User Guide to DARE:
A Diversity Approach for Research Evaluation

By

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About this guide

Collaborative interactions between researchers are a major feature of the social processes that produce and apply knowledge. These interactions are also readily observable precursors to the future outputs and outcomes that stem from research activity. While investments in research are often evaluated based on outputs and outcomes, collaborative interactions, particularly those that bridge individuals that rarely interact, are less studied and their importance less well understood.

This user guide introduces DARE – the Diversities Approach to Research Evaluation. DARE is a new tool for tracking key changes in the patterns of collaborative interaction that result from interventions in the production of research, such as the funding of new projects, programmes or organisations.

DARE provides an opportunity to learn how diversity in the constitution of research teams affects their performance, and can yield insights into how different types of team or unit work successfully (or not). DARE allows the analyst to view the diversity of a focal research initiative from multiple perspectives, to understand how the diversity of collaborative interactions have changed over time, to measure these changes, and to make comparisons that allow learning that informs the future organisation of research.

The DARE user guide presents new concepts for thinking about collaborative interactions as well as analytical methods for their study. The combination of these concepts and methods has recently been piloted as part of the Economic Impact programme of the UK's Medical Research Council (MRC).

This guide is intended to fully describe the thinking behind DARE and share tools for its operationalisation, as well as suggestions for its further development and application. Part 1 sets out the motivation and key concepts behind DARE, as well as its strengths and limitations. Part 2 describes in detail how DARE is operationalised, using illustrative examples.

Users are invited to consult the project website for further details on DARE or to contact the team to discuss application of the approach or its further development.

Acknowledgements:

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Part 1: Overview of the Approach

1. A new approach to research evaluation

This user guide introduces the rationale, design and application of a novel 'Diversities Approach for Research Evaluation' (DARE). DARE allows the tracking of key changes in the patterns of collaborative interactions that result from a period of research funding – including changes which can facilitate the application of the resulting knowledge generated by that funding. DARE is particularly useful for the evaluation of research investments that bring together multi-disciplinary teams.

DARE is a useful new addition to the existing suite of research evaluation approaches because it can be used to see how research takes place, the types of interaction it involves even while it is ongoing, and allows the identification of productive ways to organise research. This is important because research funders and their awardees are accountable to stakeholders in wider society, including governments. These stakeholders increasingly demand indications of progress to justify investments in research. Research evaluation approaches that focus on a research project's outcomes and major impacts may have to wait years after the period of funding to establish its value and can fail to observe key benefits of the funded activities. Approaches are needed by funders that allow earlier evaluation of projects or funding programmes, reveal new insights into their benefits and inform the organisation of future research. DARE seeks to address this need.

The development of DARE can be thought of as the building of a new instrument for visualising the collaborative interactions that are a feature of many knowledge-intensive activities. By analogy, consider the introduction in the early 17th century of the compound microscope, which led to the visualisation of new structures such as cells and opened up new avenues in scientific thinking about how organisms function. The microscope's utility developed over many decades with the help of new conceptual advances (such as cell theory), the incremental improvement of tools (better microscopes) and techniques (such as tissue preparation and staining). These incremental developments greatly expanded the applications of microscopy over time, allowing the microscope to become a scientific instrument used for exploration and fundamental understanding in diverse fields of science, as well as a diagnostic tool, particularly in medicine.

It is important to emphasise that, so far, DARE has only been developed and piloted. It has been trialled in prototype form on a series of case studies – each of which centres on a biomedical research project. DARE is envisaged to have potential utility as an evaluation approach in other types of research. This approach could also be useful for identifying and understanding the role and importance of different types of interactions during knowledge production activities. DARE may also be applicable beyond research evaluation, for example in corporate R&D programmes, or in policy evaluation more generally, e.g. for evaluations of international development funding. Although exploration of applications in other areas may be fruitful, such applications are not the focus in this first DARE user guide.

As DARE is more widely applied, and more is learned of the interactions that it helps to describe, it may become more useful as a tool for learning what works and what does not, and it could also be used to feed into strategic planning, for example in the design of funding programmes.

2. Why use a diversity approach for research evaluation?

Real world problems frequently require knowledge from multiple disciplines and stakeholders in order to bring about potential solutions. Attempts to develop these solutions often reveal the frail connection between our growing knowledge of fundamental processes in nature and our ability to use this knowledge productively. Application of new knowledge is difficult for several reasons. First, the knowledge on which specific applications are built needs to be adapted to their context or specific conditions of use. In addition, a combination of (perhaps quite diverse) types of knowledge, originating from a variety of scientific fields may be needed. Non-academic expertise may also be required, with further collaborative efforts needed to integrate these insights. Finally, the processes by which these different types of knowledge are combined involves the collaboration of (potentially many) different, even distant, stakeholders and organisations. Therefore, the problem of applying (or in some cases it is called "translating") scientific knowledge for solutions to practical problems can be interpreted as the challenge of orchestrating diverse actors, used to operating in different ways, to share and combine the information and knowledge required to develop new applications.

DARE provides a means to demonstrate the diversity of perspectives that a collaborative research effort involves. DARE differs from mainstream research evaluation and impact assessment methods in two main respects. Firstly, DARE does not focus on the identification and evaluation of specific project outputs or research impacts. Instead it examines the collaborative processes that lead to knowledge production and that eventually may lead to outputs and impacts. For example, medical solutions in the form of new diagnostics and therapies typically take a long time to be fully developed and disseminated. Often these emerge many years, or even decades after initial research investments have been made. While tracing these impacts and assessing them is possible, they often cannot be attributed to a single research project or team. The results of many lines of work may need to be combined to lead to impact. From a policy perspective the results of such assessment are unlikely to be timely and the specific share of credit of an individual research project may be very hard to determine or justify. Instead DARE provides a means to conduct evaluations as the research and application unfold, allowing policy makers to use evaluation results to improve implementation, to inform short and medium term policy decisions, and manage adjustments in their funding activities.

Secondly, DARE does not treat the processes that are studied as a 'pipeline' in which research results are 'transferred' downstream to actors who are progressively closer to application until they are finally transformed into applications. In a pipeline view the focus tends to be on pairs of actors involved in a transfer down a chain of linked stages, where differences between these actors can create breaks in the linear chain of knowledge transfer. Instead, DARE regards interactions across disparate networks of stakeholders as the key factor for generation of applicable knowledge. By charting the productive interactions of these stakeholders (Spaapen & van Drooge, 2011a) it is possible to see whether the conditions are in place for future impact to have the opportunity to occur. DARE can help to develop the evidence base to make such analysis possible in the future.

3. Purpose and structure of this 'how to' guide

This document provides a step-by-step guide to operationalising DARE for the study of the research collaborations that lead to knowledge production and ultimately to research outputs and impacts. It is assumed that the unit of analysis for DARE is the collective of researchers, and wider collaborators, brought together as a result of research funding awarded for a specific purpose and period of time. *The focus of the analysis is the set of interactions generated by these individuals as a result of their activities, e.g. during a period of funding.*

DARE relies on three elements: **measures, maps and narratives** which all have a role in the understanding of the interactions generated by individuals during knowledge production:

- **Measures -** give a synthetic insight into the research initiatives studied, providing rapidly accessible and objective but aggregate, indication of the extent of changes in interactions.
- **Maps -** give an intuitive yet detailed description, directly showing the interactions that underlie the measures.
- **Narratives -** provide essential information about the context, specificities and peculiarities of the funded research.

In the following sections, the steps followed for the implantation of DARE are explained together with illustrative examples accompanied by description of the experiences acquired during the design and piloting of this new approach to research evaluation. Given the novelty of the method, it is appropriate that during the description that follows, in each section we include discussion of the advantages and limitations of the methods used in order to help future practitioners of research evaluation to apply and improve the application of this new tool.

4. DARE's origins in the conceptual literature

Often research yields outcomes and impacts slowly. Input-output approaches to research evaluation cannot see these outcomes and impacts emerging as they 'black box' how researchers work together in order to produce knowledge and impact. Such approaches cannot provide any understanding about the different processes needed to achieve success for either outputs or impacts, especially in the short term when these are yet to emerge. The study of *productive interactions* has been put forward as an alternative. These interactions are the source of knowledge production which may, at some point, lead to social impact (Molas-Gallart & Tang, 2011; Spaapen & van Drooge, 2011b). Such a focus includes the connections and learning between actors which are important for successful biomedical innovation (Rosenberg, 2009; Rubio et al., 2010).

A framework developed in economic geography by Boschma (2005) is relevant to identifying different type of boundaries between individuals that affect collaboration and learning. These are identified as distances that need to be spanned across five different dimensions[1] (defined in Table 1): ***cognitive, organisational, social, institutional*** **and** ***geographic*** space. Boundaries are therefore not simply divides that are present or absent but distances in these five dimensions, where actors are more or less proximate to each other. The absence of proximity becomes a barrier to knowledge generation or transfer while the creation of proximity (the reduction of distance) lowers such barriers.

The mapping of interactions using Boschma's five proximities is suggested to provide an effective way to assess whether researchers have begun to make new connections (and especially new types of connections) as a result of a given research initiative (Molas-Gallart et al. 2016) which may lead to opportunities for knowledge creation.

DARE requires the creation of maps and measures, based on data related to the interactions of actors, as often used in social network analysis. However, the measures for DARE differ from those for social network analysis, requiring full explanation (as set out in Part 2 of this guide).

[1] Boschma uses the term proximities rather than dimensions, but for the purposes of DARE, these five different perspectives are more intuitively presented as dimensions.

Table 1: Definition of the five proximities

Geographic Proximity	Geographic proximity refers to physical distance between actors. This matters in knowledge dynamics because spatial co-location facilitates the exchange of knowledge that is complex or difficult to transfer (such as tacit knowledge).
Cognitive Proximity	Cognitive proximity refers to the extent to which actors share a similar knowledge base. The generation and application of knowledge often involves individuals with distinct knowledge bases. However, some degree of cognitive proximity is a prerequisite for interactive learning, as it facilitates effective communication and a common reference space to process and transfer complex information and knowledge. Too much or too little cognitive proximity can be detrimental to innovation and learning processes.
Social Proximity	Social proximity refers to relations between actors generally built on common experience, friendship and kinship. These relationships can facilitate empathy, communication and coordination.
Organisational Proximity	Organisational proximity refers to the hierarchical structure shaping interactions between actors. High organisational proximity is associated with belonging to the same hierarchical structure.
Institutional Proximity	Institutional proximity refers to the norms, rules and values that determine how actors behave; large institutional distances (e.g. firm vs. hospital) may impose serious impediments to fruitful interactions if the behaviour of interacting actors responds to different, even potentially conflicting, sets of incentives or values.

5. Conclusions and future work

DARE provides a platform to investigate how knowledge creation and application activities are conducted across the social, cognitive, organisational, institutional and geographic dimensions[2]. This user guide sets out the conceptual and analytical framework for DARE and provides a step by step guide for its use. It is anticipated to have applications in evaluation, particularly in research evaluation. It may also be useful in other fields where the evaluation of knowledge production and collaboration needs to be undertaken. Unlike conventional research evaluation approaches that focus on outputs, DARE can be conducted during or shortly after the period of funding, and even potentially some aspects of DARE could be applied prior to funding, such as the mapping of a proposed team's diversity, as will be illustrated below.

A number of theoretical questions are raised by the availability of a method to study the 'diversity' of interactions in knowledge production and the 'cohesiveness' of the teams that collaborate in this activity (use of these concepts in DARE are explained below - see Part 2). DARE provides a platform to explore questions such as: How much diversity or cohesiveness is there in a given team? Does too much diversity or cohesiveness adversely affect performance? Are some forms of interaction more fruitful than others? Do the forms of interaction perceived as harbingers of success by those involved in the research bear out in practice?

[2] These dimensions are explained in the more technical detail in Part 2.

At present DARE has only been pilot tested. Until DARE is applied to a wider range of cases, and until those cases are followed up to see what results emerge from the mix of interactions identified through this approach, it will be difficult to know what is normal, or exceptional, which types of mixes work and which types do not. However, as these data are collected, DARE may begin to benefit from assumptions in the values used to make maps and measures, and a more rigorous set of reference data. Only once baselines can be established from empirical work, can theory building and testing begin to facilitate predictive applications of the DARE method.

Improvements and adjustments

We recognise that as described below (in Part 2), DARE is complex and expertise intensive. However, it can be adjusted and developed to become more streamlined. For example, at present the cognitive dimension is calculated based on publication data rather than on interviews. This could be modified to allow DARE to work using interviews exclusively or structured surveys (or perhaps other reporting formats). Other data collection techniques such as ethnography could even be used.

Benchmarking could be improved by rescaling the values used for the distance calculations in each dimension, based on reference datasets (e.g. based on known patterns of international collaboration, and rates of interactions between staff in different projects). This would facilitate understanding what constitutes a common or unusual value in the various measures that DARE describes.

Limitations

DARE has a number of limitations which potential users should be aware of:

Access: In its present form, the application of DARE is limited to situations where the analyst has good access to the core research team and some peripheral members of the project. Projects with many peripheral actors are difficult to map because these individuals are difficult to engage with for the purpose of mapping the interactions. Where researchers are highly motivated to assist the analyst (or else encouraged by their funder) then data analysis would be more reliable.

Scale: One-off studies may not be worth the time-intensive application of DARE unless, for example, they focus on cases of particular importance, such as those demonstrating whether a new mode of organising might be effective.

Comparisons: With the availability of new measures of diversity and cohesiveness, it is tempting to make comparisons of the measures generated in different case studies. At present, with just a few case studies described so far (and none with known long term outcomes) we do not have reference points to make strong judgements across projects. Nor are cases likely to be truly comparable if they involve different numbers of individuals, or are run for different durations or involve different levels of resource. However, the 'before' and 'during' snapshots of projects showing change supported by an intervention can be informative and comparison between these snapshots is a useful application of DARE.

Part 2: Technical description of DARE and illustrations of its application

1. Implementing DARE

1.1 Data gathering

It is possible to apply DARE to study knowledge production by groups of different sizes. For example, a unit of analysis could be a single researcher, a line of research followed by a team during a funded project, research undertaken over several periods of funding (perhaps from multiple sources), or even to chart the interactions of an entire organisation. For the purposes of this guide, in each case demonstrated, the unit of analysis for DARE is the team of researchers supported through a grant. To begin with, funded research teams need to be selected for evaluation from the pool of those funded by a research programme or initiative.

Data are gathered to enable relevant interactions of each member of the selected team to be identified and recorded in a highly structured manner. These interactions become the basis for the generation of DARE's measures and maps. However, a narrative account of the project is also needed to make sense of these. DARE's data requirements span qualitative and quantitative tools. The next sections are divided as follows. The first focuses on the choice of individuals to collect data from. The second describes how face-to-face and telephone interviews can be used for DARE.

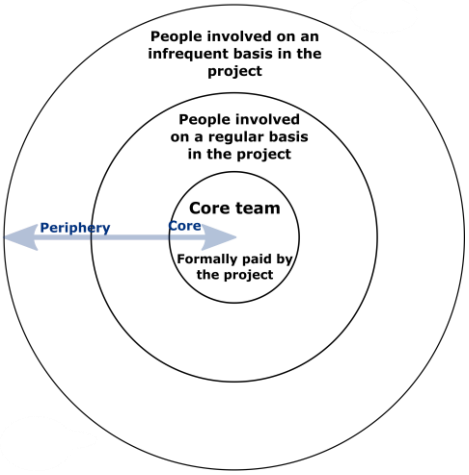
1.2 Who to collect data from

The measures and maps produced using DARE will be more robust where more comprehensive information is available on the activities of the research team. To begin with, a complete list of those individuals that comprise the research team is helpful. It is useful to obtain the work plan for the research (such as a formal funding proposal if this exists) and to then confirm with the team those individuals that worked together on the research once it commenced. Plans often change and so, once the principal investigator has been identified, communication with them is advised to confirm who was involved in the research. Each individual to be approached should also be asked to confirm who they worked with in order to triangulate data points and reveal relevant interactions that other individuals in the team may not be aware of.

A summary narrative of the project is also required (detailing its stages, the division of labour, progress, major achievements, links made beyond the initial team). This can be obtained through an interview (although funders may require progress reports which might be structured to fulfil this function too).

Contact with the Principal Investigator (PI) provides an insight into which members of the team can be approached to record the full range of activities undertaken within the scope of the funded research. However, even in relatively small projects, the PI may not be aware of all of those who have played important roles in the research and its application. It is therefore important to capture insights from those beyond the **core research team**, defined as those with formal obligations to the funder (see Figure 1 below).

Figure 1: Projects involve more than just their core team members



Limitations

While the PI might know who is formally part of the project, and who is peripherally involved or informally involved, others may not know much about project that they have actually been contributing to. Gathering data from those peripherally involved may be difficult because the scope of the project and its boundaries will be unclear to these individuals. This is particularly a problem when individuals are working on several projects simultaneously, in a series of projects, or where they are not officially part of the project team. An iterative approach to data collection may be required to clarify such details (clarifying details from peripheral contributors with the PI, for example). DARE also requires (often busy) individuals to take some time to describe their involvement in a project and this may not be a high priority for them, particularly if they are only peripherally involved in the project.

1.3 Interviews

DARE can use data collected through primary sources (e.g. face-to-face or telephone interviews, surveys) and secondary sources (e.g. project documentation or outputs such as publications). To date, DARE has relied heavily on the use of interviews and the protocols for these are discussed here. Annexes 1 and 2 contain the interview instruments for face-to-face and telephone interviews.

Face-to-face interviews are preferable to telephone interviews for core team members. Once all face-to-face interviews have been conducted, telephone interviews can be used to triangulate data gathered from these, thereby improving the robustness of the maps. To ensure the opportunities for triangulation can be maximised, it is important that interviewees should be interviewed individually rather than in groups.

Face-to-face interviews

Face-to-face interviews about projects that involve 10-20 individuals will take around 2 hours using the instrument in Annex 1. Larger projects might be expected to take longer to describe than smaller projects because there are more interactions to be described. However, it is desirable to allow individuals to describe those parts of the project which they are most familiar with, and leave other parts to other interviewees. This also limits the interview to a more manageable length.

The core of the interview is an account of the collaborative behaviour of that member of the team, how they worked with others and why – this is particularly important for the narrative part of DARE. Who individuals worked with and how often are key details to record for the measures and maps

involved in the DARE method. These interactions will ultimately be described in the five dimensions defined in Table 1. The main challenge for these interviews is to collect data consistently for each of the five dimensions in a way that can be used for creating measures and maps, but while also allowing the interviewee to provide a narrative on how research activities were developed within the period of funding.

In order to meet these requirements, it is often helpful to encourage interviewees to draw a sketch map of the project interactions (see Figure 2 below). This provides a helpful reference point for interviewee and interviewer to ensure that particular details can be indicated and recalled. Recording of interviews is advised to allow interviewers to concentrate on ensuring complete data collection.

Advantages and limitations of maps

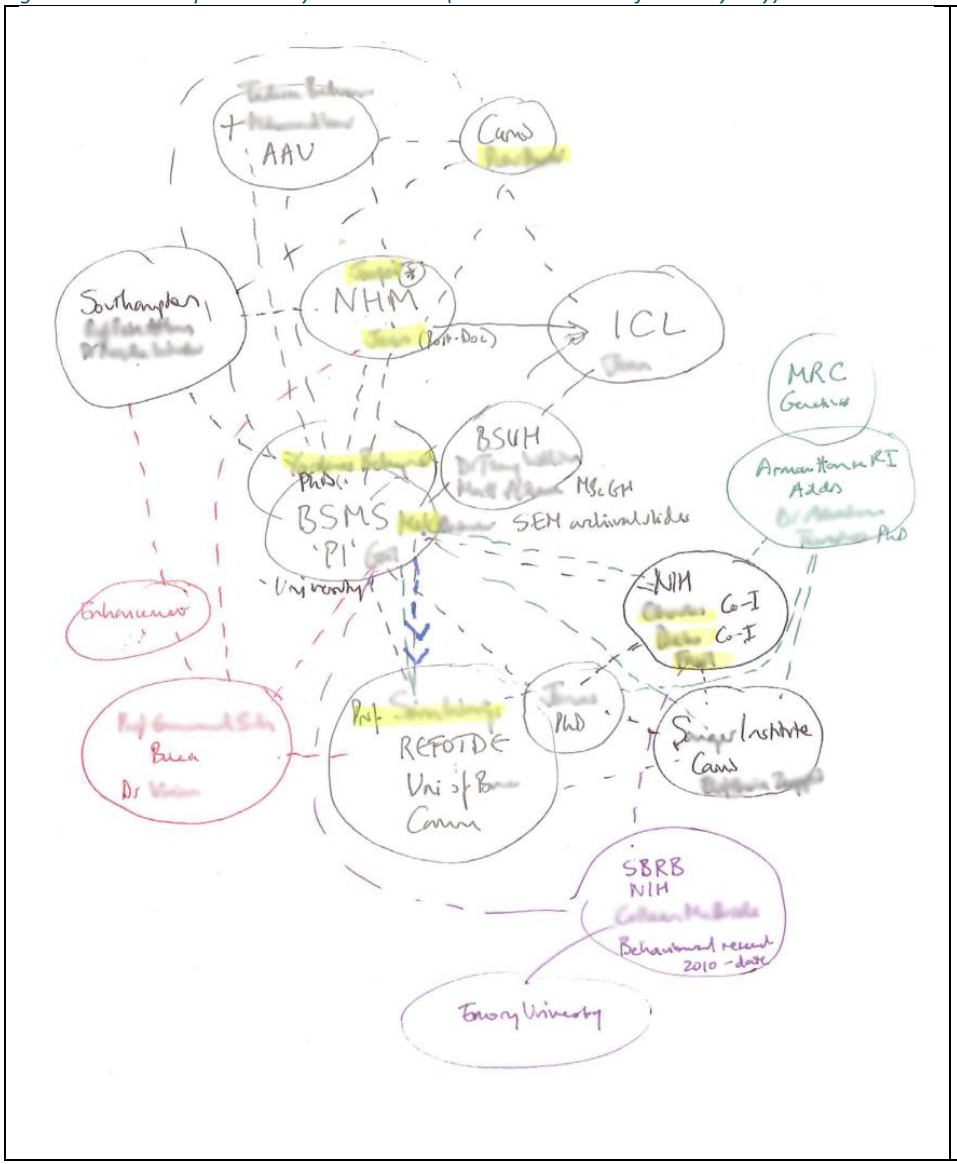
Introducing sketch maps (two examples of which are shown in Figure 2) as a part of the interview process may raise some challenges but also has considerable benefits. The first challenge lies in getting the interviewee to begin drawing on paper. Some are hesitant and in some cases senior academics have resolutely avoided drawing altogether, preferring to give only an oral account (which then requires the interviewer to respond by more systematically asking detailed questions so that the interviewer may capture the details on the project team and their interactions). Recording of interviews is advised to ensure accurate capture of this detailed information. In order to help interviewees to draw maps it may be useful to:

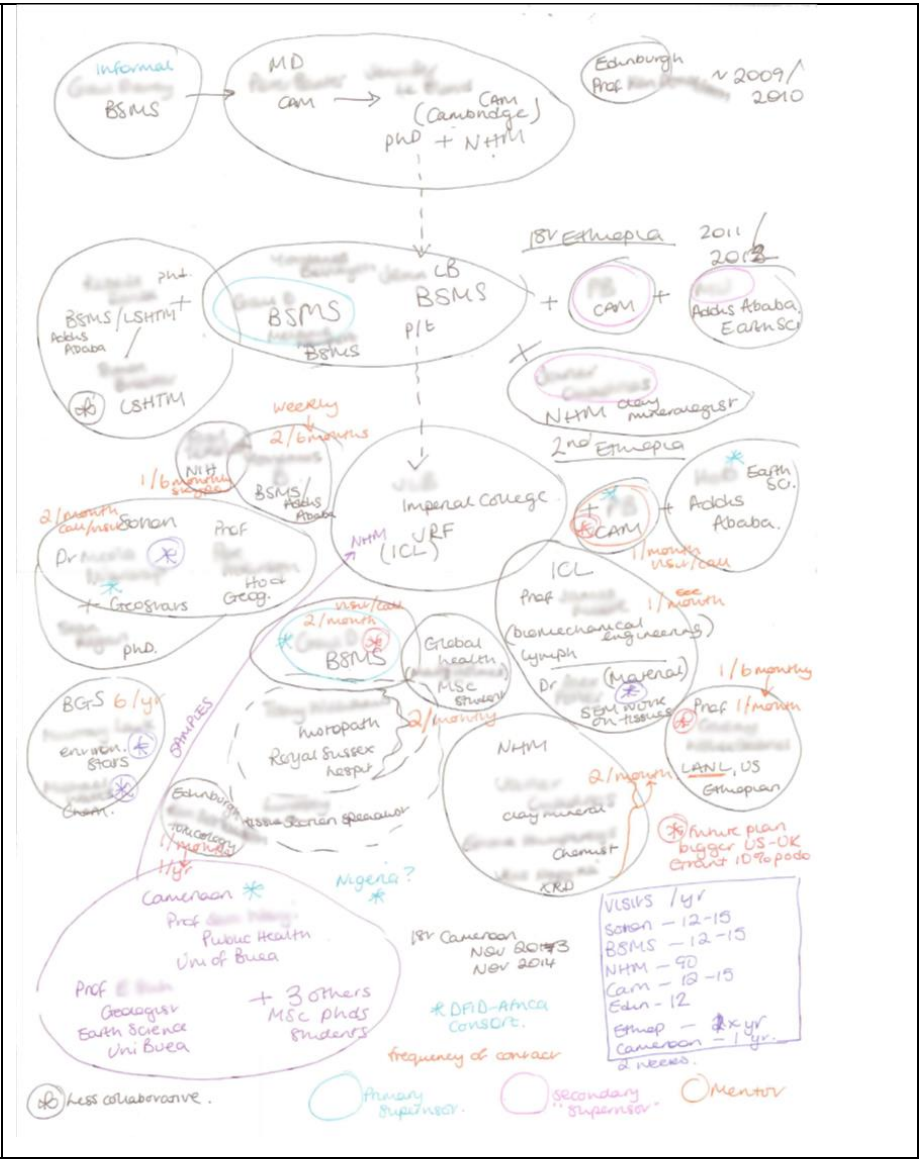
(1) Show sketch maps that have been created for other projects, but to avoid bias, it is important not to show them maps of the research they are describing.
(2) Encourage interviewees to place themselves centrally on the sketch map within their organisation and continue on to their closest collaborator next.

The sketch map allows the interviewer to gather data systematically in each of the five dimensions for all individuals named by the interviewee. This supports the data gathering for the measures and the subsequent diversity map building (more below) will be more comprehensive. It also enables the interviewee to recall the involvement of contributors to the project that they may have previously forgotten.

Descriptions are often linear accounts and the use of a sketch map allows for a discussion to loop back for additional details without the interviewer and interviewee becoming confused about the link being discussed. Eliciting details on interactions and project activities to characterise all links across the five dimensions is a repetitive task. This, coupled with the interviewee providing a narrative, is demanding relative to some other forms of semi-structured interviewing.

Figure 2: Sketch maps drawn by interviewees (names are blurred for anonymity)





Telephone interviews

DARE can make use of telephone interviews to aid operationalisation without the need for face-to-face interviews, at least in some cases (although telephone interviews may be more prone to cancellation and interruption). Using the DARE telephone interview instrument (see Annex 2) an interview of around 45-60 minutes should be sufficient. Larger teams will take longer to discuss, and more central team members will have more to say, as previously mentioned. Such individuals are best interviewed face-to-face. Team members with more limited roles within the project are the intended subjects for telephone interviews.

The primary objective of telephone interviews in DARE is to triangulate information given in the face-to-face interviews and to ensure that the coverage of people identified in the project is as broad as possible. Moreover, these interviews will also often provide important additional details to enrich the resulting narratives.

Sketch mapping without close guidance is likely to be difficult in a telephone interview. Provided core team members have been interviewed in advance, it should be possible to produce a matrix containing most people associated with the project in advance of the telephone interview. Telephone interviewees can complete the matrix ahead of the interview in order to allow the telephone discussion to focus more on narrative and clarifications (see Annex 3). In some respects, this matrix can provide systematic data more easily than in the face-to-face interviews, but this does rely on the analyst knowing the names of team members in advance (although some names can of course be added by the interviewee, where these are recalled).

Limitations of interviews

Some projects involve a small core team but have many individuals at the periphery whose involvement is difficult to characterise. For example, clinical trials have hub-and-spoke structures that include an array of individuals involved in different types of important project activity (undertaking research, recruitment of patients, gathering of data for analysis, and so on). Individuals involved in the trial may be difficult to trace and to engage in data gathering. Furthermore, given the hub-and-spoke structure of trials (with many "spokes" being unconnected to each other), the remoteness of the sites from each other may mean that peripheral interviews yield little additional information on the project as a whole.

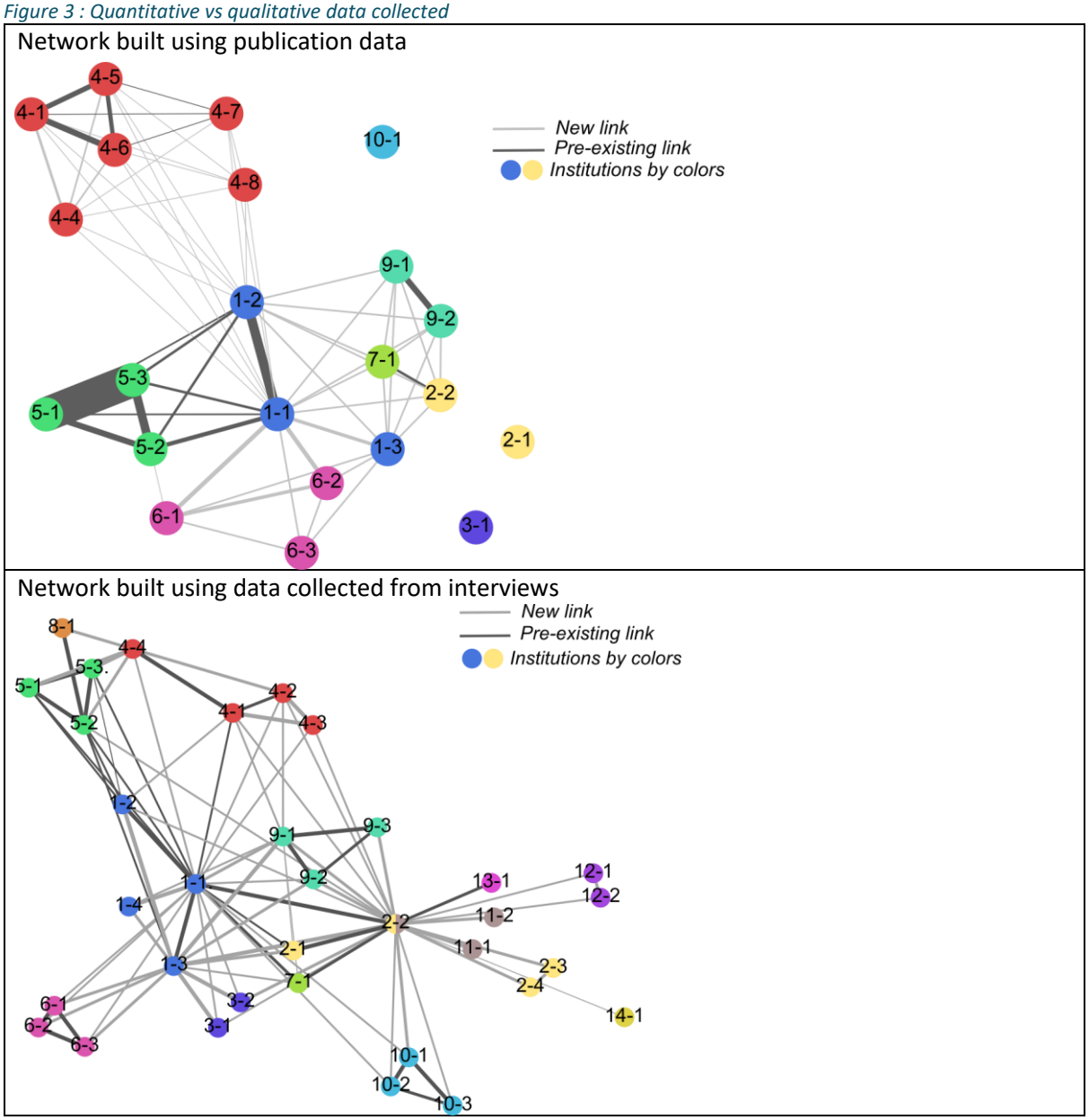
1.4 Secondary sources - publication data

Publication data are used to complement data gathered through interviews, mainly (as described above) because it is otherwise difficult to characterise at interview the cognitive background of individuals in a manner that allows differences between the individuals involved in the research to be revealed and consistently mapped.

The systematic indexing of publications by commercial databases of scientific publications provides a means to map individuals' work for comparison of their cognitive profiles. This is a well-established bibliometric approach and can be used as follows: for each individual identified as linked to a project, publication data can be retrieved (e.g. using Web of Science) from those years prior to the funded period. Once the individual's prior publications have been assembled, each reference in these publications is assigned to a Web of Science category (using the Web of Science classification). As a result, each individual is assigned a vector of 224 Web of Science categories, which is compared to other individuals in the team. The comparison takes into account to what extent others cite similar categories, but also how cognitively distant these categories are. The distance between the Web of Science categories is based on the matrix of distances used to generate the Web of Science maps

produced by Rafols et al. (2010).[3] These data are used as a proxy to determine the cognitive profile of each individual in the project, and to get an overview of the expertise of the people involved in the project. More details on this approach are provided in Part 2, Section 2.5. Publication data also provides information on which individuals have worked together previously as well as and during the period being studied (assuming publications are available). Network analysis based on co-authorship can also be undertaken using the DARE method. However, such networks are likely to be more sparse than those constructed following a series of targeted interviews (see Figure 3 which demonstrates one such example where more detailed interactions have been mapped on the basis of interview data as compared to publication data). Interview data can still be combined with Web of Science data to provide DARE measures and maps.

Figure 3 : Quantitative vs qualitative data collected



[3] The latest (2015) data on WoS Categories' distance is available at http://leydesdorff.net/wc15/index.htm as cosine.dbf

Limitations of the use of publications:
A serious limitation to the use of publications to determine the relative position of researchers in the cognitive dimension is that some people involved in research projects do not have any publication. These may include research assistants, students and early career researchers, or non-academic stakeholders that are users of the research. This therefore limits the analysis and mapping of the cognitive distance between individuals. Interview methods could be used to generate a cognitive profile for those that have no publications (e.g. allowing interviewees to identify subject categories that best describe their training) but such a method has not been used so far with DARE.

2. Data analysis – turning interview data into maps and measures

2.1 The roles of measures, maps and narrative

DARE provides three elements to aid evaluation: measures, maps and narratives. Measures give a concise and quantified report demonstrating the extent of the change in the levels of interaction that have resulted from a project in each of the five dimensions – social, cognitive, organisational, institutional and geographic. Maps enable the observer to see the individual changes that have resulted from a project and unpack some of the reasons why the measures take high or low values in particular instances.

Finally, the narrative gives context on the aims of the focal research project and explanation of why some measures may be low or high and whether this is due to certain peculiarities of the project. The narrative can help the reader to understand the complexity behind the simplified representation that the measures and the maps provide. The narrative can also show aspects of the project that the other approaches cannot describe. For example, narrative accounts can provide an early indication as to how a project may perform on a more traditional output-based methods of research evaluation.

Narrative accounts have long been used in research evaluation and these are not a novel contribution of DARE. Narrative accounts will also be intuitively familiar to most evaluators and so these are not discussed further in this user guide. However, the maps and the measures that are derived in DARE are novel and require more substantial explanation.

2.2. Introducing measures for diversity and cohesiveness

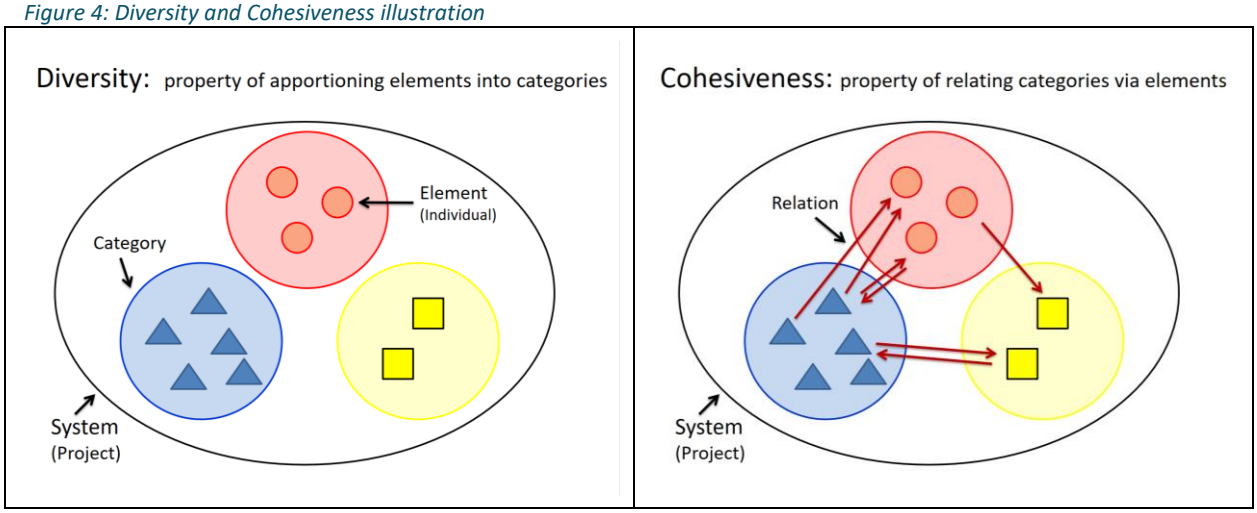
DARE relies on diversity measures (Rafols, 2014; Rafols & Meyer, 2009; Zhou, Rousseau, Yang, Yue, & Yang, 2012) which are characterised separately for each of the five chosen dimensions. Each of the five dimensions can be described using measures of diversity and cohesiveness[4] as described below. The components that these measures draw on (categories, distances, links and intensity) are also used to build maps. These measures have been used previously in scientometrics, to describe cognitive diversity. The use of these measures for the other dimensions will be unfamiliar to the reader and the operationalisation of these measures requires explanation.

This section first presents a brief introduction to the diversity framework. Here we follow the analytical framework of diversity measures defined by Stirling (2007) and applied in the works of Rafols and colleagues (Rafols, 2014; Rafols & Meyer, 2010; Rafols et al., 2010). Their framework considers the diversity of elements within a system. In the context of the cases studied in the piloting of DARE, the unit of analysis (i.e. the system) is the team working together on a research project. The elements of

[4] Previous studies (Rafols, 2014; Rafols & Meyer) have referred to this as coherence. However, cohesiveness seems to be a more appropriate term to describe the level to which diverse elements are connected to one another. The emphasis intended is on the connections between those in the maps rather than whether they can be seen as similar, compatable, or homogenious (other meanings that the term 'coherent' may suggest in common use are unintended in this context).

this system are individuals. The diversity and cohesiveness framework aims to understand first how the individuals are different at the outset of the time period studied, as measured in each of the five dimensions through the ***diversity*** measures. DARE aims to understand where opportunities arise for knowledge generation and transfer through interactions during the time period under study. These interactions are described through the **cohesiveness** measures. Figure 4 sets out the components of the system that are analysed to produce each type of measure (which are discussed in Section 2.3 and 2.4). It must be emphasised that DARE relies on each element being individually assigned to a category in each of the five dimensions. The assignment of elements to categories for each dimension is addressed in detail in section 2.5.

Figure 4: Diversity and Cohesiveness illustration



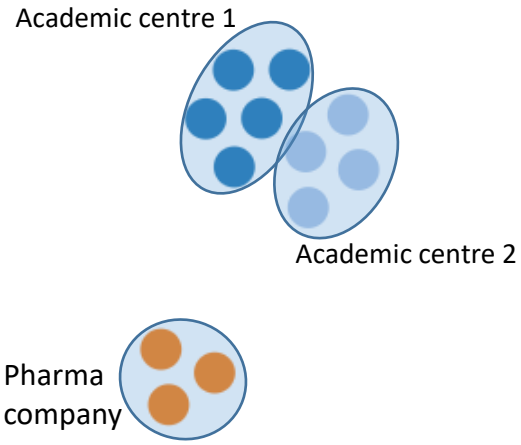
Adapted from Rafols (2014)

2.3 The diversity measure

For each of the five dimensions of interest, the diversity measure provides an understanding of the extent to which the focal system (i.e. the research project) brings together elements (i.e. individuals) who are different. The diversity measure requires assigning individuals to categories and gives a sense of how individuals are different from one another.

For clarity, the explanation of the measures will be accompanied by an illustrative example featuring the construction of the maps and measures for organisational diversity (see Figure 5). The case study used is a project to develop a Biomarker analysis platform, involving at the outset three distinct groups of individuals. The map in Figure 5 shows the organisational diversity of nine individuals working on the project spread across two academic research centres in the same university department, and a pharmaceutical company. The map represents the academic research centres as organisationally close to one another while the industry scientists are somewhat farther away. One of the main features of the diversity concept is that it takes into account how much the categories are different from one another, which is here referred to as the **distance** between categories. Later sections go into more depth about how the distances are quantified for each of the dimensions (the values for geographic distance used here are based on a scale discussed in Section 2.5).

Figure 5: Organisational diversity in the 'Biomarker analysis' project



The map therefore covers the components included in the diversity measure. It covers the **number of categories** there are in the dimension (distinguished by three large blue circles), how different those categories are from each other (represented by the **distances in the map**), and how many elements are held in each category (**proportion of individuals by category**). The diversity measure takes into account the same components. The diversity measure is characterised as follows:

Rao-Stirling diversity (α=1, β=1)	$\sum_{i,j} p_i p_j d_{ij}$

Where:

- p_i is the proportion of elements in category i
- $d_{i,j}$ is the distance between categories i and j

In the existing literature, the diversity and the cohesiveness measures were based on the assignation of elements to categories, with categories having different degrees of similarity of distance. In DARE, rather than assigning elements to categories, we compute the measures by looking directly at the distances between elements (where elements are individual researchers in our case). The Sections that follow will explain how distances are defined for each dimension in turn taking into account the relational attributes of elements.

In this section, we will first adapt the operationalisation of the concept of diversity and cohesiveness to the level of elements (as opposed to the category level as it has been used before by Rafols and Meyer 2010 and Rafols 2014).

The diversity measure as defined previously is expressed as follows:

Here d_{ij} is the distance between the category i and j

$$\sum_{i,j} p_i p_j d_{ij}$$

$$\Leftrightarrow \sum_{i,j} \frac{n_i}{n} \frac{n_j}{n} d_{ij}$$

Where n_i is the number of elements in category i. This summation can be written for all the elements rather than over categories as follows:

$$\Leftrightarrow \sum_{k,l} \frac{1}{n}\frac{1}{n}\delta_{kl} = \sum_{k,l}^{n} \frac{\delta_{kl}}{n^2}$$

Here δ_{kl} is the distance between the element *k* and the element *l*, taking into account that element k belongs to category *i*, and element l belongs to category *j*

$$\delta_{kl} = d_{ij}$$

So, from the element level this is:

Rao-Stirling diversity (α=1, β=1) – over all elements	$\sum_{k,l}^{n} \frac{\delta_{kl}}{n^2}$

The two research centres were part of the same department. Thus a low distance value between these organisations is applied: 0.15.

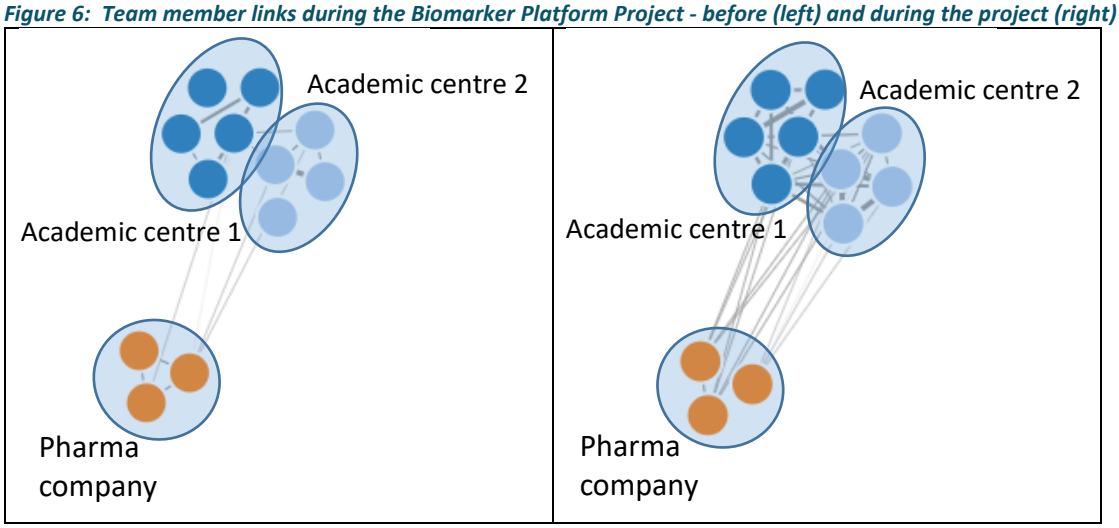
The diversity measure described above helps an observer understand the composition of a project team. A low score suggests that the team is homogeneous (in the example above, this would mean they are all in the same centre). A score of 1 would indicate that every element is located at a maximum (normalised) distance from each other. With the same scale for scoring (on a normalised scale) distances, it is possible to compare cases using the diversity measure above. This is notable because some DARE measures are not suitable for cross-project comparisons without accounting for differences in the size and composition of the project teams.

For readers that require a worked through example of how to compute the diversity and cohesiveness measures applied in DARE, see Annex 3.

2.4 The cohesiveness measure

While the diversity measure described above gives a view of how diverse the composition of the research team is, the **cohesiveness measure** focuses on **the interactions** between elements of the system (i.e. the individuals in the team during the project) taking into account the **diversity** that these interactions span. As with the diversity measure, the cohesiveness measure is applied to each of the five DARE dimensions. Specifically, cohesiveness captures **which elements interacted** (number of relationships) and **how much** (i.e. intensity). In DARE cohesiveness is computed before the project starts and afterwards (during or after the project). This enables the analyst to track change in interactions across the five dimensions. Returning to the example case study used in the previous section, Figure 6 shows the interactions existing before the Biomarker platform project started, and the ones reported as formed during the project. The diversity is represented by the distribution of the elements (into categories) on the map, and cohesiveness is represented by the links (number of lines) existing in a given period of time (in this case the period of funding). The thickness of the lines represents intensity (here interpreted as how often individuals communicate with one another). This representation follows the conventions used in social network analysis.

Figure 6: Team member links during the Biomarker Platform Project - before (left) and during the project (right)



The cohesiveness measure aims to capture the distances that are bridged in a given dimension. Figure 6 shows the increase in, and intensification of, these interactions after the Biomarker Platform Project started.

The cohesiveness measure incorporates the same components as seen in the map. It describes the sum of distances between each pair of elements (individuals) as defined by the distance between their categories, and the extent to which categories are linked by interactions between elements, taking into account the number and intensity of these interactions. It is defined as follows:

Cohesiveness (γ=1, δ=1)	$\sum_{i,j} i_{ij} d_{ij}$

Where:

- d is the distance between the category i and category j
- i is the intensity of the link between the category i and category j

Here δ_{kl} is the distance between the element k and the element l and

$\delta_{kl} = d_{ij}$, where element *k* belongs to category i, and element *l* belongs to category j

And the distance between categories i and j, is the sum of the intensities of elements

$i_{ij} = \sum_{k,l} i_{kl}$

Thus, at the element level, the cohesiveness can be computed as follows:

Cohesiveness (γ=1, δ=1)– element level	$\sum_{k,l} i_{kl} \delta_{kl}$

While the distance measure is explained in the next section, the operationalisation of the intensity concept is explained here.

The intensity of flows between categories is measured through the frequency of **interactions** between pairs of elements. Maps and measures in this guide have been generated using an intensity measure operationalised as shown in Table 2:

Table 2: Operationalisation of Intensity

Frequency of individual interactions	Intensity of individual interactions
No meeting	0
Yearly meeting	1/5
Meeting every bi-annually	2/5
Monthly meeting	3/5
Weekly meeting	4/5
Daily meeting	5/5

The scores given in the scale of intensity in Table 2 are essentially arbitrary at present. It would be possible, and even desirable, to rescale these values according to a reference dataset that could allow key thresholds to be established. However, no evidence base has been used to calibrate high or low values for intensity of interaction for this pilot demonstration. The values above are therefore used tentatively for illustrative purposes only.

Unlike the diversity measure, which was normalised to create a value between zero and one for the project overall, the cohesiveness measure has no upper boundary, i.e. it can be any number higher than zero. In particular, projects with more elements (i.e. individuals involved) have potential for more links and more possibility to have higher cohesiveness. The observed cohesiveness value, both before a project starts and afterwards, is based on the same number of elements (individuals). New links created during the project will change the cohesiveness measure's value. However, the initial pre-project value will depend on the number of elements, their diversity and prior interactions. It is the relative change that is of importance in DARE. However, because the cohesiveness measure has no upper limit, it can be difficult to interpret and is not advised, particularly when attempting to make comparisons across projects which have different characteristics (such as size).

Even in making comparisons within the same project, before it starts and during the project, cohesiveness measures will generally increase, not least because people will work more intensively as a result of being funded to work together. However because cohesiveness tends only to increase (and does not decrease) an alternative measure which can increase or decrease is used to make more use of data on changing cohesiveness. This measure is the **mean distance bridged** in the observed interactions.

The mean distance bridged is a simplified and normalised measure of cohesiveness that captures the average of the distances bridged by interactions during a project, taking into account the intensity level of interactions. The difference between the cohesiveness measure and mean distance bridged of interactions can be expressed as follows:

$$\text{cohesiveness} = \sum_{k,l} i_{kl}\delta_{kl}$$

Where i,j represents individuals here (and therefore takes into account the distance 0).

Attention: d(i,i)=0, but i(i,i) >0

$$Mean\ \ distance\ bridged = \frac{\sum_{i,j=1}^{n} i_{i,j}\, d_{ij}}{\sum_{i,j=1}^{n} i_{i,j}} = \sum_{i,j=1}^{n} p_{i,j}\, d_{ij},$$

where $p_{i,j} = \frac{i_{i,j}}{\sum_{i,j=1}^{n} i_{i,j}}$

We should notice that assuming that the intensity of interactions is randomly distributed across all the individuals, the expected proportion of intensity of interactions between categories i and j would be the proportion of individuals in i and in j, thus $p_{k,l} = p_i p_j$. Under this assumption, we can interpret diversity as the expected mean distance of interactions, which can be compared to the mean distance bridged – i.e. the observed distance of interactions.

$$Diversity\ is\ expected\ mean\ distance\ bridged\ = \sum_{i,j} p_i p_j d_{ij} = \sum_{k,l}^{n} \frac{\delta_{kl}}{n^2}$$

While in general the cohesiveness increases after the start of a project (individuals meet more people within the team and interact more often with them), this is not necessarily the case for the mean distance bridged which can increase or decrease after the start of the project. For instance, in the example above, if there had been an increase in the number and or intensity of connections within an academic organisation, and no increase of connections with the industry partner, the mean distance bridged would then decrease, because the smaller distances would weigh more in the computation of this measure.

2.5 Network maps

The above section details the main components of the DARE framework, i.e. the concepts of diversity and cohesiveness, and has explained the operationalisation of the measures associated with these. This sub-section explains how the maps (as used in the example case) have been built.

The maps represent the distances between individual elements (d_{ij}) and the intensity of the links (i_{ij}, intensity is shown by the thickness of the line), in a two dimensional space. The position of the nodes is given by the distance associated with each pair of nodes (distance measure) within a given dimension. In order to see and be able to count nodes in the maps, nodes are visualised as not overlapping even where distance between them is zero. This affects the visualisation only but not the measures. In the maps shown, the distances are based on information given in interviews (for social and organisational, institutional and geographic dimensions) and secondary data (for the cognitive dimension, in this case drawing on WoS). The visualisations are built in several steps using the JavaScript library D3 (Bostock, Ogievetsky, & Heer, 2011), and are visualised in a web browser.

Interviews often reveal individuals that have aided research but who are not formally part of the project (i.e. they may not have formal duties in the project). It may be helpful to be able to distinguish between those formally involved in the project and those who have less formal roles. This information can be captured in the maps, and are shown in this guide by node size (smaller nodes denote informal collaborators, and larger nodes denote those individuals who are formally tied to a project).

1) ORGANISATIONAL DIVERSITY

Organisational distance has already been shown in the illustrative example above. Organisational distance is assigned for each individual according to their official affiliation, which is reported in each face-to-face interview and cross-checked through other interviews and online searches for individuals. Data could also be collected using secondary data sources such as publications or through the project proposal. The operationalisation of different types of organisational level are applied using a simple system as follows in Table 3:

Table 3: Operationalisation of organisational distance

Organisational distance	**Distance = $d_{i,j}$**
Same department or centre	0
Same organisation	1/2
Different organisation	2/2

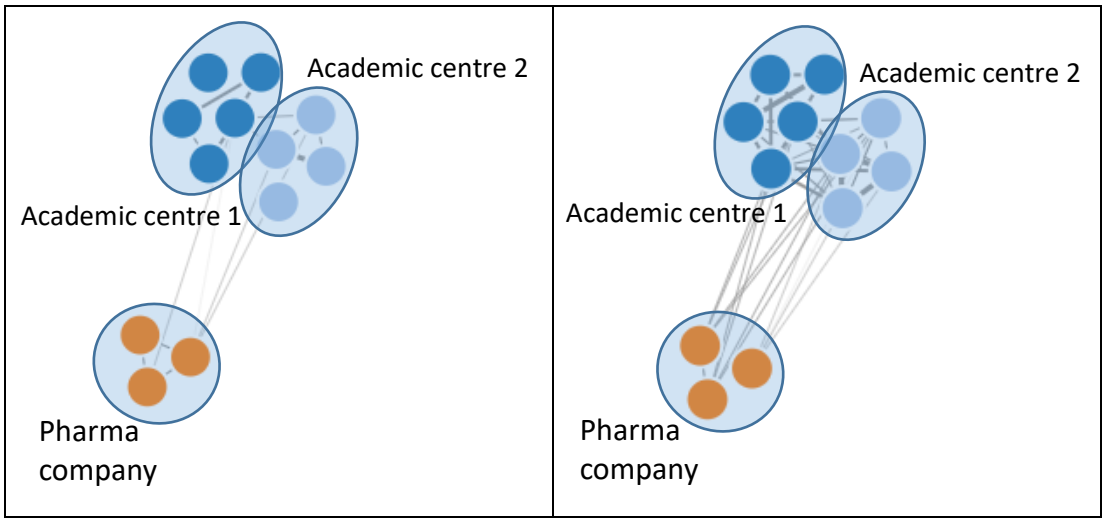
The three gradations above are not quite enough to describe the complexity of the real world of organisational links. For example, consider the status of visiting academics, with multiple affiliations. Here in the examples shown if an individual has a ***visiting status*** it has been considered to be "in" the organisation where he or she holds this position, rather than only as a member of his/ her "original" organisations (a score of ½), as these individuals may be considered closer in organisational terms than people completely external to the organisation. There is currently no empirical evidence to infer if the system used here of assigning values to organisational distance uses appropriate intervals (e.g. in a university context we could have more distances than the two selected, including distances between research centres, groups, departments, schools, divisions and faculties).

The following two examples illustrate a case of relatively low level organisational diversity and another case of relatively high organisational diversity. The first example features a project about the development of the Biomarker analysis platform (same example used above), and a second example project is an epidemiological study of a poorly understood neglected tropical disease.

Figure 7 shows that the Biomarker Platform Project involves three organisations. The fact that the majority of individuals (9 out of 12) are concentrated into two groups/centres in the same university explains the medium level of diversity. Figure 8 shows that the Neglected Disease project includes 13 separate organisations (represented by elements in 15 colours – reflecting the fact that some organisations contributed staff from more than one department/ organisational unit). The fact that there is a high number of organisations and that the individuals are quite evenly spread among these organisations makes the organisational diversity measure relatively high.

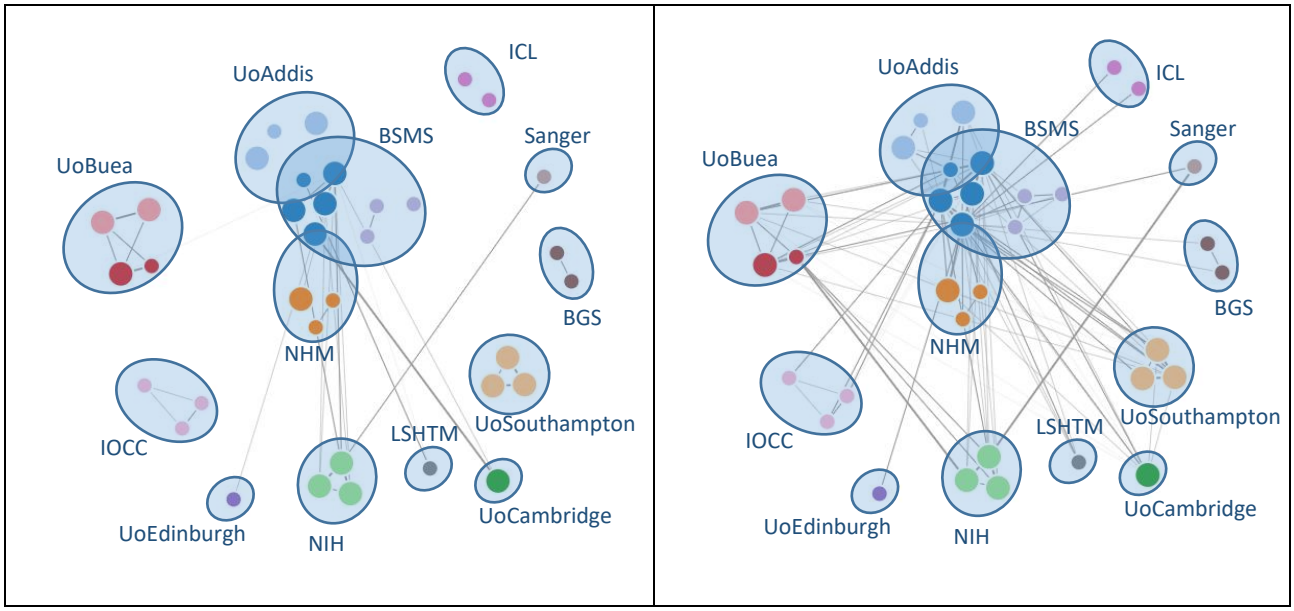
The difference in cohesiveness measures (before vs during) for both projects is positive as generally expected but note how the larger project has a much higher cohesiveness score. This higher score is in part, attributable mainly to the large size of the network and we do not therefore compare scores across projects with different network sizes. The positive change in mean distance bridged is more revealing, indicating that both projects grew the intensity of links that spanned longer distances as a result of the projects' funding (see measures for Figure 7 and Figure 8). Figure 8 also shows three organisations that are plotted as overlapping due to individuals formally connected to more than one organisation. This is the case because of individuals employed in one organisation and have visiting status in another.

Figure 7: Organisational dimension – Example 1 the Biomarker analysis platform, before (left), during the project (right)



Diversity: 0.45
Cohesiveness before: 3.10
Cohesiveness during: 12.99
Mean distance bridged before: 0.17
Mean distance bridged during: 0.27

Figure 8: Organisational dimension – Example 2 the Neglected Disease project, before (left), during the project (right)



Diversity: 0.90
Cohesiveness before: 15.4
Cohesiveness during: 96.40
Mean distance bridged before: 0.41
Mean distance bridged during: 0.64

2) Social diversity

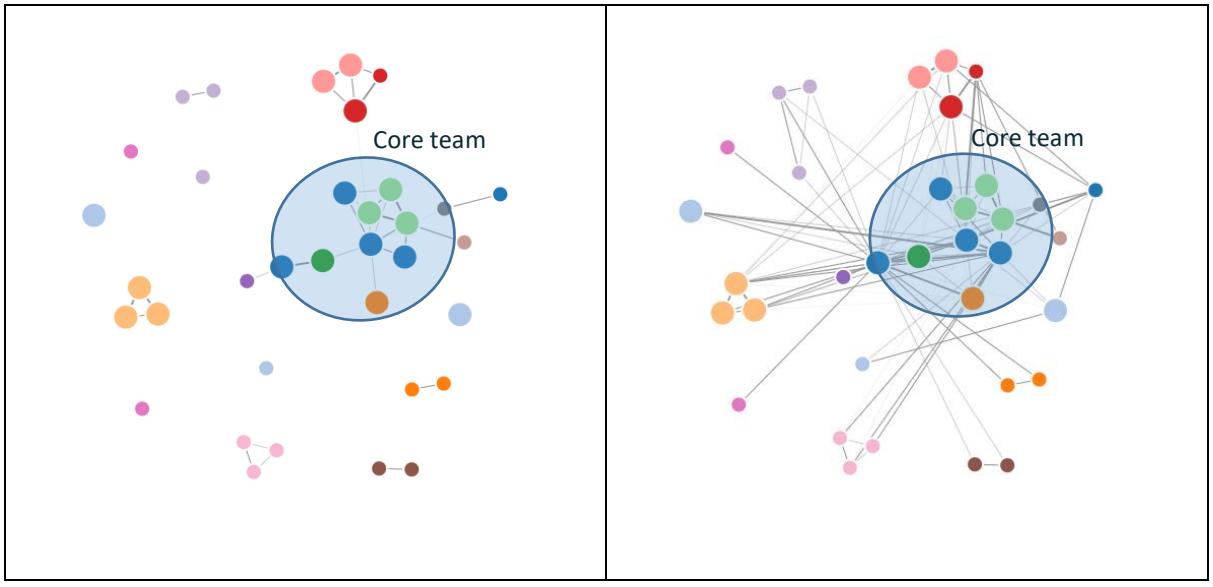
The social distance characterises peoples' acquaintance with one another. To approximate the distance on the social dimension we have distinguished three levels according to how the individuals have become acquainted through their work (naturally, there are many other ways in which this distance could have been measured). The levels are presented with the operationalisation of the distance measure, in Table 4. Thus, DARE assumes that individuals that have already worked together have established a relevant social link bringing them closer together on the social dimension.

Table 4: Operationalisation of social distance

Social distance	**Distance = $d_{i,j}$**
Have worked together before	0
Know them a little	3/4
Do not know	4/4

Figure 9 shows that a few members of the team have already worked together before the project started (represented within the shaded ring indicating the core team, that is the researchers who are funded by the project), but who have not all worked with one another previously. Just outside the ring there are a few small nodes that are quite close to the main team. These are individuals known by someone in the core team, and who have contributed to some extent to the project. In the outer part of the graph, there are individuals who were not previously known to the core team before the project started. Due to the number of new individuals in the project the social diversity is very high. The cohesiveness during the project and mean distance bridged are also quite high as many members of the team get to work with individuals they have never worked with before.

Figure 9: Social dimension – Example 2 the Neglected Disease project, before (left), and during the project (right)



Diversity: 0.92
Cohesiveness before: 0.32
Cohesiveness during: 68.80
Mean distance bridged before: 0.01
Mean distance bridged during: 0.64

In this case we see that for the social dimension, cohesiveness and mean distance bridged have increased with the project. Before the project started both measures were very low, showing that there were limited interactions between project members. The project thus built a set of interactions with socially distant individuals as well as increased the interactions between those who knew each other before the project. It is important to note that individuals who did not know each other before the project had no interaction and this is measured as zero cohesiveness, while those who had worked together have prior cohesiveness that the measure is designed to exclude.

3) GEOGRAPHIC DIVERSITY

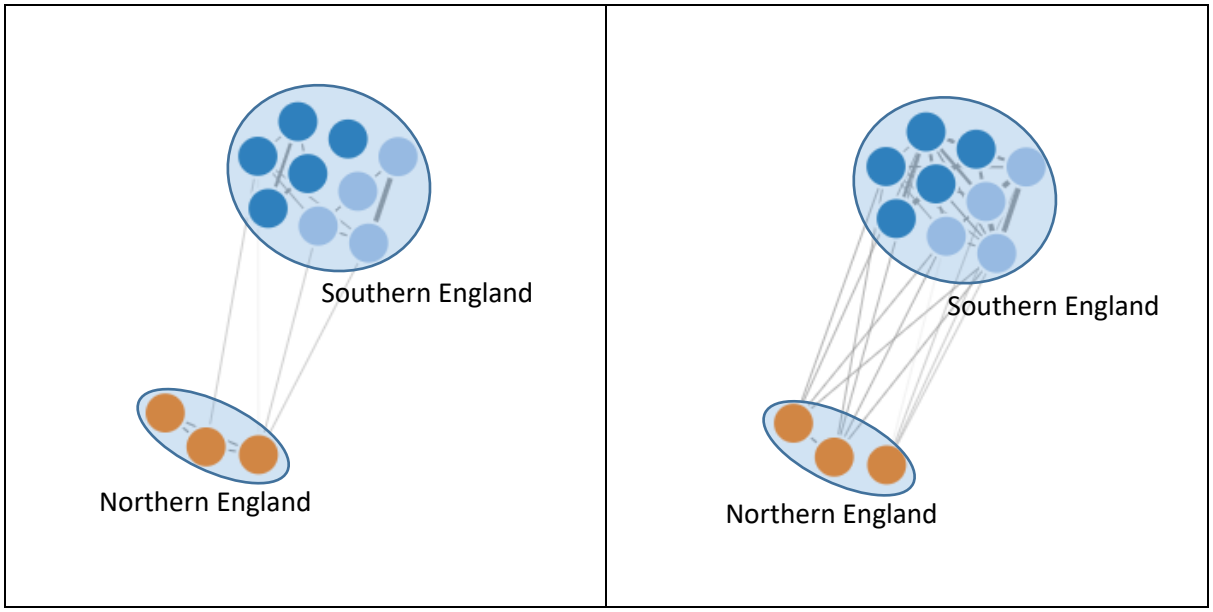
The geographic distance is represented by the distance between places of work of individuals involved in the project. The distance is not taken in absolute terms but rather in travelling time, by having different distances depending on how long it takes to travel from one place to the other (Ponds, van Oort, & Frenken, 2007). The operationalisation of the geographical distance is described in Table 5 as follows:

Table 5: Operationalisation of the geographic distance

Geographical distance	Distance (in travel time)	Distance = $d_{i,j}$
Same department	3 minutes	0
Same university, same campus	15 minutes' walk	1/5
Same city/metropolis	up to 2 hours	2/5
Same region/country	up to 4-5 hours by train	3/5
Same continent	flight or long train needed	4/5
Other continent	Long distance flight	5/5

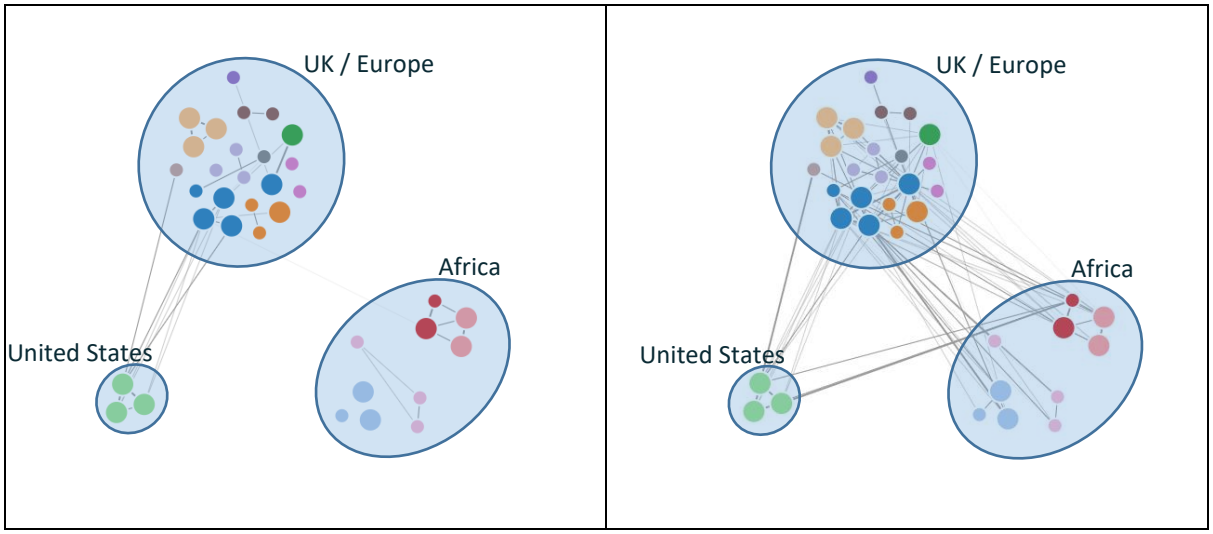
The two examples again show differences in terms of diversity, cohesiveness and mean distance of interactions bridged. Figure 10, shows the Biomarker platform project where all the individuals are within the same country. Because there is low geographic diversity, the mean distance bridged cannot exceed 3/5 (or 0.6) as per the scale defined above. Thus, if all the individuals from the two academic centres (located in the same building) connected only with individuals in industry (and not with each other) the mean distance bridged would be 0.6. However, clearly this is not the case. The mean distance bridged of interactions has increased during the project (from 0.10 to 0.15) because new connections have been established between academics and individuals in industry who are in another region of the country (note that all the academics in this case are in the same region of the country). Although this may not seem like a large increase in mean distance, one must bear in mind that given the small number of individuals involved in this project and the low geographic diversity, it is not possible to have a large increase in this dimension. The level of the mean distance bridged is also affected by the fact that interactions are here more intense for individuals located close to one another. This is in contrast with the case shown in Figure 11, the Neglected Disease project, which features a larger and much more geographically diverse team. Here the diversity was 0.74 (the team includes people from three different continents), and the mean distance bridged grew from 0.32 to 0.53 indicating that many long distance connections were formed or have intensified during the project.

Figure 10: Geographic dimension – Example 1 the Biomarker analysis platform, before (left), and during the project (right)



Diversity: 0.24
Cohesiveness before: 1.78
Cohesiveness during: 7.21
Mean distance bridged before: 0.10
Mean distance bridged during: 0.15

Figure 11: Geographic dimension – Example 2 the Neglected Disease project, before (left), and during the project (right)



Diversity: 0.74
Cohesiveness before: 11.92
Cohesiveness during: 57.12
Mean distance bridged before: 0.32
Mean distance bridged during: 0.53

4) INSTITUTIONAL DIVERSITY

The institutional dimension reflects whether individuals working together are under similar rules and incentive structures. For the biomedical sector, organisations were classified into six types of institutions with different sets of rules and incentives: academic research centres (Univ), hospitals (Hosp), governmental organisations (GO), non-governmental organisations (NGO), industry and university hospitals (Univ/Hosp). In this latter category, a distinction is made between individuals mainly working as clinicians in university hospitals (referred to as working in Hosp/Univ) and those mainly working as researchers (referred to as working in Univ/Hosp) given the different requirements attached to these roles. These different types of institutions have a different set of objectives which are set by their general mission and may be oriented towards commercialisation, care, open science, education and policy (Llopis & D'Este, 2016). The distance between each type of institution is defined by the overlap of objectives. The overlap of objectives is shown in Table 6.

Columns in Table 6 represent the attributes for each of the institutions identified. As the primary focus of University-Hospitals and universities is teaching and open science, these institutions should be closer than the ones that have their main focus on care (hospitals and clinicians at university hospitals). Univ/Hosp and Hosp/Univ are different because the first is slightly more focused on open science and the latter is primarily focused on care. Table 6 features the final vector for each type of institutions that is used to calculate distances between them.

Table 6: The missions that distinguish institutional types (with distinctions between types of University/ hospital staff)

	Univ	Hosp	GO	NGO	Industry	Univ/Hosp	Hosp/Univ
Industry	0	0	0	0	1	0	0
Care	0	1	0	0	0	0.5	1
Open Science	1	1	1	1	0	1	0.5
Education	1	0	0	0	0	0.5	0.5
Policy	0	0	1	0.5	0	0	0

Using the symmetric binary dissimilarity method (Han, Kamber, & Pei, 2012, pp. 70–71), the following distances can be obtained between each type of institution (see Table 6):

Distance (a,b)= sum(|Attr(a)-Attr(b)|)/total number of attributes

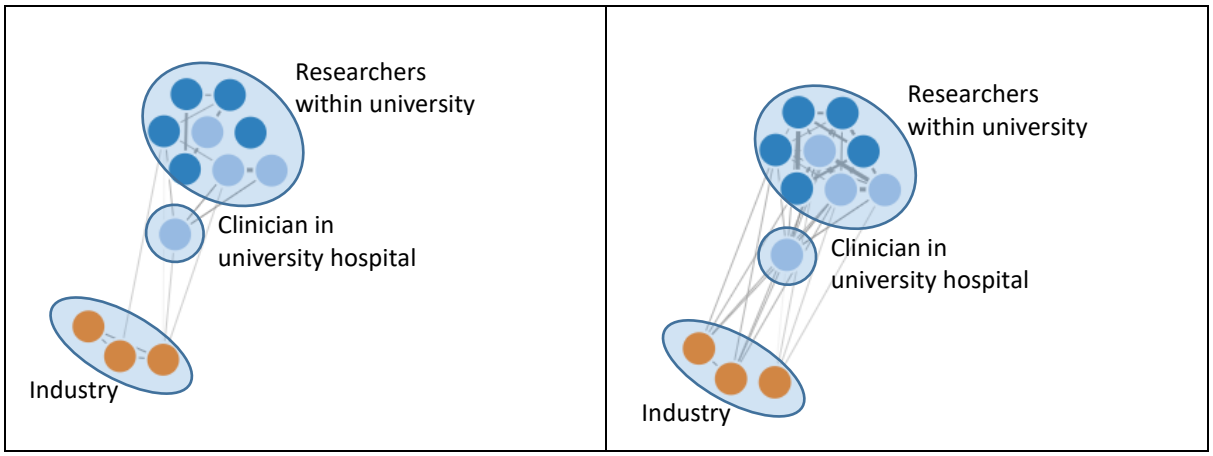
Table 7: Institutional distance defined between pairs of institutions (1)

	Univ	Hosp	GO	NGO	Industry	Univ/Hosp	Hosp/Univ
Univ	0	0.4	0.4	0.4	0.6	0.2	0.4
Hosp	0.4	0	0.4	0.4	0.6	0.4	0.2
GO	0.4	0.4	0	0.1	0.6	0.6	0.6
NGO	0.4	0.4	0.1	0	0.6	0.6	0.6
Industry	0.6	0.6	0.6	0.6	0	0.8	0.8
Univ/Hosp	0.2	0.4	0.6	0.6	0.8	0	0.2
Hosp/Univ	0.4	0.2	0.6	0.6	0.8	0.2	0

The above combinations do not cover all possible institutional types but it would be straight forward to use this approach to generate values for other institutional types that are not covered, based on their missions.

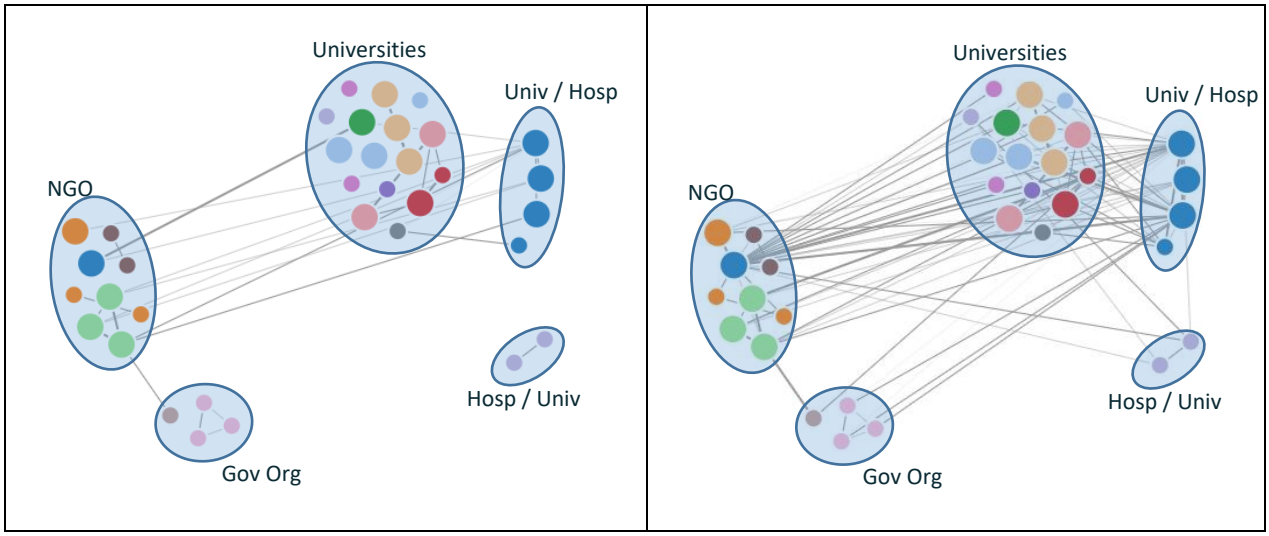
The two following examples show a low institutional diversity (Figures 12 and 13). This is partly due to the large proportion of individuals working on research in either university or university hospitals. Both examples show increasing values for both cohesiveness and mean distance bridged following the start of the project, as more individuals connect with different institutions (industry for example 1, and GO, NGO and clinicians for example 2). Example 1 also shows how the institutional dimension is different from the organisational dimension, as two individuals can be part of the same organisation but have professions with different missions impinging on their actions (for example clinician and researchers in university hospitals).

Figure 12: Institutional dimension – Example 1 the Biomarker analysis platform before (left), and during the project (right)



Diversity: 0.25
Cohesiveness before: 1.91
Cohesiveness during: 6.57
Mean distance bridged before: 0.10
Mean distance bridged during: 0.14

Figure 13: Institutional dimension – Example 2 the Neglected Disease project, before (left), and during the project (right)



Diversity: 0.28
Cohesiveness before: 5.72
Cohesiveness during: 25.08
Mean distance bridged before: 0.15
Mean distance bridged during: 0.23

5) COGNITIVE DIVERSITY

Estimates of cognitive distance between individuals working together are based upon secondary sources, in this case the publications in WoS by these individuals (although one can envisage other methods based on surveys or text-mining to recover such data). Cognitive diversity is computed looking at the references in all the papers of an individual, in particular looking at the journals cited (within a given period – here we took WoS publications in the five years' period before the start of the project). Each cited journal is attributed to its Web of Science Category[5] (WoSC). In order to compute distances between each pair of individuals, a vector of WoSCs was associated to each individual which shows the proportions of that individual's citations from each WoSC.

Then, these vectors are compared between each pair of individuals (to see if they cite the same journals to the same extent). This method also takes into account whether the WoSCs cited are similar using an underlying global science map based on cross-citation between WoSCs (Rafols et al., 2010). The similarity between two individuals is computed using the similarity measure developed by Zhou et al. (2012):

$$\varphi(\mathrm{X},\mathrm{Y}) = \frac{\varphi_{\mathrm{X,Y}}}{\sqrt{\varphi_{\mathrm{X}}\varphi_{\mathrm{Y}}}} = \frac{\sum_{i,j=1}^{N} p_{\mathrm{X}_i} p_{\mathrm{Y}_j} S_{ij}}{\sqrt{\left(\sum_{i,j=1}^{N} p_{\mathrm{X}_i} p_{\mathrm{X}_j} S_{ij}\right)\cdot\left(\sum_{i,j=1}^{N} p_{\mathrm{Y}_i} p_{\mathrm{Y}_j} S_{ij}\right)}}$$

Where p_{Xi} is the proportion of citations of the individual X of WoSC i
P_{Yj} is the proportion of citations of the individual Y of WoSC j
S_{ij} is the similarity (or 1-distance) attributed between category i and j

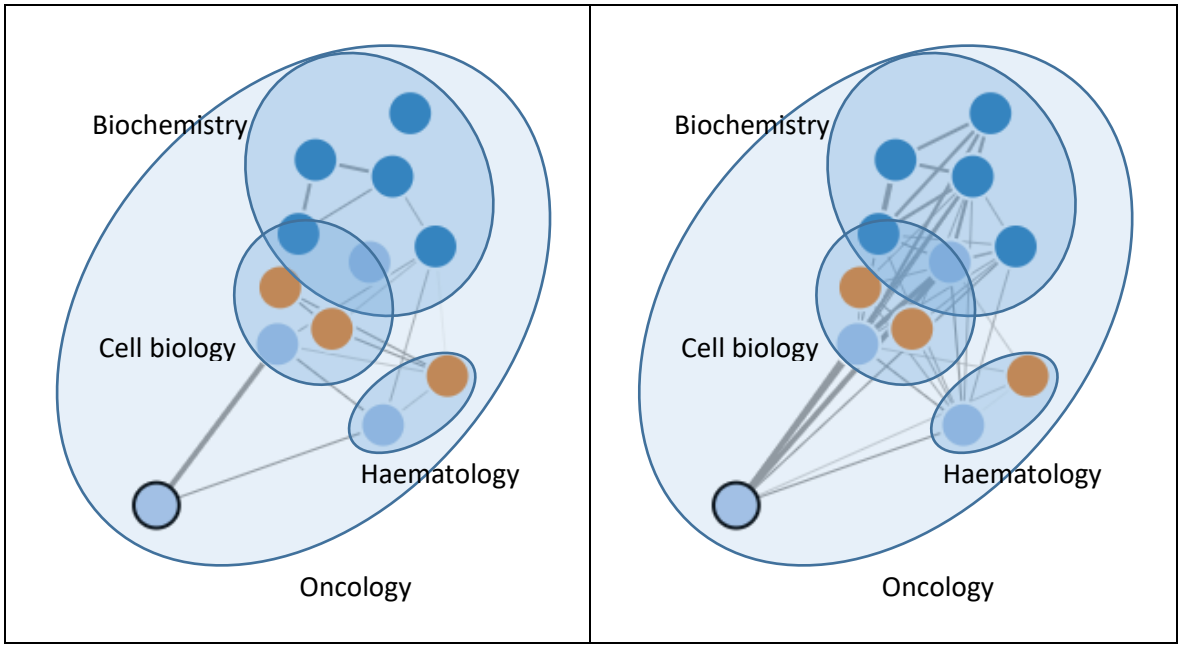
[5] See: http://ip-science.thomsonreuters.com/cgi-bin/jrnlst/jlsubcatg.cgi?PC=D

The major difference with the cognitive category (as compared with the other dimensions discussed so far) is that there is a substantial reference data providing the ability to define the extent to which scientific disciplines are different from one another. When using this diversity measure, one should bear in mind that it is very unlikely that diversity would be very high, as it is unlikely that a project involves a number of individuals evenly distributed among all the 224 Web of Science categories.

The use of WoSCs could be substituted for maps based on journal titles or topic-based clusters of publications for a more fine grained map of the cognitive dimension. However, this requires access to a journal-to-journal citation matrix or one based on a large scale topic/paper-clustering effort. Since this may not be available to many users, the more routine WOSC based approach is described here. One could also gather data to inform mapping of individuals in the cognitive dimension through interviews, by asking interviewees to identify themselves to one or more WoSCs or disciplinary labels. This seems attractive as it could be used to assign individuals with no publications to the map; however, such an approach cannot provide the level of fine-grained detail that can be obtained from a WOSC-based bibliometric analysis.

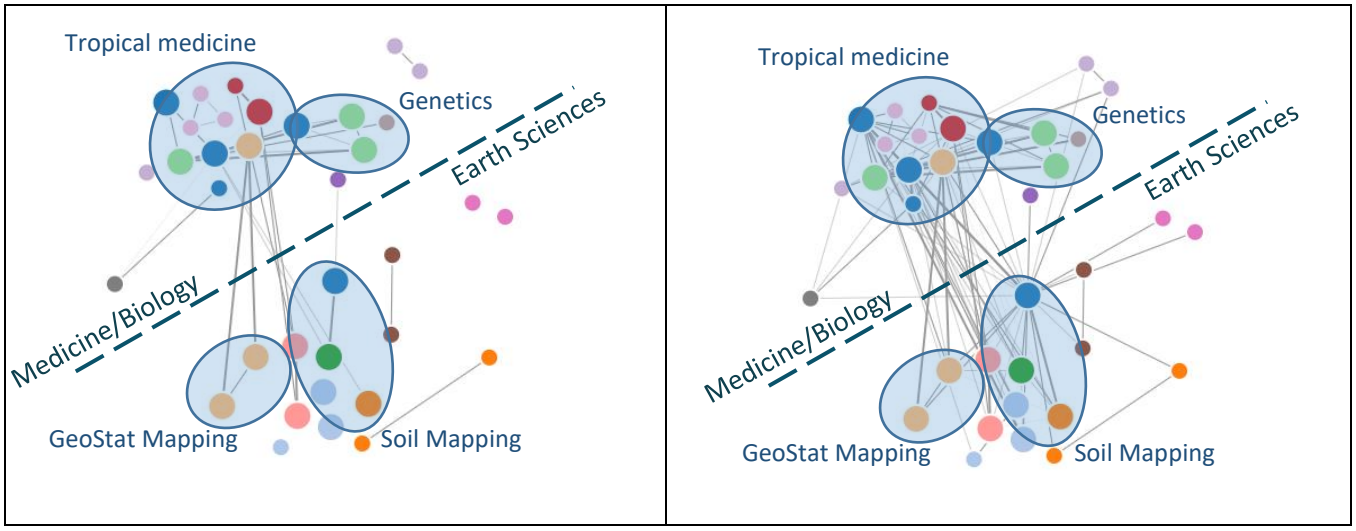
The two illustrative examples show some differences between projects. As expected the diversity values for both of them are quite low (relative to values for other dimensions discussed above). Figure 14 shows that most of the individuals are specialised in similar fields, mainly oncology, biochemistry and biochemical research methods. One individual is set apart, as he was mainly focused on oncology before the project started (but also partly due to having few publications, which decreases the accuracy of the vector). In contrast, Figure 15 shows that the second example has a higher diversity of 0.56. The diversity can be considered as quite high, as the project involves researchers from two broad fields: Earth Sciences and Biological Sciences. While the project has established some connections between the two fields (shown by an increase in mean distance bridged), the lower value of the diversity is due to a high concentration of individuals in very closely related WoSCs.

Figure 14: Cognitive dimension – Example 1 the Biomarker analysis platform, before (left), and during the project (right)



Diversity: 0.13
Coherence before: 1.84
Coherence during: 6.20
Mean distance bridged before: 0.10
Mean distance bridged during: 0.13

Figure 15: Cognitive dimension – Example 2 the Neglected Disease project, before (left),and during the project (right)



Diversity: 0.56
Cohesiveness before: 12.60
Cohesiveness during: 44.00
Mean distance bridged before: 0.34
Mean distance bridged during: 0.41

3. The DARE profile (summary chart)

The objective of the DARE profile is to combine in a single chart, measures of various dimensions that aim to summarise insights on the collaboration dynamics of a given project. A chart featuring the diversity and cohesiveness (represented by the mean distance bridged) measures can provide an overview of the results for each dimension in an intuitive manner.

The DARE profile brings together the measure of diversity (grey outline) and the mean distance bridged, which represents the average bridging effort of projects - see Figures 16 and 17. All these take values between 0 and 1 by construction (given that distances were defined in this interval). The cohesiveness measure is not included because it is not normalised by size. The measure of diversity can also be understood as an "expected" distance of interactions given the distribution of participants across categories, whereas the mean distance bridged can be understood as the 'observed' distance of interactions. Thus, this petal representation shows the extent to which the project had interaction across the categories of each dimension before and during the project.

The mean distance bridged is shown before and during the project. The mean distance bridged before the start of the project is represented by the darker shade, and the lighter shade represents mean distance bridged during the project (these three components are shown separately in Figure 17). Figure 16 and 17 are presented for illustrative purposes only and are not based on an actual case.

Figure 16: The DARE profile (illustrative profile only)

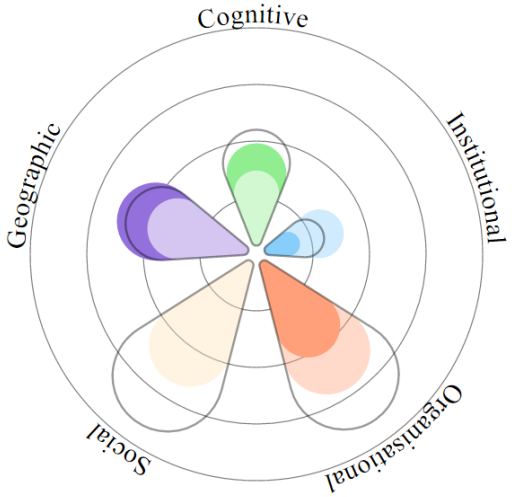


Figure 17: The DARE profile composition

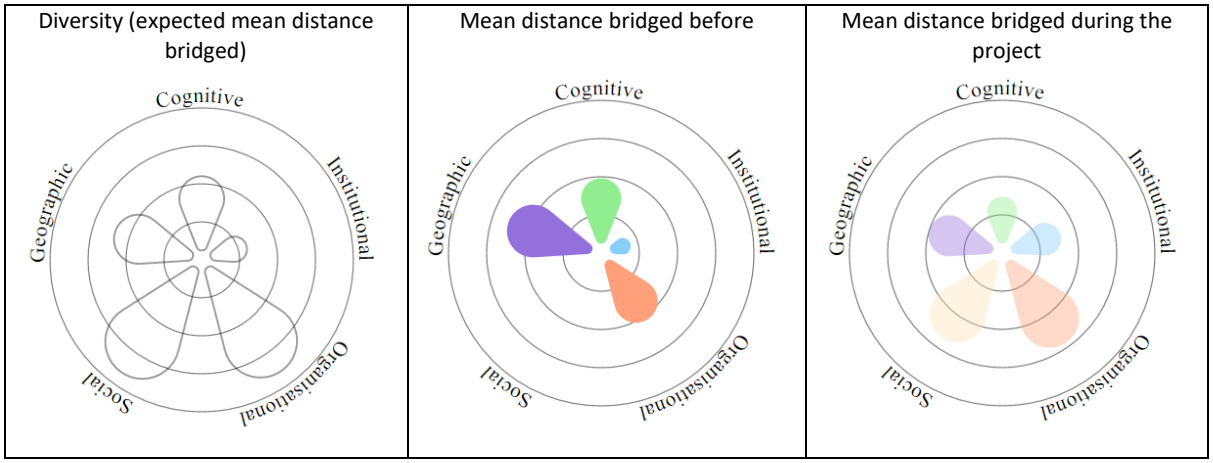
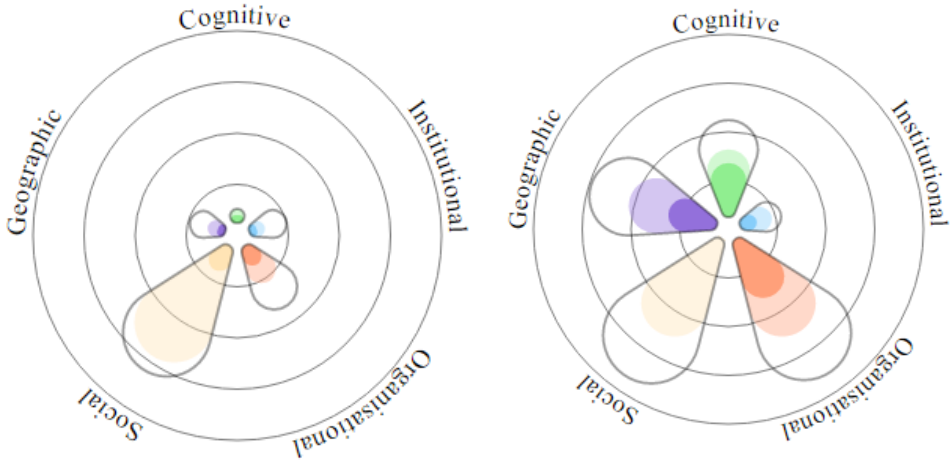


Figure 18 shows the summary chart for the Biomarker platform and Neglected Disease projects. As shown in the maps above, the Biomarker analysis platform has a quite small team over a small number of organisations within one country and therefore many of the diversity measures are quite low at the outset. However, there was a relative increase in the mean distance bridged for the geographical, institutional and organisational dimensions and therefore more individuals in the team engaged in more diverse networks in organisational and geographic terms. On the cognitive side, while the team is specialised in research areas that are quite closely related (which explains the low cognitive diversity), one can still observe an increase in mean distance bridged. The team members have from the outset been connected to people moderately different to themselves. Finally, the project has achieved the creation of many social connections.

Figure 18 Examples of the DARE profile: Biomarker analysis platform (left) and the Neglected Disease project (right)



The Neglected Disease project (Figure 18) was developed with a very diverse team from the outset, particularly organisationally and geographically. The team includes a large number of individuals spread quite evenly across organisations. In geographical terms, it also includes a variety of quite distant countries (within three different continents). The institutional diversity dimension was lower as most of the individuals work as researchers in universities. The cognitive dimension shows that the team is quite diverse as it includes people working in different areas of science (earth sciences and biological sciences). Furthermore the project has enabled many individuals in the team to work with people that they had not worked with before. In all the five diversity dimensions, taking into account

the diversity, the mean distance bridged has increased to a large extent, which is mainly due to many people connecting and intensifying relationships to quite distant individuals along these dimensions.

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Annexes

I. Questionnaire for interview

Section 1: Background

Researcher personal background

1.1) Please give a brief description :
   a) of your career path
   b) of your current role in your organisation

General information about the case study project

1.2) Please describe the case study project in a few words, with its objectives:
   a) What is the involvement of your organisation from inception to the end of the project?
      i) And your specific role (*individual to the researcher*)

Mapping exercise:

1.3) Please list the people involved from your organisation (including people working part time).

1.4) Indicate where people work, on the same site/campus, on another site/campus, in the same building or another building?
   a) What type of organisations do the projects members work in (and organisation type, e.g. university, charity, Firm, Hospital….)?
   b) Are the people you **report** (line of management for the project) to different from the ones you were reporting before you started the project?
      i) If so, please explain why?
      ii) (NOT PI) Who are you reporting to? Are they within your organisation?
      (1) If you report to people from other organisations, has reporting to people elsewhere changed expectations about the nature of your work and its potential results?
   c) How are you **organised within your site team** (who do you exchange with -informal arrangements-?) In practice who did you work with most during the project?
   d) Could you describe how the work was organised with the other members of the project team? (Frequency of meetings and interactions)

      i) What was the frequency of interactions before the project started?
      ii) What are their roles within the project?
      iii) Did you or people in your organisation already know them or work with them before the project? **
      iv) How often do you meet with the people in the other organisations and what is the purpose of these meetings?

1.5) How much time (days per year) have you spent with each person as a result of the project? Is it different from the time spent together before?

1.6) During the project did any of these individuals visit your site (or you visited their site)? How did it differ from the visit before the project started? *(only for partner organisations)*

If yes,

a) What were the purpose and duration time of these visits

1.7) Does sharing the same site as your project colleagues affect the way you work? How? *(only for partner organisations)*

1.8) Do they have a **different background**, specialisation or experience than you?

If yes,

a) What are these backgrounds or bodies of experience?
b) Was it the first time you worked with these specific individuals? **
c) Was it the first time you worked with scientists/technicians with these types of background/ experience?
d) Has this collaboration affected your knowledge and awareness of complementary knowledge capacities necessary for the completion of the project or useful in future? And if so how?

1.9) Can you indicate which organisations you have not worked with before? Can you indicate whether they are entirely new types of institutions?

1.10) Were there any difficulties in your collaboration relating to the way you are working? What are they? Do you have different goals? (when publishing)

1.11) **After the project finished** did you still meet or keep in contact with those colleagues (work or non-work related interactions)?

If yes,

a) How often?
b) By which means and how did these interactions change compared to before the project started?

1.12) Have relationships with colleagues/ stakeholders you knew before the project changed as a result of the project and how?

1.13) Do you think collaborating in this project has changed the relationship of trust with colleagues/ stakeholders in the project?

If yes,

a) Could you describe this change?

Section 2: Your organisation

2.1) What are the main (formal and informal) criteria used within your organisation to assess your performance? (we are interested in perception here, Human resources and direct supervisors?)

2.2) Does the performance criteria from the funder differ from your organisation? If yes how?

2.3) Did the project seek to address goals which are different than the performance criteria (or part of) of your organisation?

2.4) Has the work on this project involved you becoming engaged in work you don't normally undertake? If yes, are they valued by your organisation?

2.5) Do individuals face different institutional pressures or incentives between organisations involved in the project?

Section 3: Outcomes

3.1) What are the main outcomes (broadly defined) that came out of the project of real value?

a) How has this project changed your work or your vision of the future?
b) How has it changed work of others?
c) Are there outputs (including methods, policy implications not just publications) that are under development, and if so what are these?

3.2) Would you do it again (from 0 to 5 likert scale)? Why (that scoring)? (ask about difficulties vs outcomes)

II. Questionnaire for telephone interview

Section 1: Background

General information about the case study project

1.1) Please describe the case study project in a few words, with its objectives:

ii) And your specific role (*individual to the researcher*)

1.2) How are you **organised within your site team** (who do you exchange with -informal arrangements-)? In practice who did you work with most during the project? On what type of work did you collaborate?

1.3) Could you describe how the work was organised with the other members of the project team?

1.4) Have you worked with people from the organisation (cited in table) before? (Have you worked with other people of this type of institution before? Industry: pharma, biotech, Hospitals, Universities, Governmental organisations, Non-governmental organisations …)

1.5) Do they have a **different background**, specialisation or experience than you? *(Did you work with people with different background? What background? Who are they?)*

If yes,

e) Was it the first time you worked with scientists/technicians with these types of background/ experience?

f) Has this collaboration affected your knowledge and awareness of complementary knowledge capacities necessary for the completion of the project or useful in future? And if so how?

1.6) Were there any difficulties in your collaboration relating to the way you are working?

1.7) **After the project finished** did you still meet or keep in contact with those colleagues (work or non-work related interactions)?

If yes,

c) How often?

d) By which means and how did these interactions change compared to before the project started?

Did they come back to your site/ did you visit theirs? *(only for partner organisations)*

1.8) Have relationships with colleagues/ stakeholders you knew before the project changed as a result of the project and how? (SP)

1.9) Do you think collaborating in this project has changed the relationship of trust with colleagues/ stakeholders in the project?(SP)

Section 2: Your organisation

2.1) What are the main (formal and informal) criteria used within your organisation to assess your performance? (we are interested in perception here, Human resources and direct supervisors?)

2.2) Did the project seek to address goals which are different than the performance criteria (or part of) of your organisation?

2.3) Do differences across organisations (funder or partners) raise difficulties for the progress of the project?

Section 3: Outcomes

3.1) What are the main outcomes (broadly defined) that came out of the project of real value?

d) How has this project changed your work or your vision of the future?
e) How has it changed work of others?
f) Are there outputs (including methods, policy implications not just publications) that are under development, and if so what are these?

3.2) Would you do it again (from 0 to 5 likert scale)? Why (that scoring)? (ask about difficulties vs outcomes)

Table to complete ahead of telephone interview

Telephone interview: 'Grant name'

Guidelines to fill the table:

- In the column ***New (1)***, check the box if you have met the person from the first time as part of the project
- For the people you have worked with during the project could you indicate through which means you have interacted and the frequency of interactions, in the column ***Frequency and means of work (2)***
- Please indicate who has supervised you during the project (if relevant) by a cross in the column ***Supervisor (3)***
- If you have not interacted with the people mentioned do not check any of the boxes
- If you had meetings with listed individuals, please state how many days a year you spent working together, in the column ***Days a year*** (4)
- Indicate in the column ***Relationship after the project (5)***, if the relationship has changed after the project (in terms of frequency, means of interaction and type of work done together)
- In the column ***Planned Work*** **(6)**, indicate if you are currently trying to work together in the future (if yes please give a an indication of type of proposal or broad area of work)
- If there is any person missing, or if you have any information we are missing, or if you think any information is wrong, please add them to the table below.

Last name	First name	Institutions	Specialisation	Supervisor (3)	New (1)	Frequency and means of work (2)	Days per year (4)	Relationship after the project (5)	Planned work (6)

III. Computing diversity and cohesiveness measures in DARE

This annex aims at showing how to compute in details the diversity and cohesiveness measure, to make the use of the measures more straight forward. Using the example of organisational diversity in the 'Biomarker analysis' project (Figure 5), the Rao-Stirling diversity is computed as following:

Total number of elements (individuals): n=12

The two research centres were part of the same university department. Thus attributed an intermediary distance value between these organisations of: 0.15.

Total number of individual in specific category:

- Research centre 1: RC1 include 5 elements
- Research centre 2: RC2 include 4 elements
- The Pharmaceutical Firm: F include 3 elements.

Diversity = $\frac{\mathrm{RC1_1RC1_2}}{n^2}\,\delta_{RC1\,RC1} + \frac{\mathrm{RC1_1RC1_3}}{n^2}\,\delta_{RC1\,RC1} + \ldots + \frac{\mathrm{RC1_1RC2_1}}{n^2}\,\delta_{RC1\,RC2} + \frac{\mathrm{RC1_1RC2_2}}{n^2}\,\delta_{RC1\,RC2} + \frac{\mathrm{RC1_1RC2_3}}{n^2}\,\delta_{RC1\,RC2} + \frac{\mathrm{RC1_1RC2_4}}{n^2}\,\delta_{RC1\,RC2} + \frac{\mathrm{RC1_2RC2_2}}{n^2}\,\delta_{RC1\,RC2} + \ldots + \frac{\mathrm{RC2_1RC1_1}}{n^2}\,\delta_{RC2\,RC1} + \frac{\mathrm{RC2_1RC1_2}}{n^2}\,\delta_{RC2\,RC1} + \frac{\mathrm{RC2_1RC1_3}}{n^2}\,\delta_{RC2\,RC1} + \frac{\mathrm{RC2_1RC1_4}}{n^2}\,\delta_{RC2\,RC1} + \frac{\mathrm{RC2_1RC1_5}}{n^2}\,\delta_{RC2\,RC1} + \frac{\mathrm{RC2_1RC2_2}}{n^2}\,\delta_{RC2\,RC2} + \ldots + \frac{\mathrm{RC1_1F_1}}{n^2}\,\delta_{RC1\,F} + \frac{\mathrm{RC1_1F_2}}{n^2}\,\delta_{RC1\,F} + \ldots + \frac{\mathrm{F_1RC1_1}}{n^2}\,\delta_{F\,RC1} + \frac{\mathrm{F_1\,RC1_2}}{n^2}\,\delta_{F\,RC1} + \ldots + \frac{\mathrm{RC2_1F_1}}{n^2}\,\delta_{RC2\,F} + \frac{\mathrm{RC2_1F_2}}{n^2}\,\delta_{RC2\,F} + \ldots + \frac{\mathrm{F_1RC2_1}}{n^2}\,\delta_{F\,RC2} + \frac{\mathrm{F_1\,RC2_2}}{n^2}\,\delta_{F\,RC2} + \ldots + \frac{\mathrm{F_1\,F_2}}{n^2}\,\delta_{F\,F} + \ldots + \frac{\mathrm{F_3\,F_2}}{n^2}\,\delta_{F\,F}$

$= \frac{1}{12^2}\,\delta_{RC1\,RC1} + \frac{1}{12^2}\,\delta_{RC1\,RC1} + \ldots + \frac{1}{12^2}\,\delta_{RC1\,RC2} + \frac{1}{12^2}\,\delta_{RC1\,RC2} + \frac{1}{12^2}\,\delta_{RC1\,RC2} + \ldots + \frac{1}{12^2}\,\delta_{RC1\,RC2} + \frac{1}{12^2}\,\delta_{RC2\,RC1} + \frac{1}{12^2}\,\delta_{RC2\,RC1} + \ldots + \frac{1}{12^2}\,\delta_{RC2\,RC2} + \ldots + \frac{1}{12^2}\,\delta_{RC1\,F} + \frac{1}{12^2}\,\delta_{RC1\,F} + \ldots + \frac{1}{12^2}\,\delta_{RC1\,F} + \frac{1}{12^2}\,\delta_{F\,RC1} + \ldots + \frac{1}{12^2}\,\delta_{F\,RC1} + \frac{1}{12^2}\,\delta_{RC2\,F} + \frac{1}{12^2}\,\delta_{RC2\,F} + \ldots + \frac{1}{12^2}\,\delta_{RC2\,F} + \frac{1}{12^2}\,\delta_{F\,RC2} + \frac{1}{12^2}\,\delta_{F\,RC2} + \ldots + \frac{1}{12^2}\,\delta_{F\,F} + \ldots + \frac{1}{12^2}\,\delta_{F\,F}$

$= (5\times4)\frac{1}{12^2}\,\delta_{RC1\,RC1} + (5\times4)\frac{1}{12^2}\,\delta_{RC1\,RC1} + (5\times4)\frac{1}{12^2}\,\delta_{RC1\,RC2} + (4\times5)\frac{1}{12^2}\,\delta_{RC2\,RC1} + (4\times3)\frac{1}{12^2}\,\delta_{RC2\,RC2} + (4\times3)\frac{1}{12^2}\,\delta_{RC2\,RC2} + (5\times3)\frac{1}{12^2}\,\delta_{RC1\,F} + (3\times5)\frac{1}{12^2}\,\delta_{F\,RC1} + (4\times3)\frac{1}{12^2}\,\delta_{RC2\,F} + (3\times4)\frac{1}{12^2}\,\delta_{F\,RC2} + (3\times2)\frac{1}{12^2}\,\delta_{F\,F} + (3\times2)\frac{1}{12^2}\,\delta_{F\,F}$

$= 20\frac{1}{12^2}\,\delta_{RC1\,RC1} + 20\frac{1}{12^2}\,\delta_{RC1\,RC1} + 20\frac{1}{12^2}\,\delta_{RC1\,RC2} + 20\frac{1}{12^2}\,\delta_{RC2\,RC1} + 12\frac{1}{12^2}\,\delta_{RC2\,RC2} + 12\frac{1}{12^2}\,\delta_{RC2\,RC2} + 15\frac{1}{12^2}\,\delta_{RC1\,F} + 15\frac{1}{12^2}\,\delta_{F\,RC1} + 12\frac{1}{12^2}\,\delta_{RC2\,F} + 12\frac{1}{12^2}\,\delta_{F\,RC2} + 6\frac{1}{12^2}\,\delta_{F\,F} + 6\frac{1}{12^2}\,\delta_{F\,F}$

Since the distances are symmetric (i.e. $\delta_{RC1\,RC2} = \delta_{RC2\,RC1}$),

$= 20\frac{1}{12^2}\,\delta_{RC1\,RC1}\times2 + 20\frac{1}{12^2}\,\delta_{RC1\,RC2}\times2 + 12\frac{1}{12^2}\,\delta_{RC2\,RC2}\times2 + 15\frac{1}{12^2}\,\delta_{RC1\,F}\times2 + 12\frac{1}{12^2}\,\delta_{RC2\,F}\times2 + 6\frac{1}{12^2}\,\delta_{F\,F}\times2$

$= 20\frac{1}{12^2}\,0.000\times2 + 20\frac{1}{12^2}\,0.150\times2 + 12\frac{1}{12^2}\,0.000\times2 + 15\frac{1}{12^2}\,1.000\times2 + 12\frac{1}{12^2}\,1.000\times2 + 6\frac{1}{12^2}\,0.000\times2$

$= 0.139\times0.150\times2 + 0.104\times1.000\times2 + 0.083\times1.000\times2$

$= 0.021\times2 + 0.104\times2 + 0.083\times2$

$= 0.416$

The **cohesiveness** is computed as following using the above example before the project started (as shown in Figure 6 – left)

Intensity between categories RC1 and RC2: i(RC1-RC2) is the sum of intensities between individuals in categories i and j.

Cohesiveness = $i(RC1_1RC1_2)\,\delta_{RC1\,RC1} + i(RC1_1RC1_3)\,\delta_{RC1\,RC1} + \cdots + i(RC1_1RC2_1)\,\delta_{RC1\,RC2} + i(RC1_1RC2_2)\,\delta_{RC1\,RC2} + i(RC1_1RC2_3)\,\delta_{RC1\,RC2} + i(RC1_1RC2_4)\,\delta_{RC1\,RC2} + i(RC1_2RC2_2)\,\delta_{RC1\,RC2} + \ldots + i(RC2_1RC1_1)\,\delta_{RC2\,RC1} + i(RC2_1RC1_2)\,\delta_{RC2\,RC1} + i(RC2_1RC1_3)\,\delta_{RC2\,RC1} + i(RC2_1RC1_4)\,\delta_{RC2\,RC1} + i(RC2_1RC1_5)\,\delta_{RC2\,RC1} + \ldots + i(RC1_1F_1)\,\delta_{RC1\,F} + i(RC1_1F_2)\,\delta_{RC1\,F} + \ldots + i(F_1\,RC1_1)\,\delta_{F\,RC1} + i(F_1\,RC1_2)\,\delta_{F\,RC1} + \ldots + i(RC2_1F_1)\,\delta_{RC2\,F} + i(RC2_1F_2)\,\delta_{RC2\,F} + \ldots + i(F_1RC2_1)\,\delta_{F\,RC2} + i(F_1RC2_2)\,\delta_{F\,RC2} + \ldots + i(F_3RC2_4)\,\delta_{F\,RC2}$

$= 0.5\,\delta_{RC1\,RC1} + 0\,\delta_{RC1\,RC1} + 0\,\delta_{RC1\,RC1} + 0\,\delta_{RC1\,RC1} + 0.8\,\delta_{RC1\,RC1} + 0.6\,\delta_{RC1\,RC1} + 0\,\delta_{RC1\,RC1} + 0.8\,\delta_{RC1\,RC1} + 0\,\delta_{RC1\,RC1} + 0.5\,\delta_{RC1\,RC1} + 0\,\delta_{RC1\,RC1} + 0\,\delta_{RC1\,RC1} + 0.8\,\delta_{RC1\,RC1} + 0.6\,\delta_{RC1\,RC1} + 0\,\delta_{RC1\,RC1} + 0.8\,\delta_{RC1\,RC1} + 0\,\delta_{RC1\,RC1} +$

$0.5\,\delta_{RC1\,RC2} + 0.5\,\delta_{RC1\,RC2} + 0\,\delta_{RC1\,RC2} + 0\,\delta_{RC1\,RC2} + 0\,\delta_{RC1\,RC2} + 0\,\delta_{RC1\,RC2} + 0\,\delta_{RC1\,RC2} + 0\,\delta_{RC1\,RC2} + 0\,\delta_{RC1\,RC2} + 0\,\delta_{RC1\,RC2} + 0\,\delta_{RC1\,RC2} + 0\,\delta_{RC1\,RC2} + 0\,\delta_{RC1\,RC2} + 0\,\delta_{RC1\,RC2} + 0\,\delta_{RC1\,RC2} + 0.5\,\delta_{RC2\,RC1} + 0.5\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} + 0\,\delta_{RC2\,RC1} +$

$0.6\,\delta_{RC2\,RC2} + 0\,\delta_{RC2\,RC2} + 1\,\delta_{RC2\,RC2} + 0\,\delta_{RC2\,RC2} + 0.6\,\delta_{RC2\,RC2} + 0\,\delta_{RC2\,RC2} + 0.6\,\delta_{RC2\,RC2} + 0\,\delta_{RC2\,RC2} + 1\,\delta_{RC2\,RC2} + 0\,\delta_{RC2\,RC2} + 0.6\,\delta_{RC2\,RC2} + 0\,\delta_{RC2\,RC2} +$

$0.2\,\delta_{RC1\,F} + 0.4\,\delta_{RC1\,F} + 0\,\delta_{RC1\,F} + 0\,\delta_{RC1\,F} + 0\,\delta_{RC1\,F} + 0\,\delta_{RC1\,F} + 0\,\delta_{RC1\,F} + 0\,\delta_{RC1\,F} + 0\,\delta_{RC1\,RC1} + 0\,\delta_{RC1\,F} + 0\,\delta_{RC1\,F} + 0\,\delta_{RC1\,F} + 0\,\delta_{RC1\,F} + 0\,\delta_{RC1\,F} + 0\,\delta_{RC1\,F} + 0.2\,\delta_{F\,RC1} + 0.4\,\delta_{F\,RC1} + 0\,\delta_{F\,RC1} + 0\,\delta_{F\,RC1} + 0\,\delta_{F\,RC1} + 0\,\delta_{F\,RC1} + 0\,\delta_{F\,RC1} + 0\,\delta_{F\,RC1} + 0\,\delta_{F\,RC1} + 0\,\delta_{F\,RC1} + 0\,\delta_{F\,RC1} + 0\,\delta_{F\,RC1} + 0\,\delta_{F\,RC1} + 0\,\delta_{F\,RC1} + 0\,\delta_{F\,RC1} +$

$0.4\,\delta_{RC2\,F} + 0\delta_{RC2\,F} + 0\,\delta_{RC2\,F} + 0.4\,\delta_{RC2\,F} + 0\delta_{RC2\,F} + 0\,\delta_{RC2\,F} + 0\delta_{RC2\,F} + 0\,\delta_{RC2\,F} + 0\delta_{RC2\,F} + 0\,\delta_{RC2\,F} + 0\delta_{RC2\,F} + 0\,\delta_{RC2\,F} + 0.4\,\delta_{F\,RC2} + 0\,\delta_{F\,RC2} + 0\,\delta_{F\,RC2} + 0.4\,\delta_{F\,RC2} + 0\,\delta_{F\,RC2} + 0\,\delta_{F\,RC2} + 0\,\delta_{F\,RC2} + 0\,\delta_{F\,RC2} + 0\,\delta_{F\,RC2} + 0\,\delta_{F\,RC2} + 0\,\delta_{F\,RC2} + 0\,\delta_{F\,RC2} + 0\,\delta_{F\,RC2} +$

$0.6\,\delta_{F\,F} + 0.6\,\delta_{F\,F} + 0.6\,\delta_{F\,F} + 0.6\,\delta_{F\,F} + 0.6\,\delta_{F\,F} + 0.6\,\delta_{F\,F}$

$= 2.70\,\delta_{RC1\,RC1}\times2 + 0.10\,\delta_{RC1\,RC2}\times2 + 2.2\,\delta_{RC2\,RC2}\times2 + 0.6\,\delta_{RC1\,F}\times2 + 0.8\,\delta_{RC2\,F}\times2 + 1.8\,\delta_{F\,F}\times2$

$= 2.70\times0\times2 + 0.10\times0.15\times2 + 2.2\times0\times2 + 0.6\times1\times2 + 0.8\times1\times2 + 1.8\times0\times2$

$= 3.10$