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**Actor networks and the construction of applicable knowledge: the case of the Timbre Brownfield Prioritization Tool**

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**Abstract**

This article deals with experiences acquired during the process of developing the Timbre Brownfield Prioritization Tool (TBPT). Developing a decision support tool that takes into account the expectations and experiences of its potential users is similar to creating applicable knowledge by the joint action of scientists and heterogeneous actors. Actor network theory is used to explore the construction of this form of applicable knowledge as a process of actor network creation. Following the French sociologist Callon, networks are seen to be initiated and carried out by a group of scientists (tool developers) via four moments of translation, called problematization, interessement, enrolment and mobilization. Each step in the construction of the TBPT—from the initial research question to the final model—can be linked in retrospect to changing configurations of actor networks. Based on the experiences of the tool developers in the Czech Republic, Poland, Germany and Romania, we illustrate how these configurations varied across space and time. This contribution emphasizes the ability to correlate gains in knowledge with the more visible changes in the scope of actor networks in order to highlight achievements but also limitations in acquiring applicable knowledge.

**Keywords**

Actor network theory, Applicable knowledge, Brownfield prioritization, Four moments of translation, End-users, Timbre research project

## Introduction

The development of decision support tools or systems (DSTs and DSSs) has proliferated in various areas of decision-making over the last decades (Shim et al. 2002). Environmental management and policy have made no exception to this trend (El-Gayar and Fritz 2006). A recent overview of the field by Sean Eom (2011) has shown, among others, the emergence of a branch of DSS that aims "to systematically identify factors, which will influence the implementation success of DSS so that those critical factors can be managed effectively" (Eom 2011: 58).

The recognition that the interaction between tool and user is crucial for understanding how a DST will be used is anything but new. Mason and Mitroff (1973) defined an information system as consisting of at least one person, having a certain psychological makeup, facing a problem within an organizational context and employing evidence to arrive at a solution. Over the years, a number of researchers have explored the cognitive and personality characteristics of users but also their situational factors, such as involvement in tool development or experience (Eom 2011).

Still, there is a persistent gap between the scientific and technical side of tool development and its user-related (or social) side. Users tend to perceive DSTs as black boxes, when the technological operation of such tools remains obscure to them due to their mathematical complexity (Bartke and Schwarze 2015). When they do not trust DSTs, users prefer to make decisions by themselves (Semezin and Sutter 2009) or opt out of the use of decision aids altogether (Bojovic et al. 2015). At the other end, tool developers are faced with the challenge of integrating models, databases and other components of decision support and "package them in way that decision-makers can use" (Rizzoli and Young 1997: 237). This "packaging" is anything but straightforward. There are many challenges in this process, such as the existence of different categories of stakeholders with different professional backgrounds, technical proficiencies and managerial roles, located in different national and institutional contexts. This means that constructing a DST requires factoring in all these variables in a complex process of tool construction. This process is seldom exposed to critical scrutiny. Given this fact, tool developers are often deprived of the learning experience of what works and what does not in tool development and especially of which combinations lead to achievements or to failures. Actor network theory is a social science theory that aims explicitly at illuminating how hybrid constructs originate in science, are mediated by technology and are then offered on the market (Callon 1990). In the words of Callon et al. (2009: 42), actor network theory is about restoring the bond "between those whose profession is to produce knowledge and those to whom this knowledge is immediately or distantly addressed". The appeal of this theory for understanding DST development and implementation is significant, and this article shows how it can be applied in a concrete case.

We analyse the construction of a DST for brownfield regeneration—the Timbre[1] Brownfield Prioritization Tool—through an actor network theory (ANT) lens, in order to show, first, that providing technologies to support human decisions is a process of mobilizing a variety of actors, both human and non-human,[2] and that, if successful, each of these mobilizations is a gain in applicable knowledge. Second, by observing this process in detail, one is better equipped to understand the strengths and weaknesses of the proposed tool.

Employing actor network theory means elevating our understanding above the usual distinctions—such as those between social science and natural science, experts and stakeholders, tool creation and tool use—towards a more holistic, realistic and progressive view of DST development. The latter is a particular instance of what has been called "science in action" (Latour 1987). How else could a DST be better characterized if not as science put in the hands of non-scientists? The achieved understanding is deemed holistic since it considers tool construction and (test-)use as part of the same process, realistic because it traces in detail how the tool was assembled from various elements and their connections (Latour 2005) and progressive because it underscores the critical role of stakeholders in making the tool possible in the first place and in improving it continuously.

The Timbre Brownfield Prioritization Tool (TBPT) has been described elsewhere, in terms of its technical construction (Pizzol et al. 2016) and applicability (Bartke et al. 2016). In contrast to these publications, this article does not address any of the methodological and functional characteristics of the TBPT but illuminates how these characteristics are the result of more or less enduring connections established between tool developers, texts, software, stakeholders, data and national institutional practices. The basic argument is that the stronger the connections that are built among these elements, the stronger the resulting networks and the more robust the tool can be said to be. A note on terminology is in order, as ANT uses specific terms that may seem unusual to readers less familiar with this theory. Concepts such as actor network, interessement, obligatory passage point describe at a highly general level the construction of networks and will be explained and illustrated below.

The next section offers a reinterpretation of tool development as the construction of an actor network and highlights the insights gained thereby. In the third part, the case study of the Timbre Brownfield Prioritization Tool and the methods of data collection are outlined. The fourth section analyses ex post facto the stepwise building of the TBPT network, highlighting its strengths and weaknesses. The fifth section outlines the conclusion and sketches some preliminary observations and criteria derived from this case study that are applicable to DST research in general and the development of European projects in particular.

**Actor networks and decision support tool creation**

Why should ANT be relevant for the study of DST? First of all, actor network theory originated in the social scientific study of laboratory science. In one of the earliest contributions, Latour and Woolgar (1979) explored how scientific discoveries in the laboratory are bound up with a wide array of human and non-human entities. Understanding science, the argument went, is about understanding these connections rather than separating the realm of pure science from that of mundane human practices and interactions. In what seemed at first a controversial argument, the authors claimed that a scientific fact is constructed as such by carefully mobilizing natural processes, technologies and tools and scientific colleagues in showing and reiterating that the fact is real and "out-there", against all possible challenges that might show otherwise (Latour 1999). Latour and Woolgar (1979) used the analogy of constructing a house to describe scientific discoveries: the better its building blocks are connected to each other, the better it will withstand pressures and the sturdier it will be. The extent to which a science is connected to its heterogeneous "context"[3] is a measure of how accurate, verifiable and solid it is (Latour 1999).

Second, DSTs were developed early on to deal with semi-structured or unstructured decision contexts (Courtney 2001). ANT provides a way to engage with these contexts, not by trying to shed their ambiguous and messy parts (McIntosh et al. 2011), but by acknowledging that some of the messiness, if carefully studied and understood, might be a source of strength. ANT aims to bring new conceptual order into the unstructured universe of tool development (Callon 1986).

Third and most pragmatic, ANT helps address existing gaps in how scientific products are "engaged with", "used" or "adopted" by non-scientists and sundry users. In their review of the literature, Arnott and Pervan (2005: 67) identified as a "major omission" the "poor identification of the clients and users of the various DSS applications". In environmental research, McIntosh et al. (2011) outlined several categories of challenges in the development of DSTs. In the specific case of remediation DST, Onwubuya et al. (2009) contrasted, among others, the unbiased calculability of the scientific approach and the possible biases of human judgement. In all these cases, there is a problematic gap between science and real life.

The added insight of ANT for the DST literature is that it throws new light on these various challenges. They all have an underlying cause, which is determined by the kinds and strengths of connections on which they rely. This is the deep meaning of actor network theory: science and society are not separate domains or spheres but rather networks of heterogeneous materials (Callon and Law

1997). The quality of science and the degree of its applicability in society depend on the configuration of these networks. If networks are extensive across scientific and social entities, if they are convergent and stable as well as irreversible in their construction, the applicability of scientific products (such as DSTs) is high (Callon 1990). Such networks can be said to enable applicable knowledge. On the contrary, if some of the links become dis-aligned, if they lose their convergence in the course of tool construction, the limits of applicability become apparent. We therefore propose an assessment of how applicable a DST is by exploring the connections that led to its emergence.

ANT relies on several explanatory principles. First is the principle of generalized symmetry which involves treating in the same way "controversies which pertain to nature and those which pertain to society" (Callon 2007[1986a]: 72). More recently Gad and Jensen (2010: 58) have explained generalized symmetry as the principle that "all things are what they are in relation to other things, not because of essential qualities". A corollary of the generalized symmetry principle is what Callon et al. (2009) call "distributed intelligence": the achievements of scientists are possible due to the work of instruments, computers, computational methods but also of other researchers, aspiring researchers, technicians, secretaries, etc. (the entities forming a heterogeneous network) who make the scientific work possible. Distributed intelligence helps to bring to light what the concept of "decision support tool" tends to obscure, namely that the actors who are to wield the tools, the decision-makers and their consultants[4] also contribute to making the DST what it is. Tool users are themselves part of the distributed intelligence, since users embody various "forms of know-how, knacks, knowledge" (Callon et al 2009: 58), such as literacy, ability to interpret various outputs and communication skills, without which the use of the tool would be impossible.

We contend that taking into account and mobilizing all the distributed intelligence surrounding the construction of a DST makes the tool all the more robust and tailored to its various users (Gross 2006). This is also because users and consumers assume an ever greater role in defining demand and thus become "experts in experiences" (Callon and Rabeharisoa 2003: 194). Capturing these experiences in a systematic way is crucial for improving the relevance of DST research (Arnott and Pervan 2008).

However, these experiences do not always add up in a linear and transparent fashion. The process by which a "vague idea is shaped, diverted, and consolidated to build up a network of allies" (Boerboom and Ferretti 2014: 84) can have many twists and turns. In order to map this sinuous process, we employ Callon's (2007) paradigmatic case study of the domestication of scallops. His aim is to "see the simultaneous production of knowledge and construction of a network of relationships" (Callon 2007: 59), and the chosen strategy is to follow actors in their construction-deconstruction of nature and society. Tracing the actors' work occurs via four "moments of translation"—problematization, interessement, enrolment and mobilization—in which the production of networks and of knowledge proceed along parallel paths (Callon 2007). In this article, we investigate the four moments by retrospectively interpreting the actions of a group of scientists developing a DST for brownfield prioritization. Tracing these four moments is important because with every new shape that the network of actors assumes, knowledge is gained or strengthened or, on the contrary, weakened or lost. In the remainder of this section, the four moments are described in relation to DST development.

Problematization occurs when the initiating actors define a problem that interests a broader collective, consisting at a minimum of the intended users of the tool and of potential competitors similarly engaged in tool building. All these actors are assigned distinct identities and are attributed specific roles in the problem formulation so that they are "persuaded to identify with the network" (Murdoch 1998: 361). At this early stage, the initiators need to display technical skills but also marketing, networking and even moral skills, for example when debating which are the "right" or "wrong" uses of the tool to be developed (Callon 1990).

Problematization is a necessary step for DST development. However, McIntosh et al. (2011) showed that environmental DST developers often lack engagement strategies that assign clear roles to end-users in tool development (for how this may be about to change, see Sandink et al. 2016). However, problematization is broader than engagement because it is a two-way process: an invitation to join the network/collective is extended and a response expected. The question is whether the skilful deployment of an engagement strategy will actually work with the intended users. Here the concept of "obligatory passage point" furthers our understanding of engagement challenges: it shows that to all those involved, the collective about to be constructed needs to appear indispensable (Callon et al. 2009). "You cannot succeed without going through me" (Callon and Latour 1981: 279) is what the initiators of DST say and what needs to ring credible in the ears of those supposed to join. In DST terms, the tool should appear as necessary to reach developers' goals and but also for users' varied purposes. If the involved stakeholders perceive this indispensability, the problematization, as the first step of the engagement strategy, has been successful.

Getting actors to agree to become jointly involved in solving a problem of more general interest[5] is only one side of the task of the tool developers. The other side is revealed when testing whether the involvement has actually taken place. This is the second moment, that of interessement, which refers to "the group of actions by which an entity [the tool developers] attempts to impose and stabilize the other actors it defines through its problematization" (Callon 2007: 62). Interessement means interposing between the actors enticed to participate in the network and other entities that might lay similar claims on them, effective barriers. Interessement devices can be different intermediaries, such as texts, technical artefacts, humans or money (Callon 1990) that are meant to dissociate the actors from other problematizations. Interessement needs to be employed in DST development in order to deal with the adoption challenges of such tools, such as lack of capacity or system characteristics (McIntosh et al. 2011). One such device is a fully functional DST offered to end-users to demonstrate its superiority to other tools or approaches. The downside is that a complete tool cannot incorporate further feedback (McIntosh et al. 2011).

This dilemma illustrates a more general problem of interessement: managing to lock into place some actors may mean locking others out. The latter are those who refuse to yield to the problematization of the initiators and remain instead more closely tied to alternative (perhaps rival) problematizations. This creates a bifurcation in the network construction process: the network assumes an inside and an outside. Inside, the assembling of the network and its corresponding construction of applicable knowledge continue with the other moments of translation, namely enrolment and mobilization. What remains on the outside of the network, the failed connections so to speak, is also very useful because it aids in understanding the limits of the applicability of the knowledge achieved.

Enrolment is about defining and coordinating the roles in the network, once these have been accepted. "To describe enrolment", Callon states, "is to describe the group of multilateral negotiations, trials of strength, and tricks that accompany the interessement and enable them to succeed" (Callon 2007: 66). Applied to DST development, the different actors need to work together to find the best way to create the tool. Negotiations are needed because the actors who have been interested in the tool development have given up alternative networks and so need to reach a *modus vivendi* (Callon 2007: 67) with the initiating scientists and others. Trials of strength are required because actors do not remain in the network by mere inertia but have to be actively kept in.

Finally, mobilization is about setting the actors into motion. To achieve a DST, especially a web-based tool, requires the displacement of all the actors and their transfer in the abstract space of the online environment. It requires a set of complex transformations whereby actors' preferences, feedbacks, workshop discussions or survey questions and answers are converted into numbers and concepts, which are, in turn, displayed as models and tables. The latter can then be widely distributed as a generally applicable tool (Latour 1987).

Mobilization is important because from the mass of dispersed and relatively inaccessible entities, from this amorphous configuration of actors, the initiators manage to concentrate and put on display a parsimonious decision-making tool.

However, mobilization is by necessity restricted: not all actors—end-users, data, rules and regulations, policy priorities—participate directly in the final product (the DST). For this reason, it is necessary to establish representatives or spokespersons, who use chains of intermediaries going back from the abstract elements of the tool to their concrete referents. If the spokespersons are representative, the tool appears to be valid. The way a DST is constructed validates its goal of being a decision *support* tool.

This is the last moment of the actor network. Callon summarizes all that has happened during this process: "The initial problematization defined a series of negotiable hypotheses on identity, relationships, and goals of the different actors. Now at the end of the four moments described, a constraining network of relationships [an actor network] has been built" (Callon 2007: 72).

The description of the process is not complete without mentioning episodes of dissidence or betrayal of the network. This reminds once again of the principle of symmetry: humans and others can refuse to join the network and in this way place limits on the applicability of the knowledge it produces. The bifurcation of networks marks a first moment of dissidence, but the latter can happen also during the later moments of enrolment and mobilization. Controversies among scientists or between scientists and users indicate that some actors are on the verge of defecting. Callon (2007) explained that controversy refers to all manifestations by which the representativity of a spokesperson (actor) is questioned or even rejected. In terms of DST development, calling into question the presence of some actors in the network or their direct withdrawal from the same network means that the applicability of the knowledge generated undergoes some form of contraction or shift.

**Case study introduction and methods**

To illustrate the usefulness of an ANT-inspired approach to DST development, we used a case study in which a tool—the TBPT—was developed with the explicit aim to be tailorable to specific users' needs. The achievement was partial rather than entirely successful, and it is for these reasons that ANT offers a valuable ex post facto interpretation. An entirely accepted network and its corresponding DS tool shed its history (Callon 1990) so that one cannot learn much from it. We prefer to offer a realistic story, by retracing the ups and downs of tool development in terms of the four moments, and therefore illustrate in useful detail how the actors involved became engaged with one another, under which circumstances they maintained their relationships or not, and how the outcome of these relationships shaped the final DST product. The development of the TBPT was not guided by Callon's four moments. Our aim is rather to use these moments to make sense in a systematic and novel way of what happened during the development of the tool, while generating insights not available at that time. The presentation of the case will be carried out simultaneously with its interpretation; hence, this section includes only a brief introduction to the case, an approach entirely consistent with ANT-inspired analyses (Walsham and Sahay 1999).

The development of the Timbre Brownfield Prioritization Tool took place between June 2011 and May 2014 as part of the EU-funded Timbre project. The TBPT was developed within the "prioritization" work package, headed by one member of the Timbre consortium (the Institute of Geonics, Czech Republic). Seven other partners, including two research institutes, two universities, one national environmental authority, one small enterprise and one brownfield portfolio holder were formally involved in this work package. This means that they took part in formal and informal meetings to discuss what worked (and what did not) in two respects: (1) developing the tool, that is, obtaining a final output to show to the project's funders and (2) tailoring the tool to its would-be users. These two goals overlapped but pursuing them both proved challenging while constructing the network.

The main method of data collection was participant observation, by which the tool developers and their project-internal partners observed and reflected upon their experiences. This source of information was verified and complemented through the analysis of publicly available materials, especially the three deliverable reports of the prioritization work package (Frantál et al. 2012; Klusáček et al. 2013, 2014), the written internal minutes from regular project meetings and conference calls of the TBPT work package or of the steering committee of the project, and records from workshops and meetings with stakeholders in the four studied countries (Czech Republic, Germany, Poland and Romania).

The collected data were jointly analysed by the authors of this article over the following steps. First, the tool developers reported on their experiences in constructing the tool by writing an extensive description of the process. In order to ensure a useful critical distance, their report was analysed and interpreted in a second step by other project partners, who had not been directly involved in the tool development process. Their observations and interpretations, formulated in terms of actor network theory, were then assessed for validity by the tool developers. There was an almost general consensus that the interpretation of the facts was valid. In addition, the paper was reviewed by two German TBPT end-users. Although they recognized that the paper was written for a broader scientific audience, they still found the text understandable. Moreover, they strongly welcomed the effort of scientists to think about the smarter design process of practice-oriented decision support tools. They felt the paper is an important contribution in this regard.

**Results and interpretation: the prioritization tool development process as network construction**

In this analytical section, the chronological sequence of implementing the research project is presented, from the scientific formulation of the proposal to its final form.[6] Throughout the reconstruction of the tool development process, we highlight the shifting network configurations that accompanied it. In this way, we deepen the current understanding of stakeholder involvement by showing that the tool is from its very beginning to the end an outcome of connections among heterogeneous elements, including researchers, project requirements, standards, meanings and various human users, real or intended. The principle of symmetry is to be constantly born in mind, as it keeps researchers alert to the idea that any actor in the network can initiate action (establishing or reconfiguring connections) or block such action (by withdrawing from connections). We highlight both success and failure in tool development in terms of how convergent the network appears at any point in time. Throughout the analysis, emphasis is placed on gains in knowledge and on a realistic depiction of the case, with the intention to allow the reader to further reflect on similar experiences.

**Setting the stage: structured outputs expected from unstructured inputs**

The story starts with a group of scientists (geographers) from the Institute of Geonics in the Czech Republic, who join the Timbre EU-funded research project. As part of the project proposal negotiations, they agree to take over the coordination of the work package entitled "Success metrics and prioritization tool". Based on the description of work (Timbre 2010), the question that these scientists need to tackle is: how to develop a tailored tool for brownfield prioritization that enables stakeholders involved in brownfield regeneration in different European countries to manage brownfields and assess success? The question already points to two sets of relationships which the scientists need to connect: on the one hand, the project funders and managers expect them to deliver a finished product, a tool, characterized by precise and standardized norms with general applicability (Callon 1990). On the other hand, the scientists know that they need to engage with an amorphous group of stakeholders, who are expected to provide inputs for the tool (Callon 2007). In Callon's terms (1990), the scientists need to convert the stories of the stakeholders into neat numerical expressions.

Why speak of stories here? According to the description of work, the TBPT needs to build on several case studies from the Czech Republic, Poland and Romania. As the brownfield *problematique* is less than a decade old in these countries (see Garb and Jackson 2010 for the Czech Republic and Cobârzan 2007; Popescu and Pătrăşcoiu 2012 for Romania), the information available is very scant and presumably unstructured. This fact sets before the Czech scientists an unenviable task: they need to derive structured and even numerical inputs for a prioritization tool from data sources whose very existence is uncertain. With this information, the stage is set for the entry of the actors with whom the Czech scientists will need to build a complex collaboration in order to develop the tool.

**The TBPT as obligatory passage point**

Several months after the beginning of the project, the first annual meeting takes place. As with all work package leaders, the geographers present their plan for completing the tasks assigned to them. What concerns us here is their effort to establish a set of alliances to make their work possible (Jóhannesson 2005). In particular, they need support from the International Advisory Board (IAB) of the project to ensure the scientific and technical legitimacy of the research they are about to begin. They also seek to enlist the support of the national project partners from Germany, Poland and Romania to define and measure “success” in these countries and also tentatively inquire about data availability for the DST. Both groups are interested to support the project, *in principle*: the IAB, consisting of experienced scientists and practitioners, is interested in the responsible management of contaminated or derelict land, for which a prioritization tool is useful. The national project partners are expected to be similarly supportive since the tool promises to address a pressing practical problem: in the face of limited resources, how are practitioners to select the best candidates for regeneration? Moreover, a transfer of know-how from the more experienced West to the East in matters of brownfield management seems welcome (Pippin 2009).

In ANT terms, the Czech geographers position themselves as an obligatory passage point for three categories of actors. They identify as the developers of a unique tool developed at high standards of scientificity (satisfying the IAB), applied in a pioneering way to several Eastern European countries and thus benefitting the national project partners and possibly other end-users from these countries. These actors can be said to constitute the original triangle of actors having an interest in the TBPT development (see Fig. 1). The tool developers have the most direct interest in developing the prioritization tool, a fact which is suggested by the straight arrow in Fig. 1. For all the other actors, however, as the tool is not their main goal, their interests do not intersect those of the tool developers, as suggested by the parallel dashed arrows. They need to be enticed in becoming involved in the tool development process. Indeed, despite the seemingly obvious benefits of the TBPT, not everyone agrees to support the tool.

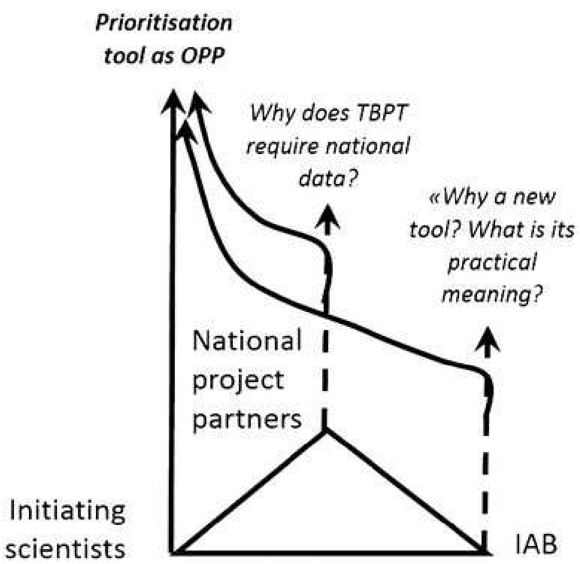


Fig. 1 TBPT as obligatory passage point for the initial network actors. *Source*: authors’ own interpretation, inspired from Callon (2007)

The curved arrows suggest that their interests in the TBPT are initially blocked by unfavourable or at least indifferent interests for the TBPT. The IAB is concerned not only with the scientific but also the practical and market relevance of the tool: "The web-based TBP-Tool is only a nice word but what is the content—what is the concrete meaning?" (IAB member, Leipzig, 2011). In particular, the IAB recommends an "expanded list of stakeholders" (IAB 2012) so that the target groups of the tools (including the TBPT) are clearly identified and engaged with. In response, the initiating scientists engage in some intensive soul-searching and "networking" by trying to learn as much as possible about stakeholders, especially about the little known ones in Poland and Romania. The outcome of this interaction is positive: the scientists take active steps to develop a stakeholder-engaging tool (TBPT), a decision which leads to an increased number of connections. The IAB, in turn, accepts the TBPT as an obligatory passage point (OPP) for it as well, by vouching for its usefulness (the initially straight arrow from the IAB suffers a detour towards the OPP in Fig. 1).

What has become a source of the scientists' strength in the eyes of the IAB—the relevance of the TBPT for end-users from different countries—is nevertheless a problem in the eyes of the national project partners from Germany, Poland and Romania. This is unexpected for the Czech scientists. Based on their experience that brownfield databases are at least partly available to the public at the national (Czech National Database of Brownfields, 2008), regional (for example Liberecký Region database 2013) and municipal (Brno Brownfields 2013) levels, they find out that in Germany and in Romania brownfield databases are not publicly available and their data under protection. The Romanian and German project partners—representing the national environmental authority and a brownfield register owner, respectively—ask: "Why do you need these databases?" (National partner, Leipzig, 2011). They imply that they do not want to join the network initiated by the Czech scientists if they need to also bring along their data. The problem is challenging for the tool developers, since the first stage of the tool development—gathering intelligence (McIntosh et al. 2011)—cannot be completed as planned. From an ANT perspective, the problem itself is significant and so is its resolution (the latter to be discussed in the following sections).

The problem is significant because of the symmetry principle: the national partners reveal themselves not as simple stakeholders merely responding to the engagement offer of the scientists. They are actors in their own right and the fact that they initially refuse to join the network is not due to some individual reasons, such as perceived usefulness or subjective norms, but to "external pressure" (Diez and McIntosh 2009). The national project partners do not partake in the actor network of the Czech scientists, but also in the *competing* networks of other actors, for example, those of their national administrations. These "troublesome" networks—as they undoubtedly appeared to the initiating scientists—will be revealed in their knowledge-generating implications in "Enrolment and mobilization: the scope and limits of the TBPT" section.

### Interessement and the bifurcation of actor networks

With the concept of interessement, we highlight scientists' initiative and continued network building efforts. To reiterate, for Callon (2007) interessement is a way of locking actors into the actor network. This locking-in can be more or less successful, since it also depends—symmetrically to the initiative of the scientists—on the willingness of actors to accept to be locked-in. In fact, by way of interessement devices—of which some examples are offered below—the actors are organized either *in* or *out* of the tool development network. A bifurcation occurs: those who remain within the network—aligned with the other actors—contribute to the growing stock of applicable knowledge. Those actors who are more powerfully co-opted by competing actor networks are organized out of the TBPT network, and hence, their potential contribution is lost.

In order to develop the TBPT, the Czech scientists use several interessement devices. The first are direct negotiations, as illustrated above with the members of the IAB. The initiating scientists also approach the national project partners with the argument that the developed tool will also benefit them and possibly other users from their respective countries. A shift in the attitude of the project partners is discernible: from the blunt questioning of why the restricted-use databases are needed to a more accommodating position: "Why don't you create the TBPT based on a generic data set, and then we will tell you if it is useful for us or not?" Even if they do not (yet) accept the TBPT as an obligatory passage point, they move closer to such a position. Unabated in their commitment, the Czech scientists explain that the brownfield databases from Poland, Germany and Romania are very important because, if the task is to develop the TBP-Tool, then it is therefore necessary to get some information about how such databases are organized and about what data and information they contain. The argument proves sensible. The Polish partners agree to provide complete brownfield databases for one region (Silesia), while the Romanian and German partners provide samples from their databases. For the initiating scientists, this is an acceptable compromise and the TBPT continues its progress.

A second interessement device is a questionnaire survey on success factors and barriers in brownfield regeneration in the four countries. Common definitions of success in regeneration are absent in these countries. First, the basic term *brownfield* is seen to have different definitions, which also vary across time in the studied countries (Frantál et al. 2015: 96). While in Romania the term *brownfield* always implies the presence of pollution, in the Czech Republic brownfields may be either polluted or unpolluted sites. This means that the brownfields listed in the Czech Republic include contaminated brownfield sites (e.g. former industrial, military or transport sites) but also sites with no pollution identified (e.g. former military barracks or unfinished supermarkets) (e.g. Review of Brno Brownfields Revitalisation 2013). Moreover, different groups of stakeholders within the same country do not necessarily share the same understanding of *brownfields*. Second, looking for examples of successful brownfield regeneration in the four countries is problematic. The Romanian project partner informs the Czech scientists that there are no official examples of regenerated brownfields in Romania and that it is therefore impossible to provide cases of successful regeneration.

Faced with these uncertainties, the survey to be applied to national stakeholder is a useful way to distill some precise and measurable meanings associated with the words "success" and "failure", from a context that is largely inimical to the aims of the tool developers. As with the negotiation on the availability of databases with the national project partners, the developers make a new gain for the tool construction network. The network is enlarged with 347 data points, the number of surveys collected. In terms of individual countries, the interessement works best in the case of Romania: the largest number of completed questionnaires (119) is collected in this country, where the Romanian project partner uses his institutional channels to request the completion of the surveys as a work-related duty. The lowest number of completed questionnaire forms (59 surveys) is collected in Germany, which may be caused by the fact that the distribution of the questionnaire forms was largely conducted by electronic communication. The Polish (68) and Czech (101) cases fall in between. From these data, the Czech scientists, together with a team of Italian scientists, derive 15 factors and corresponding weights, to be used as default values in the TBPT (Pizzol et al. 2016). Incorporating and synthesizing survey data into the network brings forward the next step of the tool construction network, namely enrolment.

**Enrolment and mobilization: the scope and limits of the TBPT**

At the beginning of the previous section, the idea of a bifurcating network has been introduced. The tool developers pursue their goal of creating the TBPT and achieve a result that holds together a number of actors. These actors have become enrolled into the network. They carry out the roles assigned to them, and the alignment of their connections reflects the scope of applicable knowledge achieved so far. They can be seen as conduits for the assembling of the knowledge that will be used in the tool. On the other hand, the actors who fail to become enrolled dis-align or disengage from the network. They indicate the limits of the tool. Both processes are depicted in Fig. 2 and are described below. The black arrows connecting different actors (full circles) reveal the channels by which the

TBPT has been assembled, while the red arrows and the dashed circles show the actors opting-out from the network.

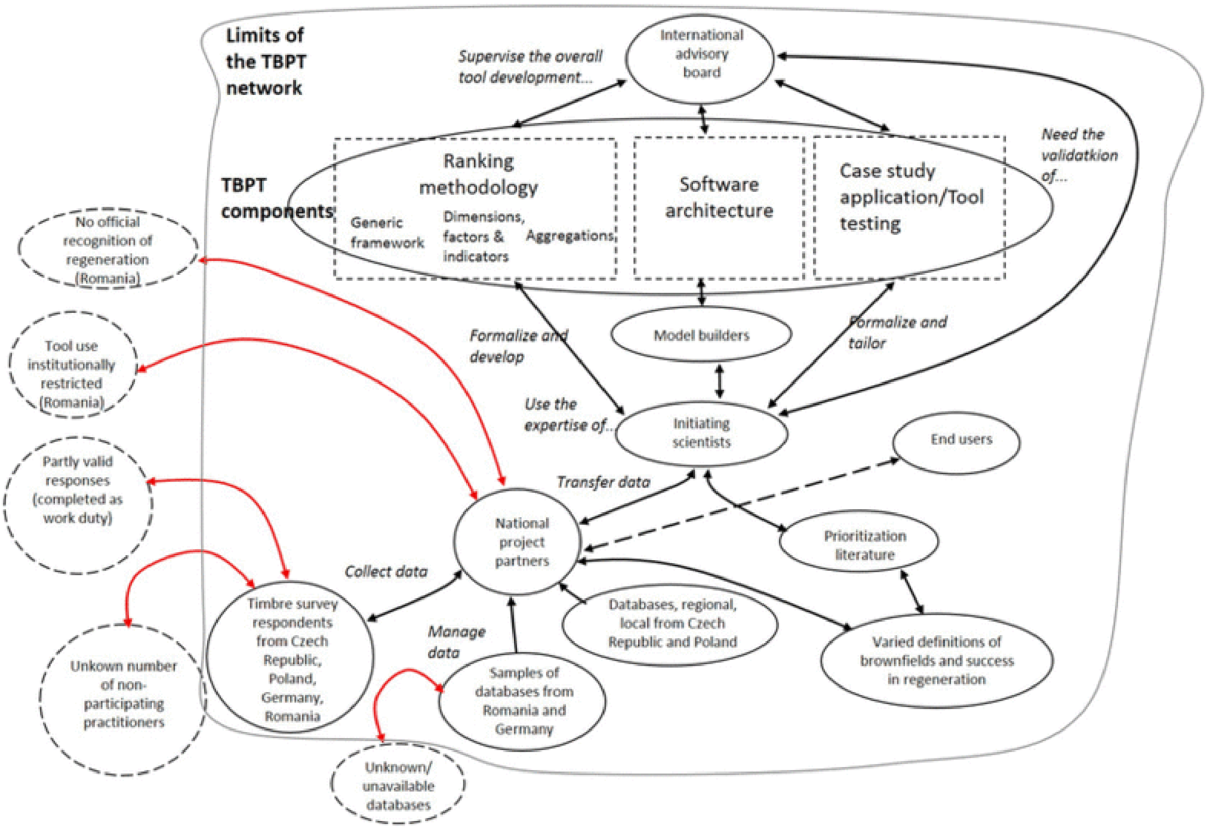


Fig. 2 Actors enrolled in the network (*full circles*) and actors leaving the translation (*dashed circles*). *Source*: Pizzol et al. (2016) for the TBPT components and authors' own interpretation

For those who accept the enrolment, mobilization is set in motion. After the cautious negotiations with various actors during problematization and interessement, the work of constructing the tool begins in earnest. The sample of survey respondents is influenced by the organizers of the survey, who contact the potential respondents among their contacts. In the countries where the survey is organized by research institutes (the Czech Republic and Poland), most respondents are from the research community, while in Romania, where the survey is conducted by the public administration, the environmental authorities are best represented. The collected data are further processed, and the scientists in charge derive from the surveys and the prioritization literature factors and weights to be used in the TBPT. In their work, they also rely on the contribution of model builders and software developers from within the Timbre project. The overall approach continues to be validated by the IAB. The final TBPT consists of three components, namely a ranking methodology, a software component and case study/tool testing component.

The tool construction proves successful. Its pilot version is tested and assessed in writing by six project-internal experts. Its usability is also tested by 55 users who were not directly related to the TBPT development, namely 24 in Ostrava, the Czech Republic, 16 in Berlin, Germany, and 15 in Bucharest, Romania. Two scientific papers are submitted to and accepted by scholarly journals. Based on the connections established, the TBPT can be shown to rest on a solid scientific and user-based foundation. The solidity can be shown by retracing the connections that made the tool possible. For example, the default weights used for the different factors in the TBPT can be followed back to the survey database, which can in turn be linked to the individual surveys and the latter to the actual persons filling them out. The robustness of the network can be assumed as long as it is not challenged by an alternative actor network, for example by an improved tool that might be developed in the future.

For those who refuse to enrol, it is obvious that the network is not sufficiently constraining to keep them in and that opposing forces sway them in different directions. Callon refers to a veritable battle that is being fought: scarce time resources, scarce financial resources, fear and misunderstanding can all prevent both project partners and potential end-users from being enrolled in the tool development. The case of the Romanian project partner, and of other actors linked in different ways to Romania, are illustrative for the resistance to be enrolled and mobilized in the TBPT network. First, only a sample of the Romanian brownfield database is made available, while the rest remains unknown to the initiating scientists and their allies. Moreover, the criteria for the selection of the sample also remain unknown. Second, the narrow definition of brownfields in this country as “contaminated land” limits the applicability of the tool for land that is derelict but not contaminated. Third, the completion of the surveys by the Romanian stakeholders is carried out via institutional channels, which can affect the quality of some responses. For example, when asked to rate a set of factors on a 0 to 10 scale (0 meaning “no influence” and 10 “very strong influence”), a number of respondents from Romania answered using just the values 0 or 10. Rather than complying with the problematization of the tool developers, by sharing their opinions over a broad range, these participants limited the quality of their inputs.

The Romanian project partner decides that while the enrolment of Romanian data, surveys and definitions is difficult, he nevertheless can participate in the network in personal rather than institutional terms. For this actor, the appeal of participating in the tool development overrides, in part, his bureaucratic responsibility of safeguarding the database of Romanian brownfields. He single-handedly selects the sample and makes it available to the initiating scientists. He also redefines his own problematization from full project partner into interested end-user (represented by the dashed arrow in Fig. 2). This happens because, due to some internal regulations of the environmental authorities, he cannot be paid from the project budget and thus comes to perceive his work as that of a volunteer researcher. This illustrates that the identities of the actors involved in the tool construction network are fluid rather than fixed, as they resemble “chemical substance[s], [passing] through successive stages” (Callon 2007: 61).

In the case just described, the limits of the tool network were negotiable through the agency of one individual. In other cases, the resistance of some actors to the proposed interessement devices can be recognized as limits of the DST being developed. For example, it became clear that in countries where brownfield databases are not public, the use of the tool will be limited. A tool test-user from Germany states that he does not want to upload data about his brownfield sites to the web-based tool, “because in Germany we really take care of data security”. Because the process of brownfield regeneration is not officially recognized in Romanian environmental policy, the tool is also likely to be of limited applicability in this country.

By retrospectively tracing the network underpinning the TBPT, one can say that it reached its project-defined goal and it delivered a specific result, scientifically validated by several peers. Its degree of tailoring was maximized in the Czech and Polish cases but was substantially lower in the German and Romanian ones.

However, ANT does not leave us hopeless. By revealing the critical issues over which actors are likely to become disengaged from the network, it can aid the design of future tools. More generally, the observation that enriching scientific knowledge with practitioners’ inputs depends on the ability of scientific actors to attract and maintain non-scientists within stable actor networks highlights the importance of selecting appropriate interessement devices (either material or symbolic).

## Conclusions

The argument of this paper is that creating a tailored tool by drawing on the inputs of various actors is essentially akin to the construction of an actor network. More generally, we propose that producing joint knowledge cannot be disentangled from the network of alliances which make this knowledge possible and reproducible. The main advantage of this perspective resides in the plain observation that networks can more easily be described, quantified and mapped (spatially and temporally) then the more elusive forms of knowledge that we wish to understand.

This paper has shown how an actor network perspective can shed light on the construction of applicable knowledge, by highlighting the processes that can increase or limit the applicability of knowledge. In this last section, we highlight in which ways an actor network perspective can provide a fresh understanding of knowledge production that is both scientifically valuable and socially relevant. We pursue this idea and formulate some criteria for DST research, by reverting to the four moments of translation and suggesting a number of insights they can offer.

The moment of problematization raises the question of who the initiating actors are and also who are those actors whose identities they define in relation to their research problem. One can say that the more diverse the actors who see their paths unfolding through the obligatory passage point defined by the initiators, the more socially relevant their project is. In other words, the more human and non-human worlds a given problematization spawns, the stronger it can be argued that it engages with real-world problems, thus making knowledge relevant for all the actors involved. This may be termed the broad-base criterion of DST development.

The moment of interessement allows an understanding of transdisciplinarity that may, at first sight, go against the common wisdom. The stronger one wants to build a form of knowledge that is at the same a well-connected assemblage of actors, the more one needs to disentangle the elements of the network from alternative connections of whatever kind. In this sense, all human knowledge is applicable, but the extent to which it is so depends on how effective the interessement devices are. Achieving applicable knowledge appears, in this light, as the ability to maintain a *sui generis* network of heterogeneous entities rather than to foster an undifferentiated aggregation of such entities. The intensity of commitment—measurable by the strength of ties—to resolve a specific real-world problem is therefore the second criterion for effective DST development.

Enrolment and mobilization both can be taken to indicate the depth of integration of knowledge that is attained. Actors who have been enrolled and mobilized support the problematization of the initiating actors. But the relationship is always bidirectional. The spokespersons of different categories of actors, who have been mobilized in achieving a given representation of knowledge (model, chart, interpretation) act on behalf of an unknown number of anonymous actors. The latter can, at any moment, call into question the representativeness of the spokespersons. For this reason, and if the goal is to achieve robust knowledge, the chains of representation through which the spokespersons are able to speak on behalf of others need to be kept open to critical scrutiny. In other words, one may say that robust knowledge is that form of knowledge that does not congeal its creation in the form of a seeming matter-of-factness. By acknowledging the history of translation—the negotiations, the struggles, the betrayals that have taken place along the four moments, as we have attempted above—a variety of actors have the genuine opportunity to learn how tools are created. Transdisciplinary knowledge thus needs to be transparent—in terms of the history of its creation—for all the actors involved, especially for those with weaker commitments, at least until the findings gain general acceptance.

We will close with some specific recommendations on the development of decision-making tools from the perspective discussed here. First, the problematization of European research projects aiming at tool development should be formulated based on the experiences of different countries and should also take into account the abilities of actors from these different countries to see the problematization as an obligatory passage point rather than as irrelevant to their concerns. Grouping together similar actors is a more sensible strategy than trying to be over-inclusive by glossing over significant differences across European countries and regions. Second, the interessement devices used by the tool developers should be effective enough to temporarily bracket other concerns so as to enable non-scientific actors to become truly enrolled in tool development. This enrolment is particularly important for the potential end-users of the tool. Third, the cases in which the tool development failed in some respects should be critically examined to identify the specific reasons for disengagement from the network. In sum, we contend that actor network theory can offer a useful and constructive approach to develop robust decision support tools.

## Footnotes

1. Timbre is the acronym of the FP7 project Tailored Improvement of Brownfield Regeneration in Europe (2011–2014).
2. This includes material objects, non-human beings and texts (Callon 1990).
3. The word context is ours rather than Latour's.
4. As used here, intelligence has a broader meaning than in that of the first phase of the decision process (intelligence gathering), which is followed by the design and choice phases (McIntosh et al. 2011).
5. This means being defined as more than of strict scientific interest.
6. Details on the background data for and development of the TBPT can be found at: www.timbre-project.eu/en/deliverables.html under D3.1, D3.2 and D3.3.


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