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Executive Summary

The measurement of scientific activity has long been developing into a vivid discourse at the intersection of innovation and science policy studies, scientometrics, research evaluation and management science. Within established methodological frameworks many approaches have aimed to enrich, improve or critically revise the existing methods for the assessment and evaluation of science and technology. A strong tendency has been the incorporation of structural approaches, that is, network analysis and other tools for mapping the organization of the science system, into the toolbox of informed evaluation practices. Despite the rapid extension of the toolbox, however, little attention has been given to a systematic treatment of the various approaches and the dimensions of scientific activity they address.

Since the SISOB platform is envisioned to provide new insight into the social and societal aspects of S&T, the present report is targeted at the systematization of the models, indicators and measurements. The aim is three-fold: (1) to uncover the mapping between existing approaches and the respective dimensions of S&T, (2) to discuss models, indicators and measurements relevant for the SISOB platform based on (1), and (3) prepare the development of "missing approaches" addressing SISOB-relevant aspects. The task is implemented as follows.

The first part of the document provides an overview on the established framework for S&T measurement. The main focus of this section is the shift from traditional input/output approaches to the applications of network analysis in evaluation and monitoring activities. Based on typical applications ("prototypes"), a taxonomy of network approaches is constructed, in terms of network type, network measures and indicators, including the exploitation of social networks, information networks and science maps (proximity networks) as well.

The second part of the document specifies the general scheme for the particular domains of the SISOB project, that is, for the three case studies under development:

Mobility. Mobility of researchers and research communities is an often prioritized policy goal, but less studied in necessary details. It is conceived as both (1) a social dimension of science production and (2) a social impact-conveying factor of S&T (c.f. academia-industry relations). Indicators for, and metrics based on different types of mobility networks are systematized, which are to be modelled as affecting the productivity of actor communities. A new set of dimensions is introduced to be incorporated as measurements, distinguishing different types of the phenomenon, including *inter-institutional* and *virtual* mobility.

Knowledge sharing. Knowledge sharing has been modelled via several types of social and information networks. A detailed taxonomy of network indicators and measurements, parallel with their typical uses, is given for the knowledge sharing case based on Appendix A of D2.1 (Common network indicators). In this section, a novel framework is outlined, appropriating a much broader community of actors than that of within-science models. This framework builds on multirelational network of artefacts (papers, prototypes, software etc.). Network models are enriched with an

ontology of relations that gives way to a whole new set of measurements using existing metrics of network analysis.

Peer review. With a few examples concerning conflict of interest detection, network effects of the peer review process have rarely been subjected to analysis using de facto network models. The peer review application is concentrated around the measurements of (1) network effects on different types of cronyism, and (2) network effects on both the scientific and public impact of actors of review networks. To this end, network indicators are interpreted for multi-relational networks linking authors, reviewers and editors. These indicators are combined with both reviewer assessments and bibliometric impact measures for actors (authors).

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1. Objectives and structure of this document

The primary objective of the present document, as the first deliverable of *WP4: Indicators and measurements*, is to prepare, inform, and assist the design of formal models implemented in the development of SISOB functionalities. The specific goals are:

- Mapping the existing pool of models, indicators and measurements applied in the analysis of S&T.
- Systematize these approaches, and identify the relevant subsystem against the purposes of the SISOB platform (applications of network analysis).
- Identify the relationship between (1) models/indicators/measurements and (2) the underlying dimensions of scientific activity that elements of (1) are aimed to formalize.
- Formulate requirements for the indicators and measurements that are not present in the existing literature with special emphasis on the social dimensions SISOB is to exploit.

The structure of the deliverable is as follows:

- The document starts with a general overview on the measurement of scientific activity. The first section discusses the classical framework within which measurements and indicators are discussed in the mainstream literature, with the aim of uncovering the aspects of science this canonical framework deals with;
- The second part, partially derived from the challenges with which the traditional framework has to face, is a detailed analysis of S&T models, indicators and measurements that jointly constitute the inventory of devices for the purposes of the SISOB system, namely, network models. This section also provides a taxonomy for those approaches, relating the modelled dimensions of science with model types, indicators and metrics.
- The third section of the document deals with the application of the outlined methodology to the domains that constitute the primary targets of the SISOB system: (1) mobility, (2) knowledge sharing and (3) peer review. Identification of social dimensions, related taxonomies of models/indicators/measurements, and special requirements of the SISOB case studies are presented here.

2. Concepts

Throughout this document, the following terminological conventions will be applied:

Indicator	The term will be used for variables that are (usually observable) proxies to some phenomena, and also the primitives upon which measurements can be formulated („non-calculated variables"). Prime examples are bibliometric descriptors (author, keyword, citation), researcher affiliations, co-authorship etc.
Measurement	The term will be used for variables that are derived from indicators via some formal operations/calculations. Prime examples are citation indices, proximity measures etc.
Network	The term will refer to all kind of relational structures (graphs), regardless of their content (social networks, information networks, proximity networks etc.)
Social network	The term will refer to networks, the definitive relation(s)/ties of which are social as to their content or semantics (co-authorship network, co-worker network, researcher-project network etc.)
Social network analysis (SNA)	The term will refer to the methodological framework/conceptual system originated from the analysis of social networks, but later extended to the analysis of large and complex networks, regardless of their content.

3. Traditional frameworks for S&T metrics and the related dimensions of scientific activity

The measurement of science and technology has long been a vivid and multidisciplinary area of investigation. Beside the continuous effort to analyze, elaborate on and improve the existing pool of metrics, however, less attention has been given to the underlying dimensions these metrics are designed to measure (Geisler, 2005). Uncovering related aspects of scientific activity is reported in the literature in either of the following forms: (1) conceptual analysis of the metrics or (2) empirical or statistical analysis of the metrics' behaviour.

In order to gain a concise overview, three prominent approaches are discussed here. Type (1) is represented by (Geisler, 2005), outlining how traditional conceptualizations of science can be associated with existing S&T metrics. In this study, seven categories of metrics are used (see table below) and analysed as to which aspect of scientific activity they address. The conceptualizations, though originally borrowed from the philosophy of science, can briefly be described as the „cognitive development" model, the „social process" model, and the „social impact" model of science. The latter, termed „humanistic" in the original context, captures the view of science production as an activity assessed by its contributions to society.

A less theoretic mapping of the metrics space was provided by Zitt and Bassecoulard (2008). Though restricted to bibliometrics, the classification of measures reflects the dimensions underlying the applications of bibliometric means. In the context of the evaluation of research, two major categories are distinguished: ranking measures and positional measures.

Ranking measures are further divided into „power indicators", and „performance indicators". Power indicators are described as conveying market share of actors in science (exemplified by such measures as „share of publications" from national, world-wide or field-specific output), while performance indicators cover size-independent quality/capability: (normalized) productivity and impact measures (and their combinations, such as the well known H-index and its variants) are claimed to belong to this class.

Positional metrics, as contrasted to ranking, allows for the assessment of the position of actors within the structure of science production, typically in networks. Positional measures and the network approach will be discussed in detail in the subsequent sections of this document.

Type (2) approaches, aiming at the empirical mapping of the metrics' behaviour, is well represented by a recent, still highly cited study undertaking the analysis of 39 measures (Bollen et al. 2009). Though these are impact measures, which constitute only a subset of S&T metrics, the results considerably contribute to the present discussion in at least two respects: a) by applying principal component analysis, the metrics have been decomposed into orthogonal dimensions they measure (based on their rank-correlations), and b) a set of relatively new metrics have also been included in the study, all based on web-based usage indicators of scholarly output (c.f. Bollen et al. 2008). As a result, two relevant aspects of scientific impact are extracted: impact measures have shown to indicate either (I) popularity or (II) prestige. In a further dimensions, impact measures unfolded as proxies to „rapid" or, alternatively, „delayed" impact. Web-based measures have proven to be „rapid prestige" metrics.

The following table is a summary of the above discussion. Rows of the table correspond to the seven consensual categories of S&T indicators, as described by Geisler (2002). The set of categories is extended to include also web-based usage-indicators, studied in detail by Bollen et al. (2009). Columns of the table are to position each category within the proposed systems of dimensions.

Category	Example indicators, measures and models	input/ output	Output dimension	Evaluative/ descriptive	Perspective on S&T
economic and financial	R&D expenditures, human resources	i, o	economic rationality	e	social process
commercial and business	S&T profit ratios, sales ratios	o	competitiveness	e	social process
bibliometrics	publication shares, citation indices, S&T maps	o	productivity, impact, diversity, power, position	e, d	cognitive process, social process, social impact
patents	patent statistics, patent profiles, patent citations	o	productivity, impact	e, d	social process, social impact
peer-review	peer-review success rates, peer-review scores	o	research quality	e	social process, social impact
organizational, strategic and managerial	project funding, success, assessments	o	effectiveness	e	social impact
webometrics/ cybermetrics	usage statistics, usage-based science maps	o	impact, diversity, position	e, d	cognitive process, social process
outcome stage	immediate, intermediate, long-term outcomes	o	impact	e	social process

Still in the mainstream discourse on traditional frameworks of S&T metrics, shortcomings and challenges have often been pointed out, or identified. As to the „missing dimensions" or challenges for recent needs of science and technology evaluation and monitoring, the following main, interrelated issues are still salient in the literature (c.f. Lepori, 2008):

- More weights should be given to positional indicators over classical input/output measures.

- Analysis (or relations) is needed on more levels of aggregation/ with an increased granularity.
- Elaboration of the analysis of human resource patterns and characteristics (career paths, mobility indicators) is needed.
- Since, as a recent trend, the market of S&T assessment has considerably expanded, with new providers (analyst organizations, data-providers) and costumers (universities, firms, governments etc.) there is an increased demand for more insightful services.

Among the purposes of the SISOB platform is to provide a response to these needs via the utilization and development of appropriate models, indicators and measurements. The primary pool of such devices is the inventory of network models of scientific activity. The following section provides an overview of this inventory. As a result, a taxonomy of related dimensions, models, indicators and measurements is proposed aiding operationalization.

4. Network models in S&T research: indicators and measurements

The utilization of network models in the measurement of scientific activity is a long-standing issue. The „received view" (RW) on the application of network analysis to this domain focuses on social networks, and can be characterized by a frequently used configuration of modelling techniques, indicator and measurement types. In the literature of science policy, research evaluation, scientometrics, innovation studies etc. however, a wide range of approaches, both evaluative and descriptive, have emerged that involve networks not being social *per se*, and apply SNA methodology in S&T monitoring and assessment.

Since these models are also highly relevant for enhancing the capabilities of the SISOB platform, the first part of this section (1) identifies some prototype cases of relevant approaches, including the received view and less-paradigmatic ones, (2) introduces necessary distinctions for systematic description of these models and their indicators and measurements, (3) outline a multidimensional taxonomy of approaches induced by the observations under (1)—(2).

1. The received view

Science policy, scientometric and innovation/R&D management studies often focus on networks of actors in the system of science and technology production. The models under study are social networks: the nodes of the network are S&T agents at various levels of aggregation (one for each network), such as researchers or organizations. The ties of the network represent cases of collaboration among agents—co-authorship, joint involvement in product development or research projects etc.

The modelling aim in such cases is to detect or predict the relation between two dimensions: **network effects** and **quality of research**. This relation is usually conceptualized in either of the following ways (Mote, 2007; Rogers et al., 2001):

- *Network effects explain quality of research.* This conceptualization is translated into models where **positional measures** of actors (nodes), or **structural measures** of aggregates (communities) are correlated with **productivity measures** of the same entities. Positional measures include centrality measures (betweenness, degree etc.) for individual actors. Structural measures include density, community structure, degree distribution etc. for subnetworks or whole networks. Productivity measures include patent statistics, publication statistics, citation statistics etc.
- *Network effects are quality measures.* On this view, the properties of the collaboration network are measured, as outcomes of collaborative efforts, against some desired policy goal. In this setting, positional and network-level measures are generally used. Prominent examples are the density of research or innovation networks, or the involvement (clustering coefficient), centralities and relatedness (e.g. degree centrality) of organizations or other actors. The main assumption behind is that certain network effects are beneficial for actors or the system as a whole, and would lead to improvements in productivity, competitiveness, impact, etc. (though the latter are not measured in this case).

In relation to these conceptions, two further notes are necessary. First,

(1) beyond node-level measures, node-level properties are equally important indicators in these models. Different categories, to which actors of the network belong, enable these networks to provide additional dimensions for analyses. Type of organization (business/governmental/public; academic/non-academic etc.) for each actor, as a node-level property, serves as the basis for investigating academia–industry–government relations that attracted much attention in recent decades. Another example is the measure of „tie diversity", interpreted usually as a measure for an actor expressing the distribution of its neighbours over different actor categories (e.g. firms, universities etc.), and hence the diversity of its relations.

(2) Also striking from this description that network measures, depending on context, policy goal etc., can play different roles in the models. In some settings, network measures are used as independent variables affecting the target variable, in others these are the very target variables or outcomes.

2. Less paradigmatic approaches to S&T/R&D studies

Beyond the received view, quite heterogeneous uses of network models can be traced in the discourse on measuring scientific activity. However, this pool of models can be characterized by prototype examples. These prototypes, in turn, can be used to extract relevant distinctions for, and induce a taxonomy on models, set up by a couple of dimensions. In what follows, we first expose four prototypes exposed in more detail that are closely related to the SISOB case studies: peer review, mobility and knowledge sharing. Then we set out a taxonomy induced by a broader set of prototype approaches.

- Social networks for detecting/predicting potential conflict of interest (COI)

Most relevant examples are the studies of network effects in the peer review process. Network models of COI detection utilize **social networks** of actors (Aleman-Meza et al., 2006). Elements of the network are hence community members participating in the peer review process (potential authors, reviewers). The edges of the graph represent social relations affecting an actor' attitudes towards the other actors: forms of collaboration (co-authorship etc.), the co-worker relation, the „x knows y" relation etc. Such a network is therefore (1) **multi-relational** and (2) each relation has a well-defined semantics, taken into account by the measures in this case.

The modelling aim is the ability to predict potential COI as a further relation of two actors derived from the abovementioned relations. The target **measure** is therefore **based on paths** connecting any two actors in question: if one actor can be reached from any other, different probabilities of COI can be identified, as a function of (1) path properties and (2) the bias-generating relations involved.

- Diffusion and differential perception of a scientific topic in science, in the public media, and in the governmental sector

Network analysis is widely used for uncovering conceptual structures. A relevant prototype is the modelling of how scientific topics, being societal sensitive in nature, are perceived in the public media and in the governmental discourse, as contrasted to the scientific conceptualization. A prominent example is the study of Leydesdorff (Leydesdorff & Hellsten, 2006), modelling these perceptions by network text analysis for topics from the stem cell debate and the GMO-debate („Frankenfood"), among others. The networks in these cases are **proximity networks of concepts** (words), based on their co-usage in the public media, in scientific texts, and in official documents, respectively. Network elements are, hence, words, while network ties depict their associations.

Since the modelling aim is to detect differences in the respective perceptions, measures serve the comparison of the three networks: (1) **positional measures** of concepts reflect their potentially differing roles in the three contexts; changes in, e.g., betweenness centrality of a concept throughout these contexts shows a shift of emphasis as we switch the domain. (2) **Community-level measures** (coherent concepts clusters, e.g.) show sub-topics, or the organization of the discourse in the three contexts.

- Measuring researcher/community interdisciplinarity

Heavy utilization of network models is characteristic of science mapping studies. Uncovering the social and cognitive organization of science, providing reference systems for research evaluation, detecting research fronts and emerging topics, measuring the growth and dynamics of specialities most often proceeds via constructing network representations based on the various relationships between journals, papers, authors etc.

A relevant prototype, and also an advanced use of science maps is the method for measuring the disciplinary diversity or interdisciplinarity of both research communities or of individual researchers. (Porter et al., 2007; Rafols et al., 2010) The method is based on a global science map, which, in this case, is a **network of ISI subject categories** (SCs). The ties of the network capture the proximity of SCs in terms of their citation pattern: the more any two SCs cite the same categories, the closer they are assessed to be in the global system of science. The type of network underlying this measurement is, again, a **proximity network**.

The measurements for community *C* or individual *I* built upon this network type requires a mapping of the publication profile of *C* or that of *I* onto the basemap. The result is a custom map for *C* or *I*, whereby node sizes jointly express the distribution of the publication profile over subject categories. More importantly, the network structure enables measurements of portfolios that take into account both (1) the size of constituent SCs and (2) their relatedness and distance in the map. Therefore, the **measure of structural diversity** can, and has been defined based on this model (Leydesdorff & Rafols, 2010).

- Usage network of web repositories

A recent approach from science mapping is the introduction of alternative measures based on the log data of scholarly repositories, that is, on the actual usage (retrieval) of publications (Bollen et al, 2008). This set of positional and impact measures were constructed within a network model, namely, defined upon the co-usage (co-retrieval) relation between documents. Elements of the network are, therefore, publications, and ties indicate the proximity of publications based on the frequency of their co-retrieval.

The metrics introduced on this structure are to capture both impact and position of individual papers, and the organization of the whole network as a science map informed by actual use of the scholarly literature. Therefore, a wide range of SNA indicators (centrality measures, tie properties, community structure) were utilized for the description.

- Interplay of networks: mobility and collaboration

An important aspect of network approaches is the relation between different types of social networks constructed for the same community. Although cross-network comparison could provide significant explanatory power, this option has rarely been explored, partially due to the lack of sufficient data. A recent example, which also qualifies as a relevant prototype, is an approach for building a „multi-layered" network by integrating (1) mobility patterns and (2) collaboration patterns (Furukawa et al., 2011). The resulting net, that is a **social network** being **multi-relational** in nature, contains organizations as its nodes. The two types of relations between organization *A* and *B* are (1) flow of researchers from *A* to *B* or vice versa, and (2) collaboration, namely co-authorship among researchers *a* and *b* affiliated with *A* and *B*, respectively. Both relations are based on the same sample of individuals.

The modelling aim in this case is to detect the effect of mobility on collaboration patterns. The network approach enables one to study this effect at the community (network) level and applying a structural perspective. The primary **measure** is therefore a cross-network construct, the **structural similarity** of the two networks (or network layers) involved (network similarity).

3. Distinctions assisting the systematization of network models

Based upon the prototype configurations of models and measurements exposed above, some useful distinctions can be drawn in order to impose a pragmatic, measure- and indicator-oriented taxonomy on the great variety of existing models. At least three observations are to be made:

O1. In network models, two roles for indicators and measurements are optimally distinguished.

(1) One set is for network construction that includes the indicators/measurements of the relation of network elements (such as proximity, co-occurrence, co-authorship etc.). Furthermore, some networks are based on „pure" indicators (e.g. collaboration networks), others are based on measurements (e.g. proximity networks).

(2) The other set, usually referred to as „network measures", is comprised of measurements for the characterization and evaluation of the network (density, centrality etc.).

O2. In network approaches, actors and networks are related in two fundamentally different ways:

(1) Actors are modelled as networks or network elements. This is the „default" interpretation of most cases of social network analysis.
(2) Actors are associated with some network. The related prototype is „measuring researcher interdisciplinarity".

O3. Network measures can play variable roles in terms of the classical „input/output indicator" distinction. Interpreted more generally, „output" on the traditional R&D conception stands for the value-carrying outcome of the science production system, while „inputs" are the factors facilitating this outcome. As pointed out previously, network measures sometimes viewed as proxies for policy goals (output), while in other cases treated as factors affecting classical outputs such as productivity (i.e., input).

4. A taxonomy of network models, based on types of models, indicators, measurements

Induced by the prototypes discussed so far, the following taxonomy is proposed for mapping network approaches to consider within the SISOB project. The taxonomy is conceived as a set of dimensions, along which the various approaches can be arranged. The dimensions are selected to jointly form an informative answer to the questions of what types of modelling techniques, indicators and measures are involved for a desired approach, incorporating the distinctions O1—O3 as well.

The taxonomy is represented in the table below, comprised of the following columns:

- **Aspect of scientific activity.** List of prototype approaches either discussed in the previous sections (as emerging or novel types of analysis) or indicating a more common type of network analysis.
- **O2.** The type of the approach under the observation O2 with values 1: actors are modelled via some network; 2: actors are associated with some network.
- **Relation content.** The semantics of the relation(s) defining the network with three categories: social/information flow/proximity.
- **Network type.** The type of the network as described in the Appendix A of D2.1. Distinctions: 1) one-mode, two-mode; 2) directed, undirected; 3) unirelational, multirelational.
- **Entities.** Types of network actors/agents/nodes.
- **Indicator of relation.** The indicator for network formation (see O1 above).

- **Measure of relation.** The measure for network formation (see O1 above).
- **Network measures used.** Measure/index categories used in the respective approach as described above and in Appendix A of D2.1.

Aspect of scientific activity	O2	Relation content	Network type	Entities	Indicator of relation	Measure of relation	Network measures used
Innovation patterns and processes	1	Social	one-mode	R&D Organizations	collaboration	degree of collaboration	Position measures; Productivity measures
Academia-Industry relationship	1	Social	one-mode	R&D Organizations	collaboration	degree of collaboration	Communities, Tie indicators, Network structure
Organizational research collaboration	1	Social	one-mode	R&D Organizations	collaboration	degree of collaboration	Communities, Tie indicators, Network structure
Peer-review effects	1	Social	one-mode, multirelational	Individuals	academic relations; co-authorship; affiliation	degree of collaboration	Tie indicators, Network structure, productivity measures
Mobility effects	1	Social	two-mode, directed	Organizations, individuals	affiliation	-	Position measures; Productivity measures
Mobility network effects	1	Social	one-mode, directed multirelational	Organizations	affiliation, co-authorship	-	Network similarity
Author collaboration	1	Social	one-mode	Individuals	co-authorship	degree of collaboration	Communities, Position measures, Network structure
Actor-project relations	1	Social	two-mode	Projects; organizations; individuals	membership	-	Path measures, Network structure, position measures
Citation Impact	1	Information flow	one-mode, directed	Individuals, papers, journals	citation link	-	Position measures
Patent impact	1	Information flow	one-mode, directed	Papers, patents	citation link	-	Position measures
Diffusion of ideas/ Public perception	2	Proximity	one-mode	concepts	co-occurrence	proximity	Position measures, communities
Structure and development of science Profile and interdisciplinarity of actors	2	Proximity	one-mode	documents, journals, journal categories	co-citation	proximity	Communities, Diversity measures
Usage impact (web)	2	Proximity	one-mode	documents	co-usage	proximity	Communities, position measures

5. Interpreting „social dimensions" for managing measurements and indicators

The strategic aim of the SISOB project is to develop a toolkit for the effective monitoring of S&T with respect to its so-called social dimensions. Consequently, a distinguished aspect for the present systematization this deliverable is targeted at, is the capability of existing approaches, or indicator–measurement configurations to report on the social phenomena, processes and effects attributable to the operation of science and technology. As a prerequisite to understand this capability, an important distinction should be made. „Social dimensions" with respect to S&T are usually interpreted in two, conceptually different, but empirically overlapping ways:

(1) **Social factors in S&T.** In this case, the concept is interpreted as the social relations, structures and processes affecting the system of scientific knowledge production.

(2) **Societal relations of S&T.** In this case, the concept is interpreted as the interplay between science and the „rest of society", ranging from the relationships between different sectors of innovation processes (academia, industry etc.) to the societal impact and effectiveness of S&T.

The case studies of the SISOB project embrace both conceptualizations. An outline of the relation between individual case studies and the two conceptual levels introduced above is the following:

Mobility. The main focus is on how various types of researcher mobility operationalized as a rich collection of social factors/indicators affect research productivity. These factors also cover various relations between different societal sectors, as mobility from academia to industry. Hence, the primary target is level (1), but level (2) is also heavily addressed.

Knowledge Sharing. The main focus is on patterns and processes of knowledge flow as embodied in (primarily) artefacts connecting different science and other societal sectors („boundary objects") The analysis of the behaviour of ontology-based artefact networks is to shed new light on the interplay between science, public media, public opinion, industry, commerce and various other layers of society. Hence, the primary target is level (2).

Peer review. The main focus is on how the structure and dynamics of network structures in large peer review communities, involving authors, reviewers, editors etc., affect the functioning of the peer review system in terms of validity, effectiveness and bibliometric productivity. Hence, the primary target is the social factors affecting scientific knowledge production, that is, level (1).

As the SISOB toolbox is to be informed by the use cases above, the main strategy implemented in the first part of this document (Sections 3, 4) is to seek convergence between the specific goals described in relation to levels (1)–(2) and the existing inventory of S&T analytics. This prototypic (network) models exposed in section 4 can directly be assigned to the case studies conveying the related social dimensions. The Table below illustrates this assignment.

Figure 1. Relation of concept levels, case studies and prototype models

Concept	Case study	Related network model prototype
Societal relations of S&T	**Knowledge Sharing**	Diffusion and differential perception of a scientific topic in science, in the public media…
Societal relations of S&T / **Social factors in S&T**	**Mobility**	Interplay of networks: mobility and collaboration
Social factors in S&T	**Peer review**	Social networks for detecting/predicting potential conflict of interest (COI)

Given this pool of analytics, the second part of the deliverable (Section 6) is to set out the domain-specific deployment of this inventory by each case study, along with the identification of their further requirements to cover the social aspects discussed so far.

6. Application to target domains of the SISOB system

1. Case Study: Mobility

1. Overview of existing approaches and current trends

The importance of scientific knowledge and university research for economic growth and competitive advantage has long been recognised. Policy makers across the world are looking for strategies to encourage scientific production and the exchange of knowledge. The establishment of research networks and mobility of researchers across different countries, fields and sectors has been identified as a major policy goal. In the EU the commitment to develop a European Research Area (ERA) also implies the promotion of "greater mobility of researchers" (EC, 2001: 1; EC, 2010: 11, 17), especially the mobility between academe and industry (EC, 2006: EC, 2010). National reports additionally point out the need for greater intra-national mobility and flexibility of researchers for knowledge diffusion between different institutions and sectors (e.g. CST, 2010).

It is assumed that scientists' mobility facilitates knowledge and technology transfer, creation of networks and productivity. Movement of scientists and scientific knowledge, and hence social capital, between different academic institutions, university and society, and between different scientific fields is believed to be vital to further scientific quality and research development. However, very few systematic studies have been carried out. If we exclude the literature on the analysis of brain drain versus brain gain/circulation,[1] only a few academic papers have focussed on the analysis of spill-over and peer effects resulting from the movement of academics (Cooper 2001, Møen 2005, Pakes & Nitzan 1983, Zucker et al. 1998, 2002), while very little attention has been given to the analysis of the consequences of mobility for researchers themselves, with the exclusion of a few sociologist of science (see for example Alison and Long, 1990).

Several papers have pointed to the importance of personal characteristics, age, cohort and gender effects on productivity (Stephan and Levin, 1992; Hall et al., 2007). Further, the importance of the research group and local peer effects have increasingly been recognised as important predictors of individual productivity, though some recent evidence suggests that these effects are not very strong, but that co-author effects, which do not need to be localised, are stronger (Azoulay et al., 2010; Waldinger, 2010).

The sociology of science approached this topic much earlier and found some weak evidence of a negative impact of immobility (Hargens and Farr, 1973) and some evidence suggesting that rather than foster productivity, mobility is a characteristic of productive researchers and does not itself enhance productivity (van Heeringen and Dukwel, 1987; Alison and Long, 1987). In more recent work, a positive impact of productivity on mobility was found; the results by Chan et al. (2002) show that very few researchers are able to move to a higher ranked institution and that these few exceptional scientists are two times more productive than the average academic at the destination university.

2. Dimensions of measurements set up by existing approaches

Some **examples** of variables used (being combined with each other) within existing models are hereafter reported in order to further highlight the possible dimensions.

Variable	Measurement	Dimension
Publication record	Number of publications (in a given time span)	*Scientists' output*
Paper cites (to papers)	Number of citations per paper (in a given time span)	*Scientists' output*
Patent record	Number of patents in a given time span	*Scientists' output*
Patent cites (to papers)	Number of citations per patent (in a given time span)	*Scientists' output*
Patent cites (to patents)	Number of citations per patent (in a given time span)	*Scientists' output*
Funding	Grants amount awarded (in a given time span)	*Scientists' output*
Relative productivity	Ratio between individual Productivity and average Productivity for each discipline individual belongs to	*Scientists' productivity*
Inbreeding	No. of co-authors from same university / No. of co-authors	*Scientists' productivity*
Principal Component	Connection dummy (=1 if scientist belongs to principal component of co-authorship network, 1995-1999)	*Network*
Closeness	Inverse of avg. shortest path between the scientist and other scientists in the principal component (co-authorship network, 1995-1999; =0 for scientists outside the principal component)	*Network*
Rank	University / Dept. official	*Prestige*

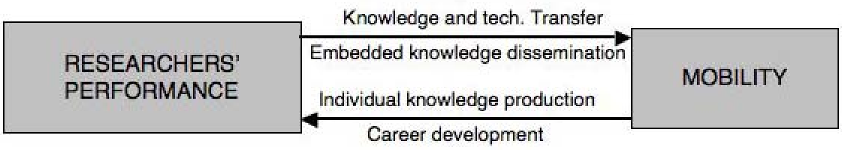
	ranking	
Tenure in position		*Scientists' characteristics*
Birth year	Age in a given xxx	*Scientists' characteristics*
Gender	Gender	*Scientists' characteristics*
Grade	Final university grade	*Scientists' characteristics*
Research field	Research field	*Scientists' characteristics*
Disciplinary mobility	Field switch (dummy)	*Mobility / Career*
Sector mobility	Sector switch (dummy)	*Mobility / Career*
Geographical mobility	Country switch (dummy)	*Mobility / Career*
Career mobility	Position switch (dummy)	*Mobility / Career*

3. Identification of missing dimensions and shortcomings of existing methods w.r.t. the SISOB system

A systemic and dynamic perspective of researchers' mobility is required in order to integrate the different dimensions of researchers' mobility. It is necessary to consider both narrow and broad conceptualisations of mobility where narrow involves changes in job position and broad means the development of inter-sector collaborations that may entail part-time secondment to companies (Zucker et al. 2002).

For a researcher to change job position and collaborate with other researchers and sectors is part of her career. Changes in the research system can make mobility – collaborations or changes in job positions – more frequent. Researchers' mobility could be affected by different national S&T training policies. Human resources management and labour markets promote different research trajectories (Gaughan & Robin 2004). Mobility can be a requisite of the system and create more mobility by itself (Mahroum 2000). However, the question remains whether there are any measurable return opportunities of researchers' mobility in career development. Addressing the relationship between mobility and career development would clarify the direction of the causality between productivity and mobility (See Figure 1 below). It is possible that the relationship between mobility and researchers' productivity not only changes across different types of mobility but also across diverse career moments. This relationship is important in order to qualify the researchers' movements.

Figure 2. Productivity and mobility relationship



Studies on the relationship between mobility and productivity so far have only given some descriptive evidence without investigating causalities. Further, they indicate that the impact of mobility may be different for different types of mobility (e.g. inter-sector mobility, upwards mobility) due to peer effects at the new institutions. However, most of the studies focussed on cross-sectional data and did not observe a researcher's whole career. Also, there has not been a systematic approach to define different types of mobility and to discuss mobility at different career moments. **Therefore, whether and how mobility affects researchers' productivity in terms of publications has yet to be explored**.

As a first contribution FR offers a robust mobility definition:

Inter-institutional "real" labour mobility (Crespi et al. 2007), which implies a change in job position from one institution to another. This excludes changes in job position within the same institution (e.g. a job change in the same university to a higher position or a different function). "Real" labour mobility considers job changes that occur after the researcher received her first tenured position after PhD or first full time position in industry. E.g. 'lecturer', 'assistant professor' 'research fellow' equivalents are considered the minimum tenure-track positions in academia. Postdoctoral research stays are not considered "real" labour mobility[2].

Further, different dimensions of inter-institutional mobility need to be considered when measuring its effect on research productivity. To this end, FR will adopt four mobility dimensions to be analysed in the context of inter-institutional "real" labour mobility:

- *Geographical Mobility*: Job transition to a different (within the same) academic market (intra- and inter-regional mobility)
- *Sector Mobility*: Job transition from academia to industry or vice versa (inter-sector mobility)
- *Functional Mobility:* Job transition to a different function (inter- functional mobility)

[2] Postdoctoral mobility and job mobility have very different patterns of mobility (Zubieta, 2009

- *Career Mobility*: Job transition to a higher/lower position or to a more/less prestigious university (up- and downwards mobility).

As a second contribution, FR and SISOB propose a new form of mobility, which we label *Virtual Mobility*. In our current academic environment it is not unusual for a researcher to be affiliated to institutions other than the main employer. Such multiple affiliations can be the results of current visiting positions (including guest lectureships, secondments and sabbatical), courtesy appointments (e.g. honorary fellowships and emeritus status), part-time appointments and fellowships (including adjunct professorships and affiliations to specialist research centres). These multiple affiliations do not represent mobility in the traditional sense, as many of these are short term or do not represent actual physical presence. However, they enable access to resources and networks and might hence play an important role in explaining research productivity. Virtual mobility leaves a trail on an academic's publications and on websites of institution's that want to adorn themselves with their affiliated members.

As a third contribution FR wants to stress the importance of longitudinal data for the analysis mobility and productivity. Considering the time dimension is crucial for identifying trends and causal relationships.

2. Case Study: Knowledge sharing

1. Overview of existing approaches and current trends

As an operative definition of knowledge sharing, it can be considered as the exchange of knowledge between persons, organizations, countries, etc. In that process, the main issue is the importance of sharing and it is important to highlight that the multiplication of knowledge has no direct costs (as knowledge is not tangible, it value does not decrease by sharing) even there are some indirect costs for transaction. On the other hand, knowledge flow can be seen as a way to observe paths and directionality of knowledge between different entities that participate in the process.

One of the results of the knowledge sharing process is the construction of collaboration links that generate new knowledge, which can be seen as a feedback of the system in some kind of "virtuous circle". Looking for tangible and quantitative evidences of this phenomenon, which can be used as an input for indicators building, it is possible to analyse the joint signature of scientific documents.

According to Gibbons (1997) Mode-2 approach there has been a change scientific production that can be described as a new way of research organization (networking). The emergence of this type of multidisciplinary scientific production is the result of the adoption of more flexible and participative organization structures, implemented to provide solutions to specific problems through the production and application of knowledge. It has an important impact on science, technology and innovation policies. The understanding of this dynamics can offer relevant information to foster the constitution of networks, seen as a specific way of management of the knowledge sharing processes. Nowadays, there are several formal efforts to support collaboration and they are part of a broader strategy for science and technology policies in many countries.

A basic taxonomy of indicators may include attributive indicators and relational indicators. Attributive indicators are traditional science indicators based on surveys, administrative records, documentary databases, etc. based on quantitative descriptions of certain characteristics of the analytical unit. Examples are:

- Expenditure on R&D certain institution
- Number of researchers
- Number of papers produced (breakdown by field of science)
- Number of patents granted

Relational indicators focus on information that is not present in each information unit and emerges from the whole dataset.

For example, the density of a collaboration network within certain field of science cannot be obtained from the information of the collaboration in certain institution but in all the institutions participating in the production of knowledge in that field.

Some examples:

- Degree of a researcher within a network based papers signatures.
- Betweenness of an institution within a network based on participation in research projects.
- Density of a collaboration network in certain field of science through time.

A taxonomy for indicators to measure knowledge sharing within the scientific community can be outlined as follows (the detailed taxonomy can be found in Appendix A of this document):

Three analytical levels are identified:

- Overall structure
- Connected components
- Node level

For each level, three types of indicators are proposed:

- Basic: to measure the main characteristics of the networks.
- Normalized: to allow comparison between communities or to compare the same community over time.
- Combined: to include other available indicators in a single measure.

2. Dimensions of measurements set up by existing approaches

Indicator	Measurement	Dimension
Publication	Number of publications	Productivity of researchers
Patents	Number of patents granted	Productivity of researchers
Staff	Number of researchers	Importance of institution or organization
Connectivity	Density of collaboration network	Potential impact
Actor betweenness	Betweenness centrality of actor	Influence

Artefact betweenness	Betweenness centrality of an artefact	Trend

3. Identification of missing dimensions and shortcomings of existing methods w.r.t. the SISOB system

The case study will introduce innovations to the study of knowledge sharing processes. One main point here is to develop a network based relational model for scientific knowledge sharing, which not only is aware about the objects but also includes the relationship between these artefacts into the measurement. In this sense a productivity indicator is a partially domain-specific measurement not only counting publications or patents or other scientific products isolated from each other. The indicator is informed by an ontology about how artefacts are related together within different scientific domains. A small software prototype for example is related to a conference paper or a framework to a journal article in computer science, but software patents have not a strong relation within this indicator. In this sense it has to be flexible itself as a kind of boundary object depending on dynamic sources for measurement related to dynamic outcome. One discipline related to media for example may make a frequent usage of social media to share information. For an applied discipline it may be important to be present in daily media. This has an influence on the weights within the model that describes the interrelations in-between the artefacts within the model.

The basic networks will be examined in different ways. One important aspect will be the development of these networks over time, which for example shows researchers moving from one institution to another thus taking knowledge gathered in one institution with them to the other where it will be shared with co-researchers.

One of the means for the analysis of the described networks could be ontologies representing domain specific meta-knowledge. Such ontologies could be used to contextualize individual scientific productions within the domain specific knowledge and could also be used to create relations between individual artefacts based on the relations existing between the concepts incorporated in the artefacts. By exploiting such semantic relationships between knowledge objects, we also get new links between researchers. These paths can indicate "congruence of interests" between actors and ensuing opportunities for sharing knowledge. Especially the exploitation of emerging links between diverse actors can have a positive influence on performance. From a methodological point of view, new semantic relations may be detected utilizing (Dynamic) Network Text Analysis and Natural Language Processing tools.

Additionally, the network analysis technique of blockmodelling allows us to observe heterogeneous actors in a typical mode-2 setting within a core periphery structure. Especially peripherally involved actors such as funding agencies or research consultants are important for knowledge sharing and mediation. Once such mediators (or brokers) are identified, also mediating objects may be found and analyzed. The notion of dynamic blockmodelling also allows for observing the changes in these structures over time.

3. Case study: Peer review

1. Overview of existing approaches and current trends

To the knowledge of the authors, the outcomes measured by existing studies of peer review are limited to:

- Reviewer assessments of papers/projects (acceptance/rejection; numerical scores)
- Citations of reviewed papers

We have unable to find any references to network analysis. However several papers use concepts that lend themselves to network analysis. In particular there is experimental support for various different kinds of „cronyism" between reviewers and authors. These include:

- Buddy cronyism (the tendency of reviewers to give a favorable evaluation of reviewers to give a favorable evaluation of authors with whom they have written papers in the past)
- Institutional cronyism (the tendency of reviewers to give a favorable evaluation of authors from their own institutions, from other institutions with whom they collaborate, from institutions with whom they have worked in the past, from institutions of the same „ranking" as their own (e.g. Ivy League Universities)
- National cronyism (the tendency of reviewers to give a favorable evaluation of authors from their own country, their own grouping of countries or their own „part of the world"
- Gender cronyism (the tendency of reviewers to give a favorable evaluation of authors of their own gender)
- „Cognitive cronyism" (the tendency of reviewers to give a favorable evaluation of authors who share their own intellectual approaches and prejudices)

The literature suggests that similar forms of cronyism may influence the selection of reviewers by journal editors. All these forms of cronyism lend themselves to network representations. However, these do not appear to be used in the literature.

A second object of study has been the correlation between reviewer assessment of papers and other measures of quality– in particular citations. The majority of studies show that this correlation is extremely poor.

2. Dimensions of measurements set up by existing approaches

Indicator	Measurement	Dimension
Institutional affiliation, gender, country		Properties of editors
Institutional affiliation, gender, country		Properties of reviewers
Institutional affiliation, gender, country		Properties of authors
	Approval of paper, score given to paper	Reviewer assessment of papers
	Citations of paper	Consumer assessment of paper

3. Identification of missing dimensions and shortcomings of existing methods w.r.t the SISOB system

SISOB will introduce three innovations into the study of the peer review system

- The main emphasis of the study will be on the way networks of authors, reviewers and editors influence acceptance/rejection, and later citation of papers. In other words the study will correlate network indicators with bibliometric output indicators.
- The study will attempt to incorporate indicators that go beyond traditional bibliometric indicators, in particular references to papers in the non-scientific press and in social media.
- The study will examine differences between two very different fields (neuroscience vs. Artificial intelligence).

The study will focus social networks in reviewers, and editors have equal status as nodes on the network. Examples of the networks we will study include

- Networks linking actors who have been authors on the same paper.
- Networks linking actors in the same institution or belonging to the same class of institution.
- Networks linking actors from the same country or group of countries or the same „part of the world" (North vs. South).
- Networks linking actors belonging to the same sub-discipline.

In each case, we will study hypotheses in one of the following formulations

- Cronyism hypotheses: an author who is close to a reviewer in a given network is more likely to receive a favorable evaluation than an author who is further away
- Prestige hypotheses: an author who has a central position in a given network is more likely to receive a favorable evaluation than one who occupies a more peripheral position
- Network hypotheses: specific configurations of a network are more favorable to producing accepted papers, highly cited papers, papers with a big media impact, than other configurations.

The main emphasis of the study will be on this last class of hypotheses.

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Appendix A: Taxonomy and list of indicators for case study: Knowledge Sharing

This document presents a taxonomy for indicators to measure knowledge sharing within the scientific community. It follows the common network indicators list proposed in Appendix A of Deliverable 2.1 of the SISOB Project.

Three analytical levels are proposed:

1. Overall structure
2. Connected components
3. Node level

For each level, three types of indicators are proposed:

- Basic: to measure the main characteristics of the networks.
- Normalized: to allow comparison between communities or to compare the same community over time.
- Combined: to include other available indicators in a single measure.

For each case, a basic list of indicators is proposed. The selection was based on the availability of the required information and the potential interest for policy making.

1) Indicators for the overall structure

Basic

Number or nodes by type

Number of edges by type

Normalized

Density (shows connection level in the network)

Density of the researchers' network, using co-production as nexus

Density of the researchers' network, using citation as nexus (A cites B)

Density of the researchers' network, using co-citation as nexus (A and B related citing C)

Density of journals network, using authors as nexus

Density of institutions network, using co-production as nexus

Density of funding agencies network, using co-funded researchers as nexus

2) Indicators for connected components

Basic

Diameter (shows distances and size in a network)

Diameter of the researchers' network, using co-production as nexus

Diameter of the researchers' network, using citation as nexus (A cites B)

Diameter of the researchers' network, using co-citation as nexus (A and B related citing C)

Diameter of journals' network, using authors as nexus

Diameter of institutions' network, using co-production as nexus

Note: Diameter may not be an interesting measure for funding agencies as they are not so many.

Average path length (shows distances in a network)

Average path length of the researchers' network, using co-production as nexus

Average path length of the researchers' network, using citation as nexus (A cites B)

Average path length of the researchers' network, using co-citation as nexus (A and B related citing C)

Average path length of journals' network, using authors as nexus

Average path length of institutions' network, using co-production as nexus

Normalized

Diameter (shows distances and size in a network)

Diameter of the researchers' network (G), using co-production as nexus, over the diameter of a equivalent linear network (L). D(G)/D(L)

Diameter of the researchers' network (G), using citation as nexus (A cites B), over the diameter of a equivalent linear network (L). D(G)/D(L)

Diameter of the researchers' network (G), using co-citation as nexus (A and B related citing C), over the diameter of a equivalent linear network (L). D(G)/D(L)

Diameter of journals' network (G), using authors as nexus, over the diameter of a equivalent linear network (L). D(G)/D(L)

Diameter of institutions' network (G), using co-production as nexus, over the diameter of a equivalent linear network (L). D(G)/D(L)

3) Indicators at node level (centrality)

Basic

Degree (shows connection level of a certain node)

Degree of a researcher in a researchers' network, using co-production as nexus.

Degree of a researcher in a researchers' network, using citation (A cites B) as nexus.

Degree of a researcher in a researchers' network, using co-citation (A and B related citing C) as nexus.

Degree of a journal in a journals' network, using authors as nexus.

Degree of a R&D institution in a institutions' network, using co-production as nexus.

Degree of a funding agency in a funding agencies' network, using co-funded researchers as nexus.

Closeness (shows the average distance to the other nodes)

Closeness of a researcher in a researchers' network, using co-production as nexus.

Closeness of a researcher in a researchers' network, using citation (A cites B) as nexus.

Closeness of a researcher in a researchers' network, using co-citation (A and B related citing C) as nexus.

Closeness of a journal in a journals' network, using authors as nexus.

Closeness of a R&D institution in an institutions' network, using co-production as nexus.

Note: Closeness may not be an interesting measure for funding agencies as they are not so many.

Betweenness (shows the "importance" of a node in the network)

Betweenness of a researcher in a researchers' network, using co-production as nexus.

Betweenness of a researcher in a researchers' network, using citation (A cites B) as nexus.

Betweenness of a researcher in a researchers' network, using co-citation (A and B related citing C) as nexus.

Betweenness of a journal in a journals' network, using authors as nexus.

Betweenness of a R&D institution in an institutions' network, using co-production as nexus.

Note: Betweenness may not be an interesting measure for funding agencies as they are not so many.

<u>Normalized</u>

Normalized Degree (shows the average distance to the other nodes)

Normalized Degree of a researcher in a researchers' network, using co-production as nexus.

Normalized Degree of a researcher in a researchers' network, using citation (A cites B) as nexus.

Normalized Degree of a researcher in a researchers' network, using co-citation (A and B related citing C) as nexus.

Normalized Degree of a journal in a journals' network, using authors as nexus.

Normalized Degree of a R&D institution in a institutions' network, using co-production as nexus.

Normalized Degree of a funding agency in a funding agencies' network, using co-funded researchers as nexus.

Normalized Betweenness (shows the "importance" of a node in the network)

Normalized Betweenness of a researcher in a researchers' network, using co-production as nexus.

Normalized Betweenness of a researcher in a researchers' network, using citation (A cites B) as nexus.

Normalized Betweenness of a researcher in a researchers' network, using co-citation (A and B related citing C) as nexus.

Normalized Betweenness of a journal in a journals' network, using authors as nexus.

Normalized Betweenness of a R&D institution in a institutions' network, using co-production as nexus.

Note: Normalized Betweenness may not be an interesting measure for funding agencies as they are not so many.

<u>Combined</u>

Degree (shows connection level of a certain node)

Degree of a researcher in a researchers' network, using co-publication as nexus, over the total number of papers he published.

Degree of a R&D institution in a institutions' network, using co-publication as nexus, over the total number of papers it published.

Degree of a researcher in a researchers' network, using co-invention of patents as nexus, over the total number of patents he obtained.

Degree of a R&D institution in an institutions' network, using co-ownership of patents as nexus, over the total number of patents produced.

Note: Patent related indicators have to be tested to confirm that they have "critical mass" for analysis.

Closeness (shows the average distance to the other nodes)

Closeness of a researcher in a researchers' network, using co-publication as nexus, over the total number of papers he published.

Closeness of a R&D institution in an institutions' network, using co-publication as nexus, over the total number of papers it published.

Closeness of a researcher in a researchers' network, using co-invention of patents as nexus, over the total number of patents he obtained.

Closeness of a R&D institution in an institutions' network, using co-ownership of patents as nexus, over the total number of patents produced.

Note: Patent related indicators have to be tested to confirm that they have "critical mass" for analysis.

Betweenness (shows the "importance" of a node in the network)

Betweenness of a researcher in a researchers' network, using co-publication as nexus, over the total number of papers he published.

Betweenness of a R&D institution in an institutions' network, using co-publication as nexus, over the total number of papers it published.

Betweenness of a researcher in a researchers' network, using co-invention of patents as nexus, over the total number of patents he obtained.

Betweenness of a R&D institution in an institutions' network, using co-ownership of patents as nexus, over the total number of patents produced.

Note: Patent related indicators have to be tested to confirm that they have "critical mass" for analysis.