What is the average time-to-market for a new idea? Indicator for time restrictions of an OI-project	weeks, months, years, decades	14
2.7.4	Need of concealment	How high is the need for concealment? Indicator for level of openess or level threads	very low, low, medium, high, very high	12
2.2.2	Location of main / biggest market	Where is the main market located?	National, Europe, USA, Asia	8
2.3.1	Variety of customer groups	How many groups of customers with differing needs do exist? Indicator for relevant groups of OI-actors which need to be integrated into the OI-project	1, < 5, < 10, < 20, > 20	8
2.6.1	Influence groups	Do specific groups exist who can influence the competition situation? (e.g. OEMs which want to avoid single sourcing) Indicator for potential benefit of OI-project as well as potential OI-actors	yes, no	7
2.6.2	Strategic cooperation	Do strategic cooperation exist within the regarded industry? (e.g. associations) Indicator for potential OI-actors, political instruments and/or threads	yes, no	7
2.6.3	Compulsory cooperations	Do external stakeholders exist who can cause forced cooperations with competitors? (e.g. OEMs wanting to avoid single sourcing)	yes, no	7
2.7.5	Market entry barriers	How easily can new competitors enter the main market? Which requirements need to be met to be able to enter the market? (e.g. technologies)	very low, low, medium, high, very high	4
2.7.6	Dynamics of competitors	How often do new competitors enter the market?	never, seldom, often, regularly	8
Collaboration experience				
3.1.1	Number of universities	With how many universities did the company cooperate in the last 10 years?	None, single ones, many	12
3.1.2	Number of suppliers	With how many suppliers did or does the company cooperate in the last 10 years?	None, single ones, many	10
3.1.3	Number of customers	With how many customers did or does the company cooperate in the last 10 years?	None, single ones, many	13
3.2.1	Number of OI-projects	How many OI-projects were or have already been conducted in the company? Indicator for experience / expertise with OI	None, single ones, many	12
3.3.5	Frequency of interaction	How often does/did the company interact with external partners?	once, daily, weekly, monthly, annually	9
3.3.6	Duration of interaction	Over which average timespan did/does the company interact with external partners?	Days, weeks, months, years	9
3.4.1	Employees attitude towards external partners	How is the employees attitude towards external partners? Do they "meet on equal footing"? Indicator for need and effor of internal incentives or threads such as Not-Invented-Here syndrome	Reserved, neutral, positive, very positive	14
3.5.1	Internal method department	Does one or more internal departmnets exist which offer methodical support for product development teams? Indicator for internal support and potential OI-actors	yes, no	13
3.5.3	IT-collaboration systems	Are there special online platforms, company suggestion systems, supplier platforms, etc.?	yes, no	12
3.2.2	Applied OI-methods	Which OI-collaboration methods were / are applied? Indicator for expertise with OI	Idea contest, co-creation, OI communities, university cooperations, cross industry, etc.	9
3.3.2	Type of external partners	With what type of external partners has the company collaborated?	B2B / B2C / academia	6
3.3.4	Type of cooperation	Which ways of communication were used?	Personal meetings, workshops, webbased,	6
3.3.7	Typical duration of R&D projects	How long does an average R&D project last?	< 0.5 year, < 1 year, < 2 years, < 5 years, > 5 y.	7
Issue / Open Innovation goal				
4.1.2	Primary OI-project goal	What is the primary goal of the OI-project? --> Ensuring necessary awarenees in OI-team	Identifying market/user needs, Generation of ideas, Solution for technical problem, others	15
4.2.1	Innovation object	What is the innovation object of the OI-project?	Product, service, PSS, process, business case	13
4.2.3	Level of innovation	Which level of innovation shall be achived within the OI-project or by the superior development project?	radical innovation, incremental innovation (e.g. improvement, cost reduction),	15
4.2.4	Product-life-cycle phase	In which product-life-cycle phase is the innovation object regarded? --> Impact on e.g. number and type of suitable OI-actors	R&D, conception/development, production, after sales/maintenance	15
4.2.6	Minimum maturity level of OI-input	Which minimum level of maturity shall the OI-input by OI-actors have? --> Selection of OI-actors and OI-methods as well as assessment of OI-input	Ideas, concepts, CAD-models, prototypes, services	15
4.3.1	Modularity of innovation object	What is the level of modularity of the innovation object, e.g. in terms of number of components?	Monolytic, single components, completely modular	10
4.4.1	Project deadline	Until which date does the OI-project be completed? --> time restrictions	(weeks, month, years)	15
4.4.2	Available man power	What is the availability of (additional) man power?	very limited, limited but negotiable, freely available	15
4.4.3	Available budget	What financial budget can be spend on the OI-project?	very limited, limited but negotiable, freely available	15
4.3.2	Modularity of process	What is the level of modularity of the process belonging to the innovation object, e.g. in terms of process steps?	Monolytic, single optional steps, completely modular	8
4.5.2	Strategic location of OI-project in company	Where is the OI-project strategically located? --> Indicator for strategic support	department, business unit, innovation management, strategic management	9

Highest link strength

Figure 8 OI-situation attributes within the tool (grey: eliminated during mapping)

KO and trigger criteria

KO-criteria are used in product development and other fields for efficiently reducing a large variety of possibilities (Lindemann 2009). The selection approach of (Rothe et al. 2014) already used KO-criteria to assess the principal applicability of OI-methods.

However, they only considered a small set of OI-methods and excluded a holistic consideration of OI-situation and OI-partners. Thus, we analysed, which attributes of the reduced set of OI-situation and OI-partner attributes act as KO criteria or trigger criteria, which would prompt an OI-method. The assessment of the KO-/trigger-DMM was conducted autonomously by five project team members, indicating KO-links by "-1" and a trigger-link by "1". Subsequently, the five DMMs were aggregated. If three or more team members had set a criterion, it was directly kept. In the case of two, it was discussed in the whole team. In the case of one, it was dropped. At this, we could also proof that no attribute was assessed as both, KO and trigger criterion. The results are consistent with the KO-criteria of Rothe et al. (2014) but do not consider trivial KO-criteria, such as 'missing Lead-Users' excluding Lead-User workshops.

5 Tool implementation

Based on the requirement analysis, we aimed on developing an intuitive software tool, which only requires minimum information to be used. Since the tool shall only support but not make a decision, the suitability of the OI-methods is displayed as ranking. This serves as basis for a subsequent decision workshop of the responsible OI-team. To allow a broad application and avoid special software systems, we implemented the tool in Microsoft Excel. The request of transparency was considered by including the DMMs into the Excel-tool, but hiding the regarding spreadsheets. The underlying matrix-/DMM-approach allows a relatively easy extension. Instead of mapping all 27 attributes to each OI-method, only a new method profile needs to be added as vector.

Figure 9 illustrates the setup in the Excel tool, differentiated in underlying workflows and views. Views that are more detailed are presented in the following.

The ranking process starts, with the analysis of the OI-situation in **step 1**. The results of the OI-situation analysis (1b) and the assessment of the pre-selected OI-partners (1a) are inserted. The selected OI-partners are the result of SOI 2 (Guertler 2014), (Guertler et al. 2015). The tool allows the consideration of up to five OI-partners for the OI-method ranking. As depicted in Figure 10, the data input is realised by a graphical user interface based on check boxes, radio buttons and slider bars. It is also possible to weight each attribute independently – starting from a default value of five, the user can increase or decrease an attribute's relevance. Ten would be the highest relevance, one the lowest, and zero would exclude an attribute from the further assessment. In addition, it is possible to enable or disable entire domains – e.g. allowing a ranking only based on the OI-situation or two OI-partners. The user input is saved and processed as a vector within the tool.

Within **step 2**, the input vectors are multiplied with the OI-partners-method-DMM (2a), respectively OI-situation-method-DMM (2b).

The resulting intermediate vectors are multiplied with the OI-method-profile vectors in **step 3**. The resulting scores indicate the OI-methods suitability.

In parallel, **step 4** multiplies the input vectors with the OI-methods' KO- and trigger-criteria DMMs (4a and 4b). Within the tool, it is realised by one DMM, which indicates KO-criteria by "-1" entries and trigger-criteria by "1" entries.

This paper was presented at The XXVI ISPIM Conference – Shaping the Frontiers of Innovation Management, Budapest, Hungary on 14-17 June 2015. The publication is available to ISPIM members at www.ispim.org.

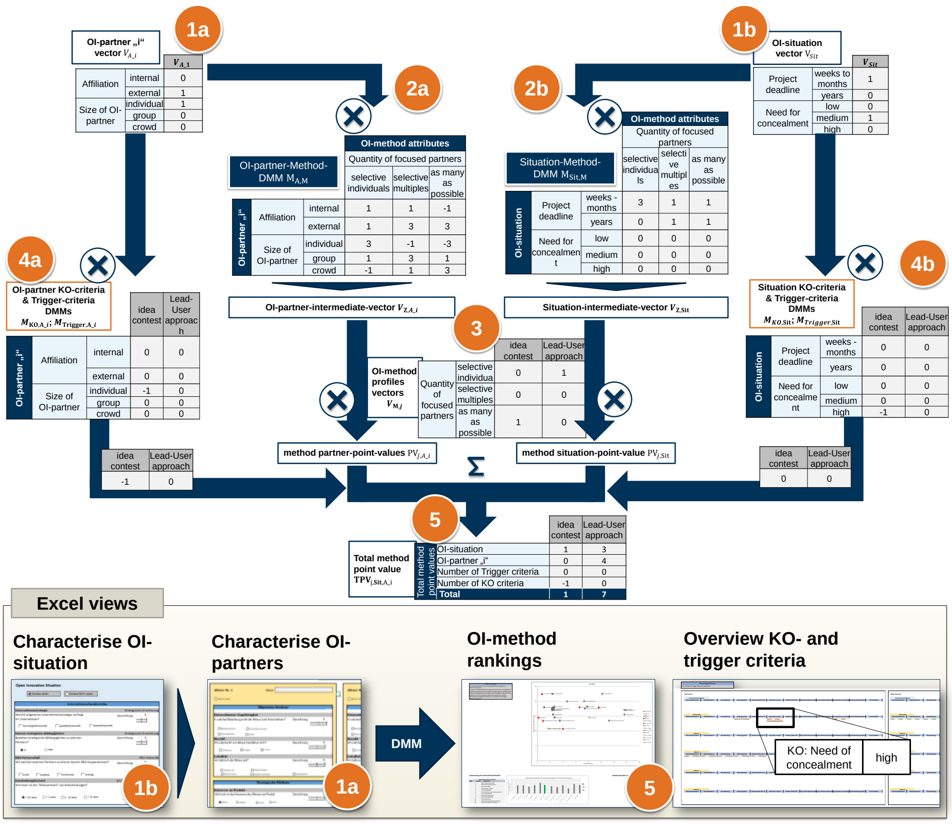


Figure 9 Simplified concept of ranking calculation and views of the Excel tool

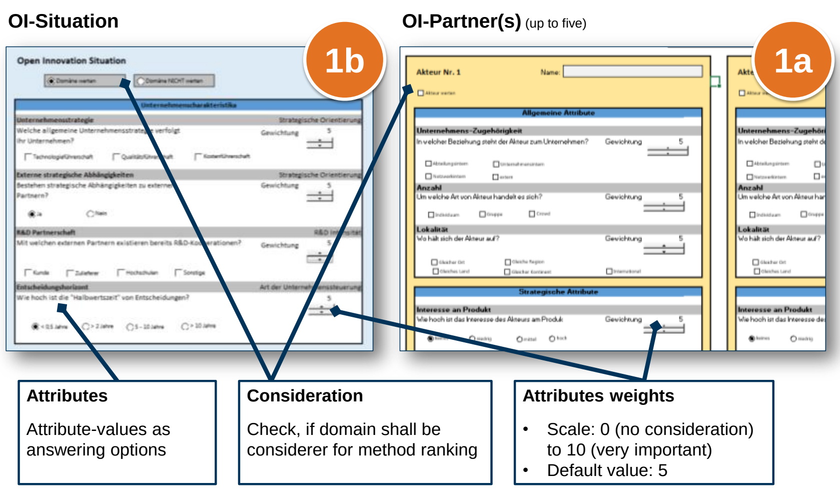
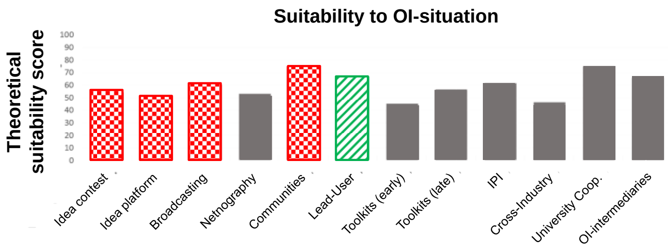


Figure 10 User interface for data input: OI-situation and up to five OI-partners

Step 5 combines the scores of each OI-method, the sum of KO-criteria and the sum of trigger-criteria. To avoid assessment corruptions, both KO- and trigger-criteria are not weighted and not considered for the ranking score. However, by colour coding and a separate spreadsheet they are transparently presented to the users. The ranking results are displayed in two forms: in a bar chart (Figure 11) and a portfolio (Figure 12).

The bar chart depicts the suitability of each OI-method. To allow a differentiated view, the tool contains different bar charts: only considering the OI-situation, as shown in Figure 11, or a combination of OI-situation and different OI-partners. The scores of each method are displayed in a table, which is automatically arranged (not possible for the bars at the moment). These scores are compared to a theoretical (in reality not existent) optimal OI-method. The resulting percentage value is then displayed in the bar chart: the higher the more suitable a method. If OI-methods hit one or more KO-criteria the regarding bars are displayed in red (for black-white prints, here: red checked). This indicates that the user needs to view the regarding spreadsheet, which shows in detail, which specific KO-criterion is not fulfilled. Analogously, OI-methods fulfilling specific trigger-criteria are highlighted in green (here: green striped).



OI-situation		
Rank	Score	OI-Method
1	1085	Communities for OI
2	1083	University cooperation
3	963	Lead-User approach
4	948	OI-intermediaries
5	887	Immersive Product Improvement
6	874	Broadcasting
7	813	Toolkit (late phase)
8	782	Idea contest
9	767	Netnography
10	738	Ideation platform
11	670	Cross-Industry
12	653	Toolkit (early phase)

normal
hitting KO-criteria
fulfilling trigger-criteria

Figure 11 Ranking according to suitability to OI-situation

The portfolio chart enhances the bar chart by a second dimension and allows a more detailed assessment, as illustrated in Figure 12. The y-axis depicts the suitability regarding the OI-situation, while the x-axis depicts the OI-partner suitability. Different OI-partners are differentiated by different marker forms, e.g. OI-partner 1 by a circle and OI-partners 2 by a square. While the y-position is the same for each OI-method-partner combination, the x-position varies. E.g., the two ‘university cooperation’ markers have the same OI-situation suitability, but the OI-method is more suitable for collaborating with OI-partner 2 than with OI-partner 1. OI-communities show the same score for both OI-partners, but the red highlighting indicates one or more unfulfilled KO-criteria.

As mentioned before, a separate spreadsheet shows all unfulfilled KO-criteria and fulfilled trigger-criteria for each OI-method, as shown in Figure 9. Hence, the tool user can evaluate if the regarding KO-criteria are critical and exclude an OI-method, or if they can be avoided by adapting the OI-method.

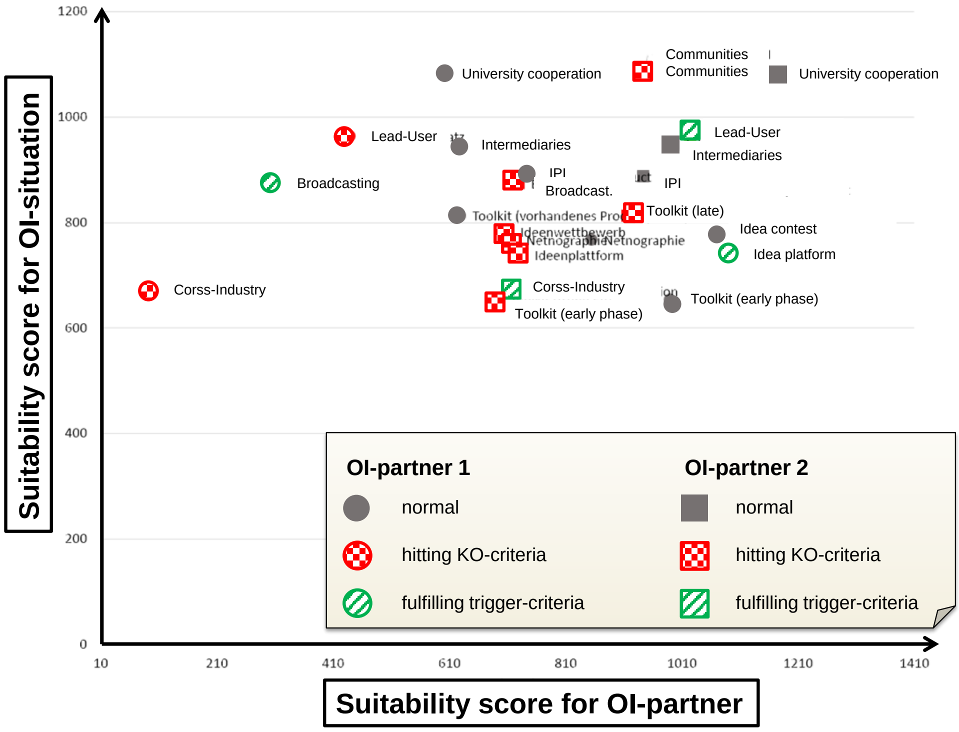
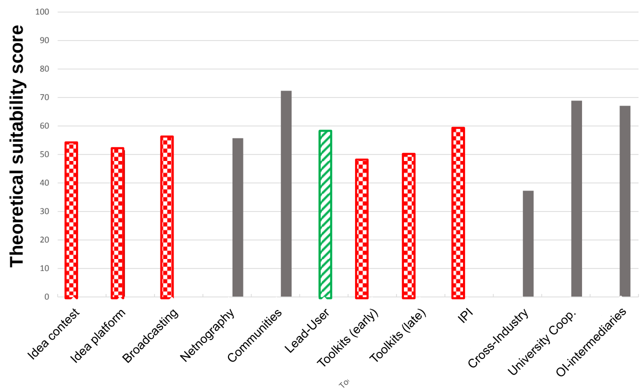


Figure 12 Portfolio ranking according to suitability to OI-situation and specific OI-partners

6 Initial industrial evaluation

The OI-method ranking and selection tool was tested in a first industrial evaluation. Due to the goals and current state of the regarding industry projects, not all features of the tool could be evaluated so far.

Company 1 was a SME and supplier of mechanical connection elements for B2B customers from the field of mechanical engineering. The overall goal was the development of a production process of a new robust material for highly strained mechanical parts. The principal process was already known and successfully implemented – but only on a laboratory-scale. Thus, the goal of the OI-project was the identification and collaboration with external partners in order to develop an industrially applicable, radical new production process. Resulting challenges of the project planning were the very specific topic and the high need of concealment due to the very competitive market situation. This was also considered in the OI-situation analysis within the tool. The attributes “Durability of strategic decisions” and “Modularity of process” were excluded since they could not be answered at that stage.



OI-situation		
Rank	**Score**	**OI-method**
1	1058	Communities for OI
2	1007	University cooperation
3	981	OI-intermediaries
4	871	Immersive Product Improvement
5	851	Lead-User Approach
6	817	Broadcasting
7	815	Netnography
8	793	Idea contest
9	753	Ideation platform
10	731	Toolkit (late phase)
11	696	Toolkit (early phase)
12	545	Cross-Industry-Innovation

Figure 13 OI-method ranking of company 1

Figure 13 shows the resulting ranking of OI-methods. Since the first OI-goal of identifying new partners was not completed, the ranking only considered the OI-situation. The most suitable OI-methods were communities, university cooperation and Lead-User approach, which also fulfilled the trigger criteria of direct access to (B2B) customers. Broadcasting, idea/tion contest and platform hit the KO-criterion of need of concealment. Both toolkits and IPI hit the KO-criterion of innovation object: process instead of product. The company could reflect if to exclude methods (e.g. due to concealment) or consider the adaption of OI-methods, e.g. implementing a special toolkit for process developments. Within the discursive evaluation of these results, they were assessed as reasonable. Only cross-industry innovation seemed to be ranked relatively low and needs to be checked in more detail.

Company 2 was a SME producing mechanical products, which were used by the customers of the primary B2B-customers. The products could be specified as non-high-tech products with a usage time of several years, which should be incrementally improved to solve a technical problem of a component. This problem had been known for decades. Though several in-house experiment had been conducted, no solution could have been found so far. Thus, the OI-goal was to identify external partners and collaborate with them for developing a new improved component. The regarding need of concealment was high but not as high as for company 1. For the tool, the duration of interaction and the product-life-cycle phase were excluded since they could not be distinctly defined. Though the partner search is still in progress, first potential OI-actors could already be identified. Due to simplification reasons, we only show one anonymised supplier. Besides others, it can be described by being in the same region, a neutral attitude to the company and the project, but only low interest in the OI-project since the regarding component was a mass product.

Figure 14 shows the resulting ranking portfolio. In this case, the relevant KO-criteria were high need of concealment and size of the OI-partner (one company), which excluded all crowdsourcing methods. The portfolio allows a better differentiation of OI-methods. While the situation-based ranking of broadcasting and university cooperation are similar, the partner-based ranking varies. Besides involving external experts by university cooperation, Lead-User approach or intermediaries, another option would be to find a way around the high need of concealment, e.g. by abstracting the technical task and submitting it to a larger group of experts by using communities or broadcasting.

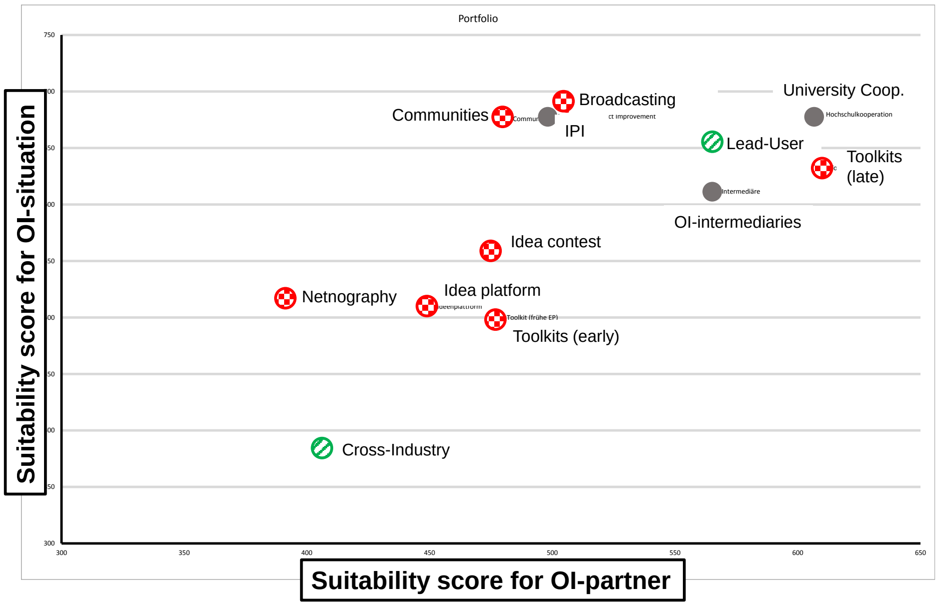


Figure 14 OI-method ranking of company 2

7 Limitations

The matrix-based OI-method ranking approach offered valuable support for identifying suitable OI-methods and indicating KO and trigger criteria, which could hinder or support the use of specific OI-methods.

However, the evaluation and subsequent discussion also revealed some limitations, which need to be addressed in subsequent research. From a research design perspective, the attribute-DMMs (Domain Mapping Matrix) showed a large variation between the team members, e.g. reaching from 277 DMM-links (unexperienced member) to 987 links. Though the independent mapping by the team members and subsequent deriving of a minimum limit of link-strengths supported objectivity, the DMM should be further verified on a sample basis. From a methodical perspective, the direct mapping of KO- and trigger criteria on the OI-methods contradicts the DMM-approach. Though the tool allows transparency in terms of providing all DMM tables, their complexity is quite high and not easily comprehensible if looking for specific links. This complicates the tool’s maintenance, e.g. when checking the reasons for the low scores of cross-industry innovations. So far, only 12 methods are included in the tool, which solely focus on outside-in OI. Though KO- and trigger criteria are shown, an overview of further advantages and disadvantages of each OI-methods is not given so far. A major limitation is a missing holistic evaluation, since the planning of the two industry projects is still in progress. Hence, only an evaluation of the suitability in terms of the OI-situation and one OI-partner was possible. At this, we need to evaluate the tool for the entire pool of potential OI-actors as well as observing the conduction of the OI-projects to check if the planning and selection of OI-methods were sufficient. Figure 15 summarizes the resulting requirement fulfilment.

	Requirement	Fulfilment	Comment
R 1	Supporting the selection decision	◔	Entire selection process could not be evaluated so far.
R 2	Ranking OI-methods regarding their situation and partner suitability	●	Realised by bar chart and portfolio chart
R 3	Ensuring transparency of the ranking process	◑	DMMs can be evaluated, but are complex
R 4	Showing advantages and disadvantages of each OI-method	◑	KO- and trigger criteria are displayed, but no further dis-/advantages
R 5	Allowing a future enhancement by further OI-methods	◕	Further methods can be added as profile vectors; but Excel not optimal
R 6	Ensuring an intuitive use of the resulting tool	◕	Intuitive use with radio buttons, check boxes, etc.; only short introduction
R 7	Using standard or freeware software to avoid acquiring special software	●	Implementation in Microsoft Excel
R 8	Using a lean approach with as small handling effort as possible	◕	Input only 27 attributes to determine; for adding OI-methods only 19 attributes

Figure 15 Overview of requirement fulfilment

8 Conclusion and outlook

The presented DMM-approach (Domain Mapping Matrix) maps OI-situation, OI-partner and OI-methods to rank OI-methods regarding their OI-project specific suitability. The mapping itself was realised by attributes characterising those three domains. Firstly, we mapped attributes, and then attribute values. Where necessary, we concretised attributes and defined regarding values. This also revealed attributes, which were mentioned in OI-literature but whether did not contain any link in the DMM, or for which no sufficient value scale could be defined. Thus, by deleting those characteristics, the profiles and linking model could be kept lean. Our industry partners stated this leanness as success criterion for industrial application. The linking model was implemented as Microsoft Excel tool, which allows a transparent tracing of the decision process. Another advantage is the easy extensibility by the use of DMMs: new OI-methods can be added as profile vectors. These OI-method-profiles allow the consideration of values ranges and can also be used tool-independently for a discursive selection process. The depiction of different ranking graphs and listing of KO- and trigger-criteria support an easy comparison of OI-methods. Besides the identification of suitable OI-methods, the DMM-approach/tool also allow the identification of suitable combinations of OI-partners and OI-methods by the portfolio chart.

The sets of characteristics allow a systematic and objective description of an OI-situation, OI-partners and OI-methods. We also evaluated these characteristics regarding their validity and applicability. By this, we contribute the three sets as well as the single characteristics to academia. In contrary to many other publications, these characteristics are distinctive and measurable. Other researches can benefit by using and adapting these characteristics for their own research. The selection tool for OI-methods and underlying linking model can be used by academia and industry to plan their OI-projects and systematically derive a ranked list of potential OI-methods. This especially supports planners with no or low OI-experience, but also supports experienced planners by suggesting alternative OI-methods. The ranking of OI-methods highlights the most suitable OI-methods but still leaves the final selection to the planners. This and the transparent ranking process allow a discussion of the suggested OI-methods within the planning team and considering of company-specific constraints. Other researchers can also adapt or enhance the linking model for their own research.

Though the results of the initial evaluation were promising, in the next step we need to further evaluate the DMM-approach. For this, we further observe the previously described industry projects in their conduction phase. In addition, we conduct a retrospective analysis of finished OI-project in industry to identify relationships between OI-situation, OI-partners and OI-methods. In the medium-term, a tool implementation in Microsoft Access is planned. This will combine the advantages of standard software with a better data handling, which better supports the expandability of the DMM-approach. In parallel, we will include the KO- and trigger-criteria in our DMMs to achieve a consistent mapping model. Based on this, we will enhance the pool of considered OI-methods by further OI-methods, such as tech shops, application research and inside-out OI-methods.

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