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Four types of knowledge integration management in interdisciplinary research on cities and the environment

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Abstract
This article provides an overview on different types of managing interdisciplinary knowledge integration in environmental urban research projects: 1. "synthesis-then", 2. "synthesis-online", 3. "synthesis-first", 4. "synthesis-as contracted". We present two projects in the context of urban ecology, in order to discuss two types of integration management in more detail. In the "synthesis-first" type of project management, interdisciplinary knowledge integration is organized through "syntheses groups" that represent the relevant perspectives on a case. We introduce "synthesis-first" using the Zurich North case study as an example. In the "synthesis-online" type of project management, interdisciplinary knowledge integration is wanted but occurs only occasionally. As an example, we present the interdisciplinary Berlin project on urban ecology. This article argues that knowledge integration in general requires sufficient management and an audience for the products of knowledge integration (scientific or not). We emphasize the importance of "boundary objects" for interdisciplinary knowledge integration in general and for urban ecology in particular.

Key Words
Interdisciplinary knowledge integration; synthesis; transdisciplinarity; urban ecology; boundary objects; urban research; stakeholders; Zurich; Berlin.

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Cities and the Environment 1(1):2008

Interdisciplinarity and knowledge integration is a goal often claimed in research projects, especially in urban ecology and projects on sustainable urban development. However, anybody who has any experience in interdisciplinary work knows that there are difficulties such as (Mieg 2003a):

-The huge gap in the scientific cultures between natural sciences and social sciences or: science and humanities;

-The impact of the disciplinary peer reviewing system that does not really reward inter-disciplinary work;

-No or low budgets for knowledge integration management.

Although many scientific innovations emerge at the borders of disciplines, scientific careers generally are made within disciplines. The most prestigious journals of a discipline rarely accept interdisciplinary work. Thus, even widely acceptable fields of interdisciplinary work such as the environmental sciences seem well-advised to develop into a particular discipline in order to provide scientific career opportunities (Mieg 2003b).

The aim of this article is to describe different types of interdisciplinary knowledge integration, or: how to attain knowledge integration under different preconditions. The focus is on the consequences for urban ecology.

BOUNDARY OBJECTS

Some methodologies have already been defined for interdisciplinary work. One of the most simple and robust ones is the use of so-called "boundary objects" (Star and Griesemer 1989). Boundary objects are means of translation, especially useful in modular, interdisciplinary work (Mieg et al. 1996). Simple boundary objects are physical objects that can be studied simultaneously using methods from different disciplines. In the context of urban research, the particular concrete *case* can be considered as a boundary object as well. For instance, an abandoned former industrial or commercial site, now a vacant lot, that can be studied from the perspective of ecological succession or from the perspective of urban real estate investment. The study of the particular case helps to translate one perspective (ecology) into another (real estate market), for instance by assessing the site's potential as an urban pocket park. Every physical part of a city can be subject to a multitude of possible analytical perspectives that may overlap to a certain extent.

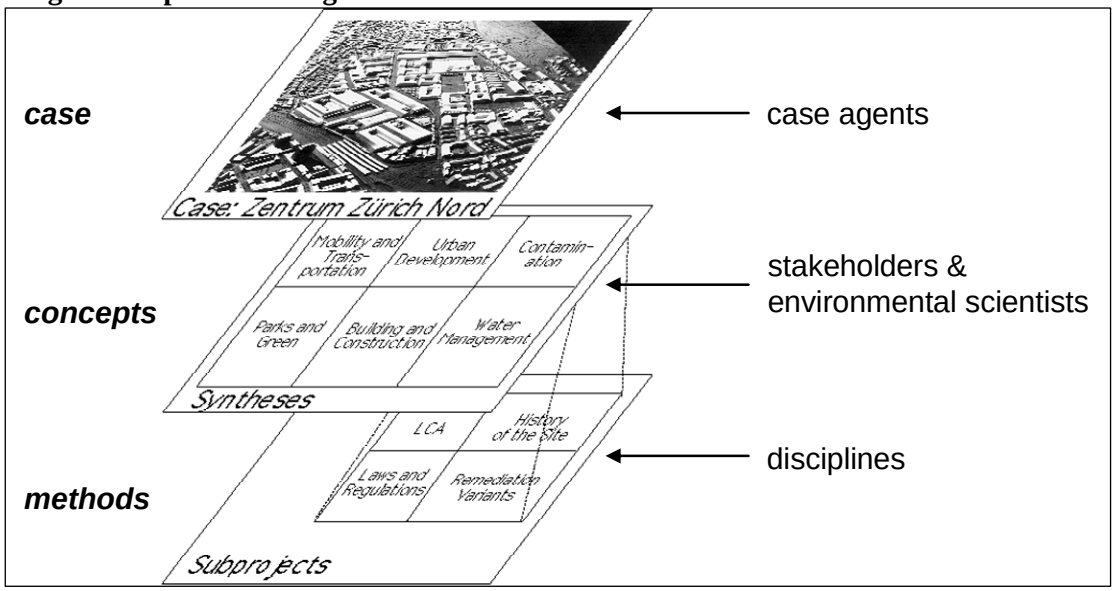
Boundary objects cannot only be physical cases (sites) but also *concepts* such as "traffic" or "urban planning". In general, abstract concepts are under-determined and leave room for interpretation through different disciplines and from various viewpoints. For instance, traffic can be considered from the perspective of air pollution but also as a problem of traffic management.

Both the cases and the concepts help to define the *epistemic integration*, which is the conceptual architecture of how to view a particular case or project. Figure 1 shows the epistemic integration of the 1990's revitalization case of Zurich North, a former industrial site of about 70 hectares in the North of Zurich, Switzerland. This was a joint project between property owners, science and the municipal authorities. The overall goal was to induce sustainable development (Scholz and Tietje 2002; Scholz et al. 1997). The "case" was viewed from six perspectives, addressed as "parks and green", "water management", "urban development", "contamination", "mobility and transportation" and "building and construction". These were the main conceptual descriptors and points of synthesis of the project. Figure 1 shows three levels: the case, the descriptors (here: syntheses) and, finally, the subprojects which were defined by the relevant disciplinary project. For instance, "contamination" was broken down into an analytical, historical, technical and juridical subproject. As Figure 1 indicates, the main input at the subproject level

Mieg et al.: Knowledge Integration

came from the disciplines, whereas the inputs at the conceptual level came from interaction between environmental scientists with stakeholders (citizens, property owners, shop owners, politicians...).

Figure 1: Epistemic integration of the Zurich North case



(Scholz et al.1997; Scholz and Tietje 2002)

Thus, as seen in the Zurich North case, boundary objects not only support interdisciplinary work but also transdisciplinarity that is consensus building when cooperating with stakeholders.

TYPES OF INTEGRATION MANAGEMENT

An epistemic reconstruction of an urban development case as presented in Figure 1 can be found in many projects. Differences in knowledge integration do not, so much result, from differing conceptual architectures than from differences in *integration management*. In practice, we can distinguish four types, listed in Table 1 under the titles of "synthesis-then", "synthesis-online", "synthesis-first" and "synthesis-as contracted". In this section the three types called "synthesis-then", "synthesis-first" and "synthesis-as contracted" are presented. The fourth type ("synthesis-online") will be discussed in the following section that deals with the Berlin urban ecology project.

Table 1: Four types of integration management

	Synthesis-then	**Synthesis-online**	**Synthesis-first**	**Synthesis-as contracted**
Type of research	multidisciplinary	interdisciplinary	transdisciplinary	professional
Audience	scientific community	scientific community / interested public	scientists and stakeholders	client
Epistemic integration	additive	partial	hierarchical	report
Typical project members (cf. Mieg 2000, 2006)	scientists	scientists, co-ordinators (also for external communication)	scientists, stakeholders, project management	staff (scientific and other)
Performance (what is paid for?)	scientific papers	scientific papers, scientific training	transfer, report, scientific papers, scientific training	project output (report, treatment)
Integration management	weak, or contracted (moderated) synthesis moderation	on occasion	methodological, high input	task-oriented, efficient
Science-society knowledge transfer	haphazard, scientific conferences	through inter-action, scientific / public conferences	through parti-cipation, a series of meeting and public events	contracted, meeting
Interdisciplinary output	exchange of methods	exchange of views; theory inputs	joint products; theory inputs	professional product
Examples		Berlin "urban ecology" project (see Table 2)	Zurich North (see Figure 1)	

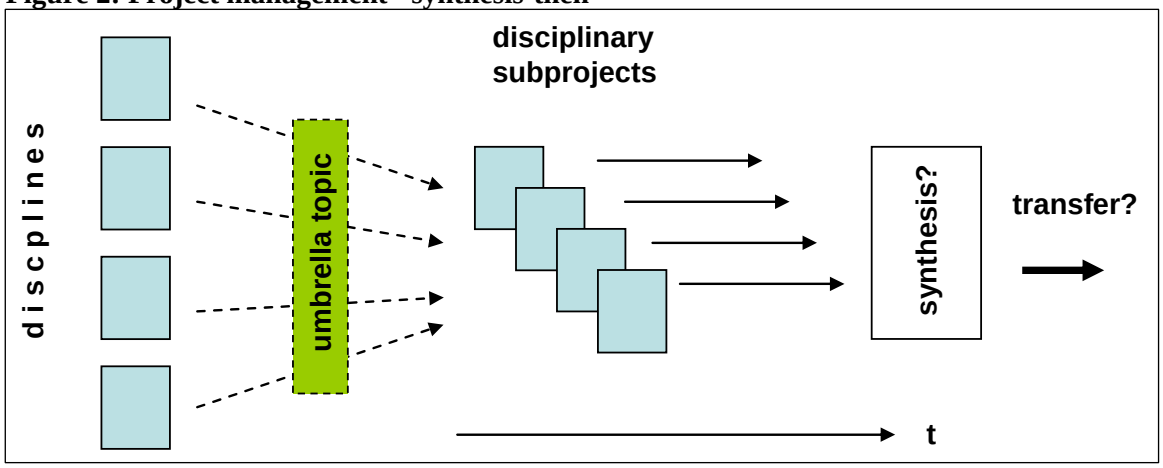
Synthesis-then

The most common case of multidisciplinary work is a "synthesis-then"-type project. This type refers to agglomerations of projects from several disciplines. The single projects run under an umbrella theme but follow separate paths. Figure 2 sketches this type of integration management. It is called synthesis-then, because the synthesis is postponed to the future. The subprojects are focused on producing "good" science, which are high-quality research papers. The subprojects and papers are oriented towards specific disciplines, especially when the involved doctoral students can only be promoted within a particular discipline - as in the case of the German university system. In general, there are no or few resources for knowledge

Mieg et al.: Knowledge Integration

integration; there is also a lack of interest. If there is a significant interest in a synthesis, for example through the project sponsors (scientific or not), then, usually, an outsourced integration moderation is organized, for example a delphi, an expert workshop, a conference, a hearing. However, as Table 1 shows, for the typical project member, the main audience is his or her scientific community.

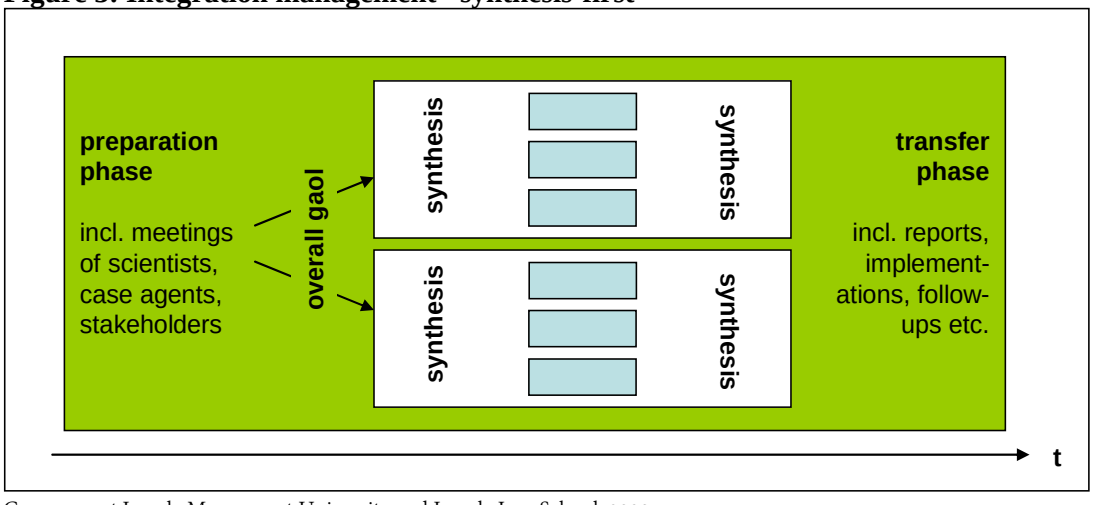
Figure 2: Project management "synthesis-then"



Synthesis-first

The project-type "synthesis-first" follows a completely different, transdisciplinary approach. In this context, transdisciplinarity means the integration of stakeholders with the project from the beginning, particularly when defining the overall goal of the project and the relevant research questions (cf. Thompson Klein et al. 2001). This happened in the case of Zurich North. The property owners and some politicians ("case agents") approached the Swiss Federal Institute of Technology (ETH Zurich) for a joint project in order to redevelop the area. The project title was Zentrum Zürich Nord (Urban Centre Zurich North). The project included - in various roles - stakeholders, environmental scientists, planning and design professionals, associated engineering firms - and students, in all about 200 people. Work was organized through six synthesis groups (see Figures 1 and 3), for instance a group that was concerned with the contamination problem. The goal was to develop a basis on which a "sustainable" decision regarding the contamination of the site could be found. The disciplinary subprojects were defined accordingly. Working in syntheses groups guaranteed knowledge integration at very high conceptual and planning levels.

Figure 3: Integration management "synthesis-first"



Knowledge integration was supported through a toolset of synthesis methods, such as formative scenario analysis or formative multi-attributive assessments (Scholz and Tietje 2002). As the stakeholders participated (including the property owners and the municipal authorities), the project contributed heavily to the revitalization of this site. For instance, a platform was created for a joint traffic infrastructure planning (property owners, city, and local grass root association). The project also contributed to the integration of multi-attributive methods in the assessment of remediation technologies for contaminated sites (Schwarzenbach et al.1999). The core problem of "synthesis-first"-projects, however, is the complexity of project organization that necessitates the allocation of project management resources. In general, the project requires long preparation and - equally important - the management of post-project knowledge transfer. In the case of Zurich North, the core project took half a year, but preparation and transfer required another 1.5 years. The management costs were paid partly by the property owners, because of their interest re-developing the site; and partly by ETH Zurich, as the project also served as a training course for students of environmental sciences.

Synthesis-as contracted

The last type of integration management, "synthesis-as contracted", refers to professional work, e.g. by landscape architects, environmental engineers or market research institutes that also conduct urban research (e.g., Prognos, Mercer). These experts and institutions may be independent or university-based. In this case of integration management, a specific task or project is contracted by a client, for example the city office for green spaces. The contracted work may comprise:

- An expert opinion on land revitalization and reuse planning for contaminated sites.
- An annual report on municipal waste management.
- A comparative study on the liveability of particular cities.

In the context of "synthesis-as contracted" work, knowledge integration has to fulfil a specific task; the results are transferred within the professional-client relationship (Mieg in press). The client defines the product (e.g., a report) that has to be delivered; the choice of the suitable methodology (e.g., types of soil probes) remains at the discretion of the contracted professional. This is the reason why many professionals feel restricted and uneasy when they are involved in "synthesis-first" projects with their strict process methodology (Mieg 2000, 2006). Whereas "synthesis-as contracted" work is oriented towards the contracted product, integration management of the types "synthesis-first" and "synthesis-online" are more focused on the process.

“SYNTHESIS-ONLINE:” THE BERLIN URBAN ECOLOGY RESEARCH PROJECT (RTG 780)

In 2002, three Berlin universities and two non-university research institutes launched a joint research training group (RTG 780) called "Urban Ecology" (www.stadtoekologie-berlin.de). This project is funded by the German Research Foundation, divided into three phases and runs until 2011. It provides an example of the "synthesis-online" type of knowledge integration.

The project RTG 780

Table 2 provides an overview of the three projects terms and the involved boundary concepts. During the first research term, research was organized on a northwest-southeast transect through the Berlin metropolitan area from the centre to the very outskirts. Research focussed on a variety of subjects such as the changing conditions of neophytes (von der Lippe et al. 2005), urban air quality (Wolf-Benning et al. 2005), soil conditions in urban environments

Mieg et al.: Knowledge Integration

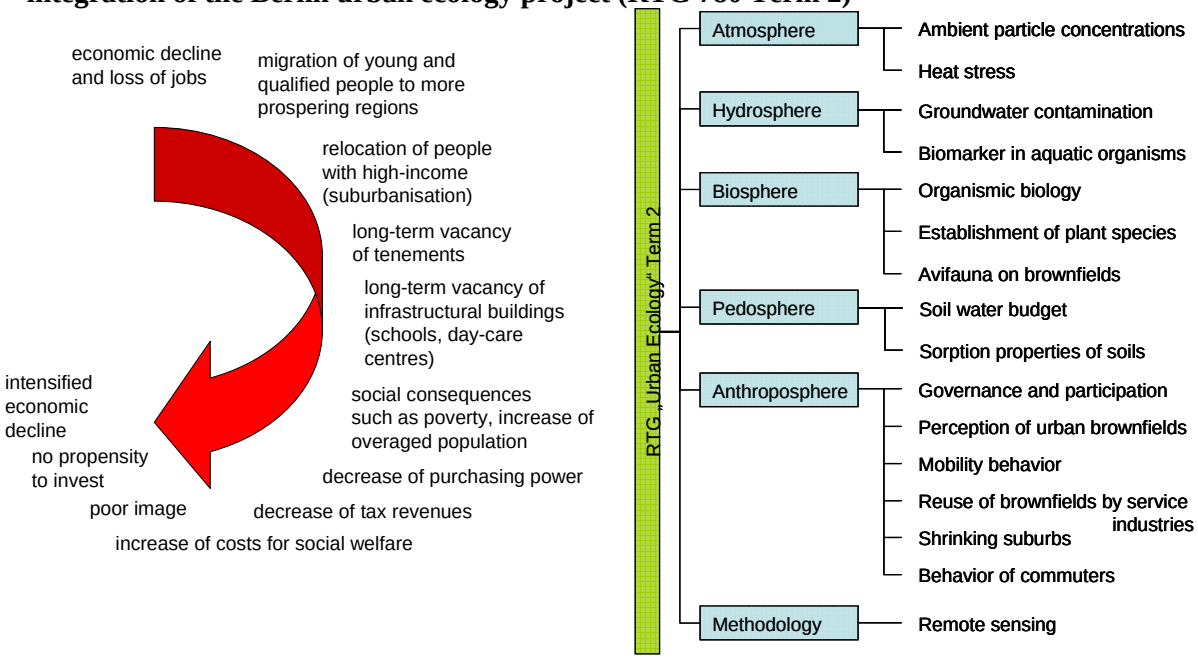
(Nehls et al. 2006), the habitat of kestrel (Kübler and Zeller 2005) or community gardens (Rosol 2005).

Table 2: The Berlin urban ecology research project (RTG 780)

Term	Year	Guiding topic	Boundary objects / integration concept
Term 1	2002 – 2005	ecology of the European metropolis	northwest-southeast transect
Term 2	2005 – 2008	shrinking cities	vacant lots (in 3 Berlin districts)
Term 3	2008 – 2011	optimizing urban-nature development	research clusters

Research in the second term focuses on urban vacant lots. The guiding topic of the term is "shrinking cities", a demographic and economic phenomenon that has hit many cities in Central Europe. It leads to a downward spiral of aggravating problems particularly in economic terms (see Figure 4, left side). Vacant lots represent a typical feature in shrinking cities and are of special interest to urban ecology. They offer - often only temporarily - habitats for plants and animals as well as opportunities for real estate investments and urban restructuring. Figure 4 (right side) provides an overview of the epistemic structure of the project that includes 16 subprojects. The inputs come from a wide range of disciplines, including geography, biology and psychology. The joint focus however is on urban vacant lots.

Figure 4, left: Downward spiral of shrinking cities (Fritsche et al. 2007), right: epistemic integration of the Berlin urban ecology project (RTG 780 Term 2)



Research in the third term of the Berlin urban ecology project will be clustered around four topics:

1) Biodiversity and optimizing ecological functions of roadside areas
2) Reuse of former housing estates

3) Strategies for temporarily used urban sites
4) Psychosomatic health of city residents

The organizing principle is to conduct research at ecological hotspots such as roadside areas. These hotspots again serve as boundary objects.

Synthesis-online

The Berlin urban ecology project RTG 780, as far as it has been introduced, appears to be a project of the "synthesis-then" type. In fact, many of the subprojects shown in Figure 4 (right side) are disciplinary projects and follow the logic of disciplinary science production as one aim is to produce papers for high-ranking disciplinary journals. We can also perceive typical side-effects of multidisciplinary work from the exchange of methods. For instance, psychologists and ecologists started cooperation by selecting urban habitats that displayed systematically varying parameters that were relevant both to ecology and the human perception of urban situation (e.g. different types of urban parks). Another example of such side-effects is the use of remote-sensing methods to analyze floor sweeps, a non-standard-procedure that was necessary because of the specifics of urban soils.

However, as an interdisciplinary research training group, the Berlin urban ecology project has a particular resource: active doctoral students. Though there are very limited means for integration management, several measures and integration activities have been implemented thanks to the active contribution of doctoral students. Besides internal scientific workshops, these comprise:

- A bi-annual interdisciplinary conference on urban ecology open to the public (e.g., www.uecb-2006.de).
- Lectures series (e.g. on transdisciplinarity) and an urban ecology theory group.
- Interdisciplinary publishing projects (Endlicher et al. 2007; Fritsche et al. 2007).
- Cross-cutting projects (e.g. on urban geo-data management in cooperation with Berlin Senate).

Knowledge integration is realized during particular occasions such as conferences or meetings with the Berlin administration. It is realized "online" because of two reasons, first, there needs to be a certain readiness to find or create such occasions; and second, on the occasion, knowledge integration is triggered by the interaction of the participants.

Thus, "synthesis-online" knowledge integration depends on the activity of single actors involved in a project or process. In the Berlin urban ecology project, many of the integration activities are carried out by doctoral students. Their motivation is that they profit from learning by doing and networking. The project provides the necessary means, such as budgets, a general time frame, professional advice and space for self-organization.

However, the initiative for "occasional" interdisciplinary knowledge integration is not confined to doctoral students. The involved researchers and the cooperating Berlin administrative agencies are active in this area, too. Conferences and workshops are the main, but not sole examples. For instance, an interdisciplinary teaching project on the City and the environment was launched by scholars of the project RTG 780 in 2004. It commenced as a lecture series, but the concept was revised annually in order to better define and understand the interfaces between the involved disciplines. Thus, elements of system theory and the theory of science have been added to the lecture series. Another example is the cooperation between the Berlin office of municipal sanitation and the environmental psychologists of the Berlin urban ecology project. The goal was to find out more about the people's perception of and preferences for "cleanliness" of urban space (streets, parks, etc.). This task was made necessary through the advice by architects and biologist.

Knowledge integration of the "synthesis-online" type might be innovative or not, however, it generally leads only to partial or fragmented knowledge integration. Efforts towards systematic knowledge integration would require more means and management capacity and

Mieg et al.: Knowledge Integration

would probably end in a "synthesis-first" type of integration management. This happened in the case of the annual Swiss environmental sciences case study of regional planning that started in 1994 as a "synthesis-online" project and developed into a "synthesis-first" type project (Mieg 2000) - as interdisciplinary knowledge was a primary goal of these projects.

DISCUSSION AND CONCLUSION

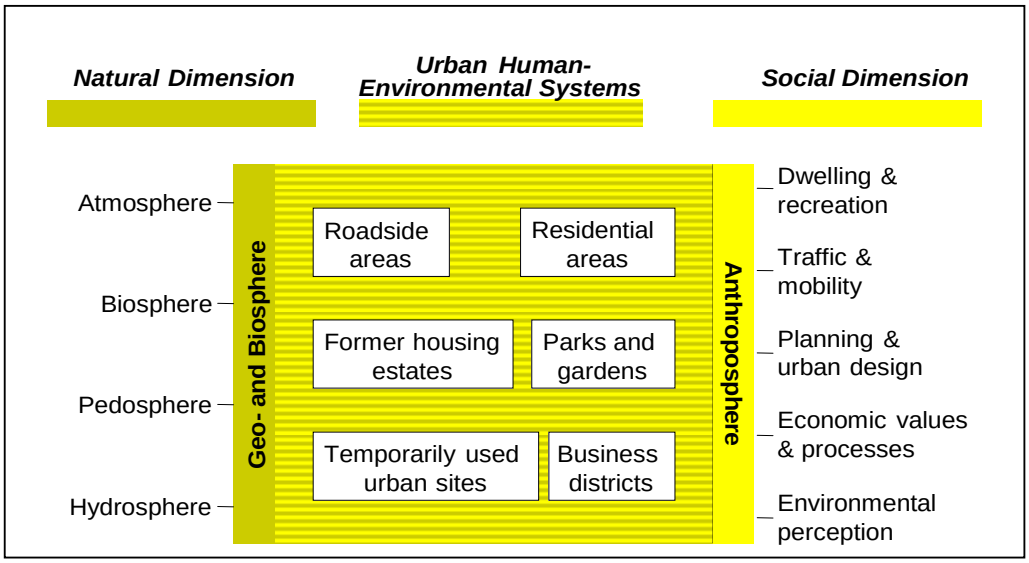
The discussion focuses on two points: the consequences for research in urban ecology and on methods of integration management.

Research in urban ecology

Urban ecology suffers from the divide between natural and social sciences. The challenge lies in “integrating humans into ecology” (Alberti et al. 2003; Marzluff et al. 2008). Urban ecology cannot do without integrating the human dimension. This is reflected in the definition of urban ecology by Sukopp and Wittig (1998): They define *urban* ecology as the research of ecosystems that are linked to typical urban functions or "uses", such as: dwelling, industry, commerce, traffic, or urban administration (p. 4).

The Berlin urban ecology project (RTG 780) attempts to translate this definition into a research methodology. The project has so far identified specific ecology hotspots in cities: e.g., roadside areas, former housing estates, etc. Figure 5 provides an overview. These hotspots reflect the ecological dynamics of cities in Central Europe and can serve a map or program for future research paths.

Figure 5: Concept of integrated research in urban ecology (Endlicher et al. 2007



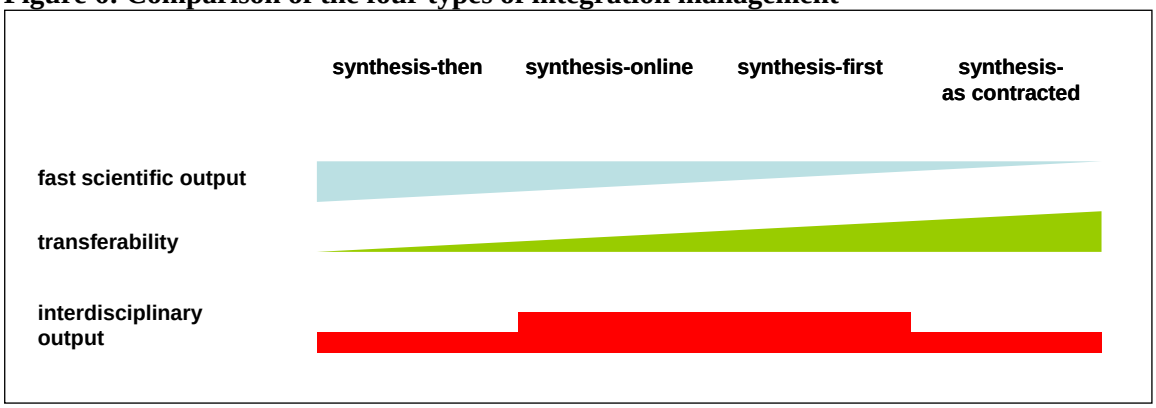
Defining hotspots as boundary objects may support interdisciplinary knowledge integration in urban ecology. However, there shouldn't be too many as otherwise complexity is unduly increased. Also it should be noted that the use of boundary objects does not guarantee interdisciplinarity. Interdisciplinary work requires both the declared intention to integrative research and above all organizational means for integration management.

Cities and the Environment 1(1):2008

Integration management

The four types of integration management introduced in Table 1 serve different functions and work on different assumptions (see Figure 6). "Synthesis-then" and "synthesis-online" have a scientific focus. Their performance is measured by their scientific output such as papers or completed doctoral theses. "Synthesis-first" and "synthesis-as contracted" are focused on transfer. All types are open to interdisciplinary innovation. There is often a distinct lack of transfer of interdisciplinary research back into the scientific community. However, "synthesis-online" and "synthesis-first" often have explicit interdisciplinary goals. In these projects, experience with interdisciplinarity is more or less systematically produced and communicated.

Figure 6: Comparison of the four types of integration management



To summarize: If interdisciplinarity has to be put into practice, then at least two conditions have to be fulfilled:
1) There must be an audience for the interdisciplinary results, which is someone who has a real interest in knowledge integration.
2) There must be some means provided for integration management.

In transdisciplinary projects, or: mode-2 research (Gibbons et al. 1994), we see a very strong interest in synthesis results and, hence, in interdisciplinary knowledge integration. In this type of research, stakeholders are integrated with the project organization, especially during the definition of project goals and conceptual descriptors. This results in forms of project organisation such as "synthesis-first" (see Table 1).

In projects without stakeholder participation, there needs to be a serious scientific interest in interdisciplinary results. In many multidisciplinary projects, we find a lack of both, methods of interdisciplinary knowledge integration and resources for integration management. Integration management of the "synthesis-online" type can compensate the lack of means, for instance through activities of the doctoral students involved as in the case of the Berlin urban ecology research project (RTG 780).

On the basis of the current concepts and experiences of interdisciplinary work, future research on urban ecology will be able to more clearly define methods of knowledge integration in interdisciplinary projects.

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Mieg et al.: Knowledge Integration

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