Research Paper

Intra- and interdisciplinary communication as a critical factor for integration of geoscience into urban and project planning

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Abstract

The importance of geoscience in urban planning and governance has gained traction in recent years. The research project "Under Oslo" being carried out by the Norwegian Geotechnical Institute (NGI) investigates interfaces between the geosciences and current planning regulations and processes in Norway, amongst other topics. The work builds on the hypothesis that insufficient integration of the geosciences in planning processes results in delays in understanding of potential ground-related risks and uncertainties - and ultimately to unforeseen consequences.

To identify the most relevant factors that influence how and when geoscience is brought into the planning process, three systems-mapping workshops were conducted with geoscience and urban planning experts. The current paper gives a brief introduction to the topic area as well as systems thinking, describes the methodology and results of the workshops, and presents ideas for future developments. The work revealed that, whilst a lack of integration of geoscience into planning processes might exist, the reasons for this are not necessarily perceived as a result of a regulatory gap. Rather, it appears that there is insufficient information sharing, and knowledge exchange related to geoscience with relevant decision makers in the planning process. To build this awareness, intradisciplinary exchange must also be fostered.

Keywords

Urban subsurface planning, Systems mapping, Geoscience communication

1. Introduction: geoscience in urban and project planning

In recent years, academics and practitioners alike have developed an interest in the role the underground plays for urban areas. Disciplines engaged with urban planning and the built environment span human geography (e.g. Connor and McNeill, 2020) to urbanism (Reynolds, 2020) and geotechnical engineering (e.g. von der Tann et al., 2021). The need for *masterplans* for the urban underground and the introduction of the subsurface into urban planning more broadly has been discussed, and in particular by authors in journals from the tunnelling or geotechnical engineering disciplines (Bobylev, 2009; Delmastro, 2016). As such, this discussion focusses on built structures in the subsurface, emphasising the observation that any structure permanently alters the available space, and that a "first come, first served" approach prevails in underground space allocation without adequate planning (Admiral and Cornaro, 2016). This is described as resulting in an increasing complexity, both in the current disposition of structures and for the design and building of new structures. Urban underground space has also been connected to urban sustainability (Paraskevopoulou et al., 2019) and cities that have or are creating a masterplan that includes their underground. In particular Helsinki (Vähääho, 2016) and Singapore (Zhou and Zhao, 2016), are widely referred to.

For masterplans to be feasible, or to find other ways to manage the urban subsurface in a sustainable manner, aspects of the underground that are not part of the built environment also need to be captured. *Urban Geology* studies the interdependencies between the human and geological environments in cities and provides data to take them into account in relevant processes such as spatial planning. As "the application of the earth sciences to problems arising at the nexus of the geosphere, hydrosphere and biosphere within urban and urbanizing areas" (Wilson and Jackson, 2016), it has been conceptualised as part of engineering geology (Culshaw and Price, 2010), but importantly looks at the geological setting and processes beyond the site-scale of built environment interventions such as buildings or infrastructure. Independent of a specific discipline, looking at the underground as different resources has been suggested (e.g. Parriaux et al., 2007, Volchko et al., 2020) and the recently defined concept *geosystem services* (GS) is also discussed in the context of urban planning (Bobylev, 2022; Sandström et al., 2021). GS are an expansion of the *Ecosystem Services* (ES) concept to include the geological – abiotic environment (van Ree and van Beukering, 2016). GS might provide a framework in that approaches for valuation and assessments developed for ES can be adapted to capture and assess many different aspects of the urban subsurface.

In Norway, between 2013 and 2017, the municipality of Oslo and the Norwegian Geological Survey took part in the research project "sub-urban" funded by the European Cooperation in Science and Technology (COST) that focussed on making geological data and information accessible and useful for urban planners and municipalities (COST project TU1206, www.sub-urban.squarespace.com). Both organisations have continued their efforts to increase awareness and consideration of these topic areas in municipal plans (see, for example Davidsen, 2021; de Beer, 2014). In their biannual meeting in 2021, the Norwegian Housing and City Planning Association (BOBY) recognised the importance of understanding of subsurface properties and how the subsurface is used for strategic planning (Sjødahl et al., 2022). The Norwegian Geotechnical Institute (NGI) is currently carrying out a research project called "Under Oslo" that started in 2019 and will finish in 2022. The overarching objective of the project is to develop methods and tools that support sustainable development of Oslo's underground. One of the project's work packages, Holistic Planning, looks at how specific ground-related construction challenges, typical for Norwegian soil conditions, are linked to wider questions related to planning processes. The work builds on the hypothesis that insufficient integration of the geosciences in planning processes leads to delays in understanding of potential ground-related risks and uncertainties - and ultimately to unforeseen consequences.

The above disciplines and concepts emphasise that the consideration of geoscience in urban planning is a complex topic area. The problem itself might not be fully understood, a diversity of viewpoints exists, and there may be a multitude of interconnections with the broader environment. All of these points suggest that a systems approach might be useful to develop a better understanding of the topic area and determine what to focus on in its development (The Omidyar Group, 2017). To test this formulated hypothesis, and to investigate the effects and challenges relating to how and when the geoscience are currently considered in the planning process, two systems mapping workshops were conducted by NGI in 2021 and 2022. The current paper presents the methodology used, as well as the background of such methodology and the results of the workshops. Key challenges emerged around intra- and interdisciplinary communication and collaboration. These are discussed and ideas for future developments are suggested.

2. Methodology: systems mapping

Systems thinking shifts the focus of problem solving (a) from the specific function of individual system elements to their role within processes or in achieving the overall system's purpose, and (b) from functionalities of independent system parts to relational and emergent properties. These properties can manifest as unexpected consequences – that we want to prevent or manage, or as learning that we want to foster. This emphasises that systems are not static, but continuously changing. Due to the interdependencies between systems parts, their behaviour cannot always be predicted. Systems approaches expand the analyses of technical systems to include organisational principles that govern (and explain) the emergent properties of the whole as well as interaction patterns. They aim to understand these underlying patterns to identify leverage points and embrace complexity for continuous learning.

In the current study, the methodology for systems mapping described in the workbook by the Omidyar Group (2017) was adapted in accordance with the project aims and the available time frame for the workshops. Additional input was taken from a report by the Royal Academy of Engineering where systems mapping was used to work towards sustainable housing policies (RAE, 2020) as well as from the methodology of participatory systems mapping as taught at the University of Surrey (CECAN, n.d.). Two workshops were conducted guided by the principles of systems mapping to better understand the interfaces between geoscience and urban development and planning in Norway, to identify possible leverage points and to formulate focus areas for further work. Accordingly, the aim for the workshops, set by the project team, was to develop propositions about *how* and *when* to bring geotechnical expertise into the planning process that is different to the status quo. Ultimately, this should contribute to the vision of a planning process that – related to the geoscience – enables the right people to take well-informed decisions at the right time.

The workshops (workshop #1/workshop #2) were attended by geologists (3/1), project owners (1/1), urban planners (-/2) and geotechnical engineers working in different project roles for infrastructure providers (3/2), as general consultants (3/3) and for contractors (1/-). The five main steps followed in the current study were:

Exploration of factors (workshop 1, part 1): Working in two groups, participants were asked to brainstorm and collate a list of (a) elements that influence the consideration of geoscience in the planning process ("upstream influences" of the main theme) and (b) effects that the consideration – or lack of consideration – of geoscience in the planning process might have for urban planning and construction projects ("downstream effects" of the main theme).

Analysis of causes and effects (workshop 1, part 2): To analyse the collected factors, participants were asked to discuss them with a focus on how they are connected. Connections were drawn using pen and paper and intermediate factors added where necessary. Participants were then challenged to find at least one feedback loop. For the workshop, due to time constraints the concept of feedback loops was simplified as a circular connection between more than two of the identified factors.

Creation of a systems map and core narratives (between workshops): Following the first workshop, the project team reproduced the post-it notes and connections drawn in the workshops using the online platform kumu (kumu.io) to reflect on and further develop the maps drawn in the workshops. The digital format allowed the project team to cluster factors, logically arrange the clusters and notes, identify central topics or dynamics, and reveal gaps or assumptions that required verification. This led to the development of a meta-framework of the system, capturing a limited number of themes that appear relevant for the consideration of geoscience in urban planning as elaborated in the workshop, and two main narratives describing core challenges as seen by participants.

Discussion and iteration of core narratives (workshop 2, part 1): In the second workshop, the narratives that were developed were presented to participants to interrogate whether they adequately represent current processes as perceived by the participants, as well as if the elements captured were relevant and if the connections between them were sufficiently described. As the workshop had to be moved online, the platform Miro (miro.com) was used to facilitate the workshop.

Developing ideas for leveraging geoscience in urban planning processes (workshop 2, part 2): With the core narratives as input, workshop participants discussed possibilities to create change and develop ideas for future activities guided by a number of structured questions.

All results were discussed in the workshop group and presented back to participants in a workshop summary that is available online (NGI, 2022).

3. Results and discussion: enhancing integration of geoscience into urban planning considerations

The systems-map and conversations in the workshops developed around four general interdependent themes that provide a meta-framework for the understanding of where and why the geoscience are or should be considered in urban planning (Figure 1): (a) the overarching aim for sustainable development and welfare that can be supported by (b) sustainable technology that fosters understanding of the environment by visualising and interpreting data, and by (c) sharing and development of knowledge and experience to prevent repeated mistakes and identify problems early. Both the development of sustainable technology and fruitful knowledge exchange can be enabled through (d) interdisciplinary collaboration and mutual learning between society and economy/business interests. This will lead to a more holistic understanding of situations and influence the associated decisions. In this framework, the geosciences were linked and discussed mostly with regard to the latter two points. It was concluded that geoscience knowledge needs to be more efficiently shared within and beyond the geoscience professionals themselves and that geoscientific expertise should be included in projects requiring an understanding from various disciplinary viewpoints early on. These two points are reflected and further elaborated in the two specific narratives that emerged which are described in the following sections.

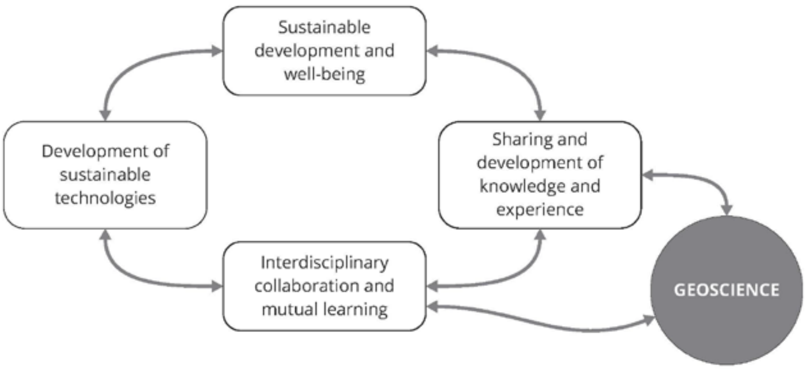

Figure 1. Main aspects of consideration of geoscience for sustainable urban planning. Source: NGI, 2022.

3.1 Main narrative #1: misalignment between expertise and responsibility

Workshop participants agreed that expertise in, or understanding of, the geosciences in urban and project planning is often insufficient. This was seen as a core for the consideration of geoscience in urban planning processes and a first narrative was developed around this topic (Figure 2). In particular, it was pointed out that project managers on the client's side often lack the necessary experience and understanding to request the right expertise at the right moment in time. Participants expressed that project managers of projects involving the ground and ground-related considerations – next to economic understanding – need to have sufficient understanding to link their holistic oversight with more specialist knowledge and judge where additional specialist knowledge might be required. This judgement will manifest in project descriptions, for example in tender documents, that set the parameters for a project's implementation. If these documents are not prepared in the most professional manner, experts' confidence in the client and conditions they set will probably decrease, also decreasing their willingness to share experience and thus worsening the overall communication between client and designer. Difficulties in communication, in turn, will lead to less knowledge transfer and not foster the building of expertise of the project manager.

One of the reasons for the lack of experience of project managers was explained by the tendency of experts to prefer specialist technical work over coordinating or management tasks, and thus not to perform project management roles. This was connected to the more general observation that specialist knowledge is often valued higher in society than integral or "holistic" knowledge. In addition, the number of ongoing parallel projects, and subsequently higher demand for project managers, was identified to put extra stress on the situation.

Figure 2 also illustrates one possible way to influence the described loop in a positive way. This may occur if the project manager identifies the need for support in understanding if and in which way the geoscience influences or might influence their project. In this case, additional expertise could be mobilised early on, for example by establishing an advisory role for the project manager. Working as a team in this way would facilitate efficient management at interfaces. Holistic and specialised knowledge would be better linked, having a positive effect on project descriptions, the communication between client and designer, and ultimately lead to more knowledge transfer and learning of the project manager.

Another aspect that was discussed, alongside sometimes challenging client relationships, was the ability of experts in the geoscience, or geotechnical engineers more specifically, to communicate their knowledge so that the client/project manager understands the relevance of their insights. Participants concluded that such ability can not be taken for granted and could be a relevant area for improvement.

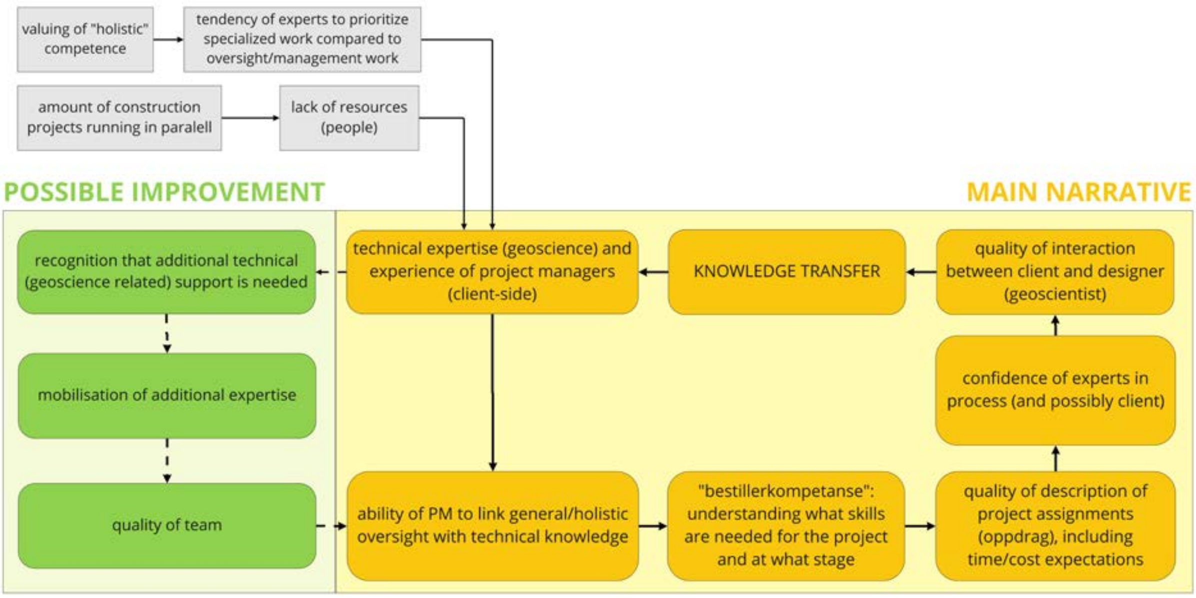

Figure 2. Main narrative #1. Adapted from NGI, 2022.

3.2 Main narrative #2: Geoscience in urban decision making

The second narrative (Figure 3) started with the general observation that decisions about how a city should develop into the future will be influenced by where the current political focus lies and aspirations of relevant authorities. These include considerations about aspects such as climate change or liveability and will look at the spatial context of a city through these aspects. That means that strategic decisions will often not proactively take the spatial context into account, but can have a large effect on the development of that context. In addition, cities are growing and most areas are already built up and have been influenced by the development of the city over the last centuries. Consequently, adding additional structures, specifically if located in or interacting with the subsurface, becomes more complex.

In areas where many functions overlap, such as large transportation hubs, interaction with the subsurface is particularly relevant and should be considered when urban development decisions are taken. Participants discussed that experts of different areas should be consulted for projects with increasing complexity. The more complex a project is, the higher the associated uncertainties in the project and thus the risks taken by the client and project consultants when progressing the project. This, in turn, could make the different players protective about certain project details and reduce their willingness to share their experiences and data. Consequently, the available geoscience related maps and thus information for decision makers remains limited, affecting the decisions taken. As illustrated in Figure 3, one way to improve the situation without altering the available database could be for geoscientists to learn more about what knowledge might help urban decision makers to take well-informed decisions and how it could be communicated to them. Earlier involvement of geoscientists as advisors for planning decisions could be the positive outcome.

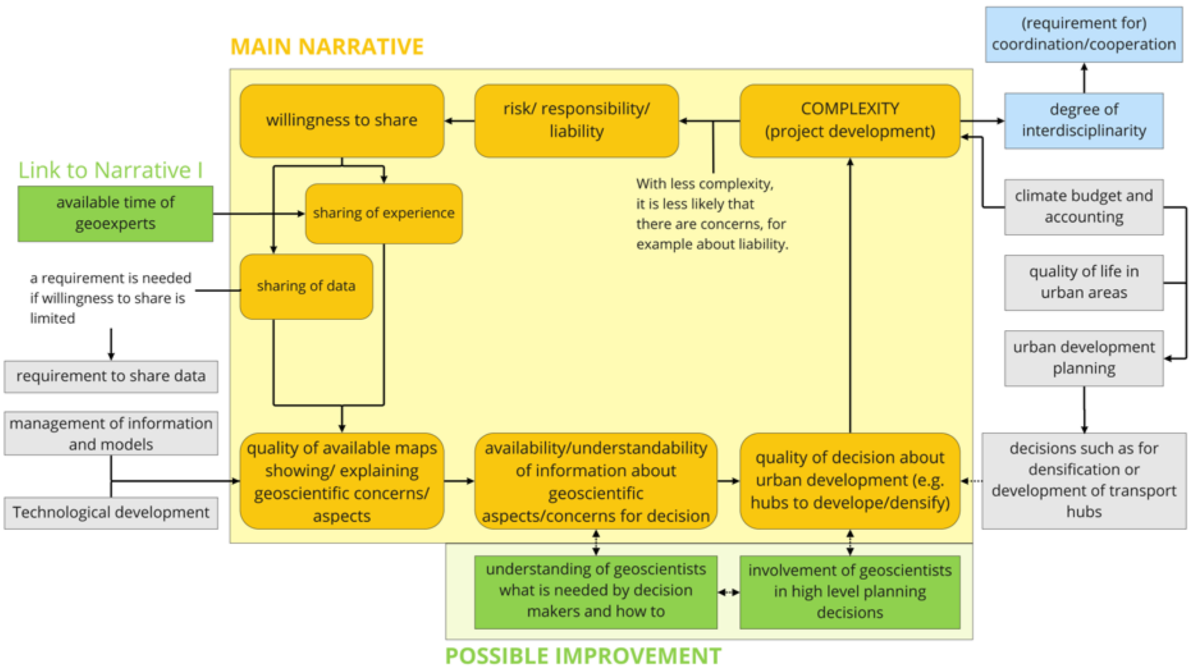

Figure 3. Main narrative #2. Adapted from NGI, 2022.

3.3 Improving communication and knowledge exchange within and beyond the geoscience

The emerged narratives regarding the integration of geoscience in planning processes in Norway were not questioned in principle by participants. Therefore, it can be assumed that, for the group of participants here, these narratives reflected the main aspects of the system explored to an appropriate degree.

The discussions around areas for potential improvement were not – as might be expected when reviewing the literature – linked to regulation for which master planning or geosystem services could be relevant. Rather, in both narratives the need for increased communication and knowledge exchanges was emphasised – within the geoscience as well as between geoscientific and other built environment related disciplines.

Urban development necessitates the involvement of many experts and institutions with different skills and backgrounds to appropriately capture and manage the complexity and local specifics of a given spatial situation including the surface and subsurface. Depending on the project scale and scope, for example, experts in urban planning and planning law, urban design, geotechnical engineering and tunnelling, geology, water management, environmental science, or archaeology might be consulted. Each of these communities has a specific expertise that needs to be communicated to efficiently plan and coordinate urban projects without neglecting or potentially obstructing any of the various services the subsurface provides. A lack of coordination and mutual understanding may lead to solutions that are not optimised regarding aspects of sustainability, including project costs.

In this context, using existing tools in the Norwegian planning regulation, workshop participants discussed the potential for defining a new kind of consideration zone for regional plans. Consideration zones are areas marked in urban or regional plans. They define specific considerations that must be taken when developing or building in that area. For example, in Oslo, consideration zones are set where development is restricted because of underground utilities, catchment areas for drinking water, or existing landfills, as well as areas with an increased risk for natural hazards to occur (Oslo Kommune, n.d.). Workshop participants suggested using existing information and maps to identify zones where the interplay between surface and subsurface characteristics and assets appears particularly complex. Requirements could then be attached for the constitution of the project team should development of these areas be considered and thus formalise a requirement for earlier involvement of geotechnical expertise. In this way, participants stated, various problems could be pre-empted, and the allocation of resources optimised.

The sharing of data, in particular site investigation (SI) data, has been discussed repeatedly within the geotechnical industry. In Norway, following a vast quick clay landslide in Gjerdrum in 2020, a requirement to share SI data was proposed by The Norwegian Water Resources and Energy Directorate (NVE). Yet, whilst such a requirement will facilitate intradisciplinary exchange of data, it does not necessarily mean that these data are accessible for people of other disciplines. The discussions in the workshops conducted here suggest that access might not only be restricted by seeing or downloading data, but also by the ability to understand them. The need expressed by project participants to improve the ability and willingness of geoscientists to communicate their knowledge was paralleled by the described need to understand what bits of their knowledge are most relevant for which community and in which project stage. A discussion was prompted in the workshop about how the different disciplines could be involved in each other's training through lectures or joined projects. In the context of projects, communication of expert knowledge to the public might become more relevant if public participation in decision making processes is sought.

In addition to the sharing of data and communication of their meaning between disciplines, workshop participants also pointed out that learning from one project to the next often happens only on the individual level and is rarely shared across the industry. Experiences that cannot be expressed as a specific data point will remain usually with the individual expert, but also personal observations for example of ground conditions in particular locations might not be captured. Crowd mapping could provide an approach to capture such experiences once specific shortcomings are formulated.

The here revealed narratives, given the limited time at the workshops, cannot claim to represent the whole system that shapes and is shaped by the interfaces between geosciences and urban planning. Nonetheless the insights gained represent main areas of consideration of the group of participants. The discussions in the workshops showed the importance of conveying technical data as meaningful information for people with different disciplinary backgrounds and that sharing experiences, next to data, would be relevant for continuous learning and improvement. More work would be necessary to validate and expand the map drawn with additional feedback loops and in-depth discussions with geoscientists and other urban stakeholders.

5. Conclusions

The subsurface is a complex system with a multitude of interactions between natural, technical, and social elements. It is important to understand the relevance of this system for cities as they are structured and managed today and how this might change in the future. Yet, the consideration of geoscience in urban planning is often described as limited.

To analyse how the geoscience are currently considered in urban planning in Norway, and where the limitations lay, and to pinpoint specific areas where improvements appear necessary and possible, two expert workshops were conducted by NGI in 2021. The workshop format was based on systems mapping, collating multiple elements that influence the topic area, and structuring them through exploring connections between. Two main narratives emerged that represent key problem areas for participants. On the one hand a general shortage was described of people trained in the geoscience that might lead to a misalignment between the expertise of people working in the field and what they are tasked with. This leads to increased need for knowledge sharing. On the other hand, workshop participants discussed that the complexity of urban projects in that the subsurface is altered needs to be represented in the project team and available data needs to be shared in an efficient manner.

The strategy of creating a masterplan for the subsurface, or the introduction of novel concepts such as geosystem services, that are discussed in literature, were not mentioned in the workshops. Rather than in regulation, the current potential for change was seen mainly in improving communication and knowledge exchange within the geoscientific community and between the geoscientific community and other disciplines. Increased and improved communication of geoscientific knowledge could play a key part for experts of different disciplines to extract and interpret the relevant information when working on specific urban projects.

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