466

Equal living environments

Universal design and (un)equal access from a syntactic perspective, Uppsala, Sweden

DANIEL KOCH, & ANN LEGEBY,

KTH, STOCKHOLM, SWEDEN

ABSTRACT

Syntactic analysis focuses analyzing space from a general perspective, where connections of 'visibility and access' are analyzed through different geometrical abstractions. In universal design research, the point of origin is that what is 'visible' or 'accessible' is different for different people depending on for example age or disability. This paper addresses challenges in the way models are made, used and theorized in space syntax research as capturing or describing relations between people and environment, specifically from the perspective that if people are *different,* so are their respective 'connections of access and visibility', and potentially their subsequent patterns of centrality and accessibility. Such difference, as recognized in universal design research, may appear on both the local (molecular) and the global (molar) scale; i.e., the effects of accessibility difference can be on a local scale of whether a relative detour is needed or not, but also on global structures of centrality in a city or municipality as a whole. However, there is need for structured understanding of the 'molar' level, and the interrelation between scales. Following Gibson's theory that affordances exist neither in the environment nor in species, but in the specific relation between them, this paper engages with how such differences can be empirically, methodologically and theoretically understood based on empirical research in the city of Uppsala, Sweden. This work utilizes municipal data and input from disability rights organizations to explore the problem, and presents important considerations for both research and practice as comes to inclusiveness in spatial analysis and accessibility.

KEYWORDS

Universal design, spatial analysis, affordance, spatial cognition, molar accessibility

1 INTRODUCTION

Over the years, syntax research has built a solid understanding of relations between spatial configuration and a range of different aspects of society, social structures, and human behavior. Especially solid, one might argue, is the thoroughly investigated relation between movement and configuration, in particular movement flow rates and the configuration of public space in urban environments (Hillier, 1996; Hillier et al., 2012). This has been further complemented by an increasingly thorough discourse on how these patterns link to human cognition. The link to cognition comes in many forms, from theorizing why and how syntactic models work for analyzing behavioral patterns (Hillier, 2003; Marcus, 2018; Hillier and Iida, 2005; Kim and Penn, 2004) to comparison of configurational analysis to cognitive maps (Kim and Penn, 2004; Conroy-Dalton and Bafna, 2003), to cognitive research in a more direct sense—not seldom in controlled experiments (Dalton, 2005; Emo, 2014; Hölscher et al., 2006). This has also increasingly become the explanatory model of the theory, with the main argument often building from individual perception through movement, constructing understanding of our environments as we navigate and experience them (Marcus, 2018; Peponis, 2012; Marcus et al., 2016). Along these lines of reasoning, this is often linked to Gibson's theory of affordance (Gibson, 1977; 1979) as a way of explaining just why this constructed understanding affects actions while not doing so in a deterministic manner.

In Universal design research, a similar argument around relations between environment and people are made, also often based on Gibson's theories and relying heavily on cognition (Lid, 2014; Law et al., 2018; Iwarsson and Ståhl, 2003). However, while Universal design has developed a lot of knowledge of how local conditions affect people's possibilities and actions, the knowledge is less concrete when it comes to the environment in a larger or more systemic scales; known in the field as 'molecular' (local, individual features) and 'molar' (environmental, overall) aspects of accessibility respectively (Marcheschi et al., 2020; Küller, 1991).

Key in Universal design research, however, is that the environmental conditions affect *different individuals differently* (Law et al., 2018; Watchorn et al., 2018), whereas overall, syntactic research operates with generalized accessibility, sometimes tending towards universality. In this paper, we will study, on the one hand, the potential of syntactic research to contribute to the 'molar' level of accessibility research, and, on the other, implications for syntactic research of integrating difference in the human-environment relation into the analysis. We will do so through a study of the city of Uppsala, north of Stockholm, Sweden, where we have worked together with the municipality and the Disability rights organizations of the municipality and the region to develop the approach and through which we have also worked with validation of methods and results. In this we have worked from two ends: together with the municipality to make sure the questions we address are relevant for them, and that we find relevant, updated geographic information regarding factors that differentiate accessibility for different individuals. From this we have proceeded to make 'system-world' analysis, that is, based on the municipality's data,

how would differentiation affect the accessibility system—such as, what is the systemic effect of being unable to traverse stairs? On the other hand, we have worked with the Disability rights organizations to understand the 'life-world' of how accessibility is lived and experienced, including conducting a questionnaire from which we will build a few 'life-world' analyses making use of real, perceived challenges. Both of these pose noticeable challenges which we will return to in connection to the analyses.

The paper will first briefly go through affordance theory in relation to configurative and universal design research and the research challenge in principle. We will then introduce the municipality and show a few analyses that demonstrate the impact including difference in configurative analysis can have, before concluding with a discussion of implications this might have for spatial analysis and planning.

2 AFFORDANCE AND ACCESSIBILITY

James J. Gibson's theory of affordance (Gibson, 1977; 1979) has proven fertile ground for understanding the link between people, cognition and the environment as investigated in syntactic research. In short, the theory describes how one needs to understand such a link between species and environment not as residing in conditions of the environments or in faculties and abilities of the species, but specifically in the *interaction* between these. Perception is seen as embodied and dynamic experience. Affordances thus neither exists in the environment or in the species but in how they interact, in relation to what the species in question seeks from the environment. This means that opportunities and constraints in the environment are relative to the characteristics of the organism perceiving them. As Greeno (1994) explains, "affordance" as an integrated, interactive phenomenon does not only narrowly denote "possibility," but refers to modes of orientation, exploration, and a range of other factors: the capacity to see or otherwise perceive a distant possibility of rest or danger might affect affordance just as much as the possibility to traverse the distance, depending on the species-environment interaction in question. From this reasoning, the syntactic models are understood not as essential geometry but to capture specifically aspects important for how humans can move in and make use of their environment. As John Peponis (2018, p.37) describes it: the models and analytic methods are based on "a descriptive theory of the perceptual, relational and functional affordances of inhabited space that are relevant to its cognitive and social intelligibility".

Gibson's theory is also important within Universal design research, where the Person-Environment-Occupation model (PEO) is prominent (Law et al., 2018; Watchorn et al., 2018). However, the PEO model, more so than many uses of the affordance concept, and especially the affordance concept in syntax research, puts emphasis on the *individual's particular* relation to their environment and their (potential) occupation thereof. While entirely within Gibson's concept, and he did reason around individual beings, his focus was rather on faculties, abilities and so on as different *between* species rather than *within*. In our research, we bring in the PEO-

thinking of differentiating affordances on an individual level, since a model following the basic syntactic modelling principles of "where one can see and go" would look different depending on one's visual and mobility capacities.

Important to learn from these theories, and central in syntactic research, is that the common approach in planning and design to consider planning for or from the perspective of different groups or categories can be problematic (see further e.g., Bricout and Gray, 2006). From the perspective of spatial analysis, the key question is finding relevant "PEO-bundles", that is, relevant relations between people and their environment. If one is to use groups, the groups must be reasonably much defined along such lines. That is, many groups often discussed in planning (e.g. children, elderly, men, women, et cetera) are not differentiated or categorized following different individual-environment relations, but based on other principles, which risks leading to mistakes when preparing and interpreting analysis. Ceccato, for instance, demonstrate how a category of "women" relate to sense of safety in the environment in at least four, partially contradictory ways depending on individual and context (Ceccato, 2017; Vanier and d'Arbois de Jubainville, 2017). Thereby, rather than using regular terms that group people following various principles, we will *primarily* make use of specific person-environment relations in the coming, linking to other categorizations only occasionally to show societal relevance. As an example, while many older individuals may have difficulty traversing stairs, we would not analyze the environment for "older people" or "people in wheelchairs", but "individuals unable to traverse stairs". This also operates intersectionally (Crenshaw, 1989) so that challenges shared between some individuals in different groups can be analyzed without ascribing the challenges to whole groups, or exclude affected individuals in other groups. In extension, in line with intersectionality, it would is also possible to investigate if and how *combinations* of difference generate further, unique results.

Further important for our research, however, is to understand how the environment may look different on a systemic level, or, how the configuration of space might be different for individuals with different faculties. As a result, we are not looking to understand particular objects or situations and how they differentiate between people (a "molecular" approach), but how they—regardless of their individual size or extension—affect accessibility in a larger scale (a "molar" approach). As an example, we can use a principle figure (Figure 1), which shows the configurational centrality in two systems where the only difference is what in the left figure is marked in grey. Such a difference could, for instance, be caused by a set of stairs in a street system, where the left and right figure would show the centrality configuration for people who can and who cannot traverse stairs—and additionally, how accessibility to two amenities (A and B) would be different.

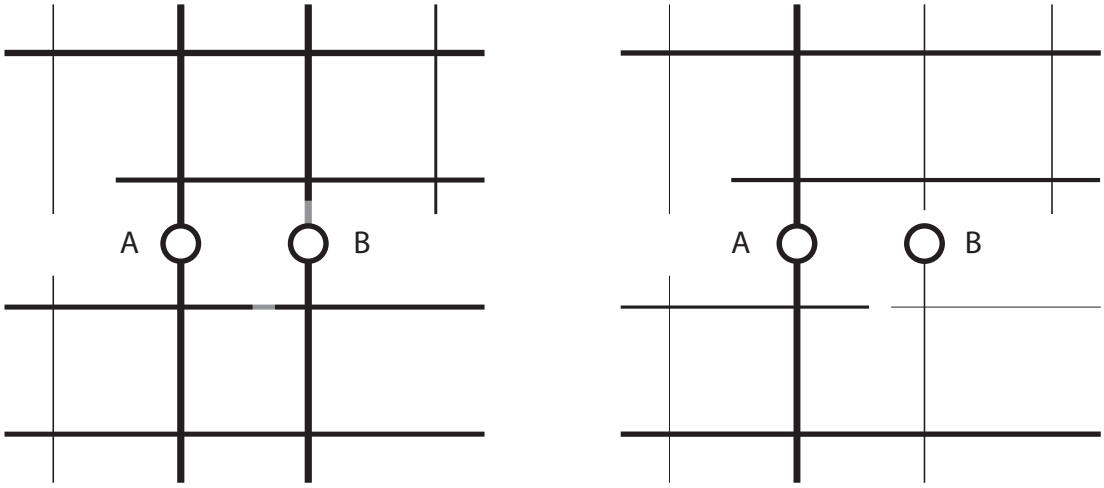

Figure 1: Two principle systems with only minor differences in their 'streets', and their closeness centrality represented through thickness of lines. The small differences make a large difference in the centrality pattern, as well as how centrally located location A and B are.

This way of investigating different models have been done before in syntactic research, but except a small study by Heitor et al (2013), the different models tend to be between for instance visibility and accessibility (Zhu, 2012; Koch, 2012; Hanson, 1998; Dalton and Dalton, 2009; Hanson, 1996; Psarra, 2018), between 'scales' of space (Koch, 2005; de Holanda, 2021) or between before and after a change such as for instance disasters (Esposito and Di Pinto, 2015; Cutini et al., 2020; Abshirini and Koch, 2017; Koch and Miranda, 2013) or re-designs (Conroy-Dalton and Kirsan, 2005; Peponis et al., 2015). When working in urban environments and understanding how accessibility might differ between people, the general differentiation made is rather between measures, either different centrality measures, different radii, or different distance concepts such as angular and geometric distance or primary and dual graphs (Hillier and Iida, 2005; Marshall et al., 2018; Hillier and Hanson, 1984; Feng and Zhang, 2019). There is also other research related to the overall question of Universal design and spatial configuration (Grzeschik et al., 2021; Bafna et al., 2021), which is of importance for our work, but which tends to focus on understanding what kinds of configurations are more easy or difficult to navigate for different people, not directly comparing differences in spatial models for different individuals within the same environment. In some methodological perspectives, our research builds upon and develops these kinds of approaches, but in other respects our approach is quite different as we consider the models to be different for different individuals. All our analyses are performed using the open-source application PST (Berghauser Pont et al., 2019).

3 ANALYZING ACCESSIBILITY DIFFERENTIATION IN UPPSALA

Uppsala, the fourth largest city in Sweden, is an old city that has been the ecclesiastical center of Sweden since 1164 and with Uppsala University founded in 1477 being the oldest center of higher education in Scandinavia. The city traditionally has a 'town and gown' divide with clergy, royalty, and academia historically residing on the western side of the river, including the cathedral, castle and university buildings, whereas eastern Uppsala historically contain more

'worker' districts. Today, retail activity is geographically mostly focused on a small number of blocks and pedestrianized streets on the eastern side of the river, with the narrowest definition of the 'center' to be found between the river and the railway station just a few blocks east of it. Like most cities in Sweden, it also has a small set of suburbs built during the 'Million programme era' of the mid-20th century. This long history poses some particular challenges for research into Universal design, since it has many historical layers that are important from a cultural heritage point of view which may conflict with ideals of equal access for everyone (e.g., Cutini, 2007).

The municipality itself works consciously with accessibility challenges (Uppsala kommun, 2016), including such questions in their comprehensive plan as well as forming special working groups around the challenge and establishing a council where the municipality interacts with citizens and interest groups around the questions. This research project thus comes partially as integrated into this ongoing process, but also challenges and develops some of the aspects of how it is done. Since 2016, the municipality is participating in the WHO network, *Age friendly cities and communities*. A policy program aiming to transform Uppsala to become elderly friendly (Uppsala kommun, 2020) addresses goals related to public health, well-being and strategies specifically for elderly but is including needs also from other groups, for example disabled and children. Among many things, there is an emphasis on possibilities for physical activities and maintain social networks and support participate in social activities. In this study, we focus upon aspects related to the physical environment important for those with mobility impairments and low functional mobility, limiting basic physical activities.

3.1 Structuring the analysis

Translating the theoretical reasoning above into concrete analyses poses a range of challenges. Environmental data, in GIS systems or other forms such as drawings, are generally not gathered and structured from a universal design perspective either in content or form, and complex and gradual differences when translated into models need to be simplified and categorized. Any and all analyses must therefore be understood as *indicative*, to identify potential challenges and effects. While arguably this is true for all models and all syntactic analysis, it becomes even more important in our case. It also means that which analyses we can do is affected by what data is available with dependable detail and completeness. In the current work, we have gotten quite far with some particular analyses, which have also been validated by municipality and Disability rights organizations as relevant and informative. This makes us confident of the approach and relevance of the research, but the particular analyses presented remain test-cases to be further investigated, validated, and tested in the coming.

The choice of analyses we present here has been worked out with the municipality and the disability rights organizations and has emerged from an explorative process. In this discussion it has become clear that there is no "silver bullet" analysis to be done, but rather a wide range of different situations which can be analyzed. However, when working with the municipality and geodata, it becomes clear that from our perspective, the data is problematic. The issue is not that

Uppsala has little data, but a combination of what is gathered, how it is digitized, and practical restrictions on digitalization. For instance, we can see how much of the data is correct from a data point of view—that is, it is registered correctly following the standards and formats expected, and so on. However, the data can still be challenging to use: the dataset does contain most stairs in public space, but it does not tell whether the stair is actually 'blocking' a pathway or not, why every stair would need to be checked individually for if they affect the configuration or not. Second, some data is correct and of high quality when it is entered, but is incomplete: Uppsala is an old city with many different kinds of street surfaces, and while it is certain that a street registered as 'cobbles' actually is a cobbled street, there are many streets that are cobbled that have not yet been entered into the system (Figure 2). In addition, different kinds of 'cobbles' be barriers or not for different individuals. The 'system world' analysis therefore needs to balance quality and completeness of data with what can be learnt from analysis, together with, of course, quality checking and completions of datasets when possible. For overall analysis of the whole city, however, this has not been possible within the project so we have had to lean more on which datasets have enough completeness to give an overall valid picture.

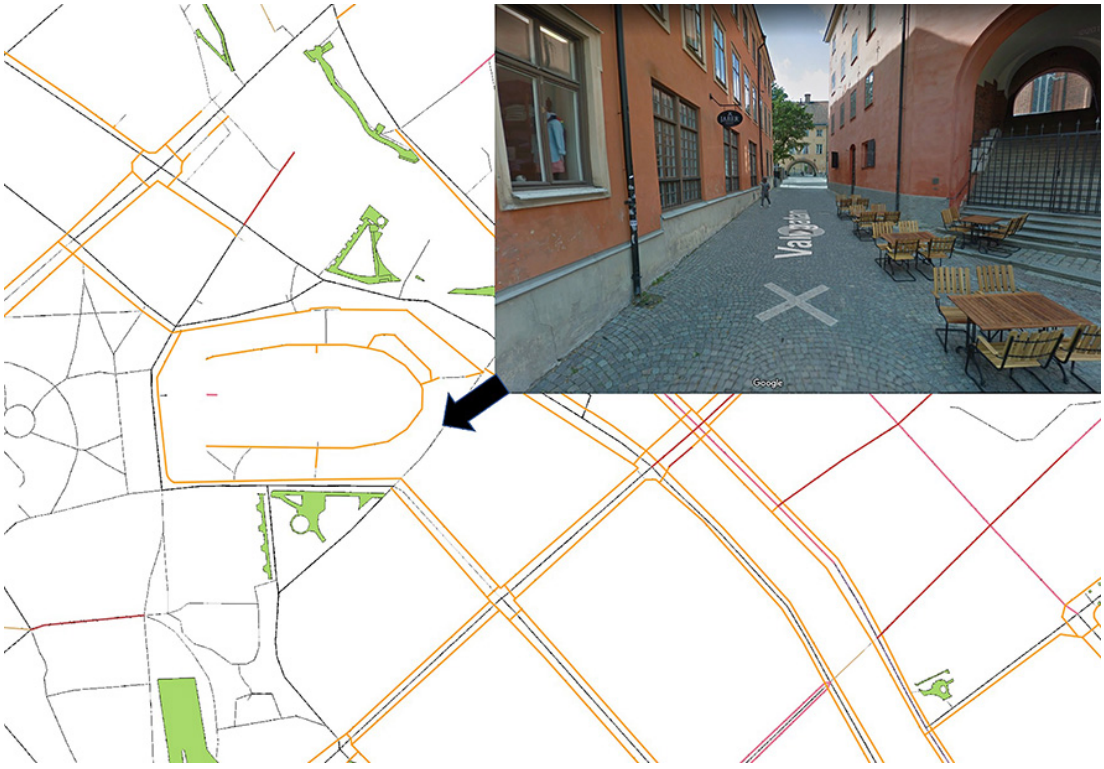

Figure 2. Streets registered as being 'cobbled' in orange, and a photograph of one of the streets next to Uppsala Cathedral, demonstrating the incompleteness of the street surface data.

The individual analyses pose different, but highly informative, challenges, one of which can perhaps best be described by how one respondent to our questionnaire states regarding a street that "it has been difficult to move around in an electric wheelchair, but I discovered today that the surface was even and good". This respondent has avoided these streets for a long time, and the improved surfaces (depending on exact street segments) may have been done quite a while ago. Another challenge is how bundles of factors can come to characterize whole areas, even if

the particular factors act rather locally or small-scale. Reported problematic locations are thus subject to when and how experience and behavior stems from, and may reflect issues that are no longer there in the material environment, while individuals still avoid going there because they believe they are problematic. This means we have at least three disparate situations, which we, drawing on Habermas (1987), can term the 'system-world' dataset, the 'life-world' experience-based situation, and the 'material-world' current environment. Not only does this create challenges in analyzing the environment, however, it causes further challenges for validation. In our analysis, we lean on the idea of cognitive maps (here meant as the 'map' operating in an individual's spatial and navigational understanding of their environment) as major link between the material environment and affordance, but consider them to have what one could call an 'information lag' in that they are constructed over time and are to various degrees thereby reflecting a patchwork of different historical states of the environment. We further draw upon Jean Francois Augoyard's work on how perception guides how one relates to the environments including how cognitive 'maps' are constructed, such as what is included or excluded (Augoyard, 2007). On this basis, we consider the *perceived* accessibility to be what affects behavior, which of course may change over time.

Finally, while the project deals with Universal design and disabilities in a wider sense, we will here, based on affordance theory, study accessibility and the possibilities to move around in the city having various disabilities. What barriers may be found in the outdoor environment and how do we model the conditions in a way that may be relevant from an architectural perspective? For those with impaired mobility the design of walkways is decisive but for many people the possibility to rest and sit down every now and then along a walk is equally important, which has been acknowledged by the municipality in various policy documents. This limitation to movement impairment is for the sake of narrative consistency, showing how different kinds of analysis can relate to aspects of potentially interlinked environmental challenges. They are also chosen because we can demonstrate not only system-world and life-world analyses, but because we can demonstrate how what we will term 'enablers' and 'barriers' operate in relation to spatial analysis, and because the data is clear and communicative. In this paper, we will analyze 'enablers' as a 'system-world' analysis, utilizing municipal data, and 'barriers' as 'life-world' analysis, using user-reported challenges in navigating the environment.

3.2 Enablers

The notion of 'enablers' in our analysis builds on how Julienne Hanson (2004) demonstrates how public toilets can work to restrict or enable accessibility in urban environments. She argues that while for many, moving in the city is dependent on closeness to a toilet, the limitation is systemic rather than particular: it is not accessibility to any particular toilet, or that one *has* to stop every so often to go to the toilet, but the possibility to do so that is limiting. As long as the possibility exist to reach one easily, one might be quite mobile. That is, the 'system of accessible public toilets' is a limiting but also enabling factor; by adding public toilets, accessibility is expanded. In such systems, the deciding factor is dependency and continuity of closeness to toilets, and

chains of public toilets close enough to one another can create a possibility to navigate large portions of the city. Such chains can of course be vulnerable, where individual breaks might fully disconnect parts of the city for those who would not move between them. They thereby also operate to make *other amenities* accessible: with possibilities of visiting a public toilet between one's home and the drug or grocery store, one might be able to solve everyday errands on one's own, moving in and sharing public space with others, and thereby, as Zukin (1995) notes, becoming part of society—and, furthermore, ensuring that people with different abilities are seen and encountered. Cities where certain groups are excluded from using public space will not foster social inclusion or the acceptance of 'the other', and it risks having negative effects for participation and engagement (Legeby, 2013). This is the approach we take when studying the distribution of benches in Uppsala.

Benches

In a report from 2017 (Linder et al., 2017) has proved large differences within the municipality regarding conditions important for elderly people. Important aspects identified are for example outdoor environment, access to service, and public transportation. One of the conditions raised in the report and highlighted in this paper, is the design of the pedestrian network. While the survey shows that separation of bicycle lanes from pedestrians and poor maintenance of pedestrian paths are important constraints, as much as 80% perceive that there are not enough benches (or other adequate place to sit) where it is possible to sit down and rest during a walk. Just the fact to know that there is a possibility to rest at frequent occasions implies for many people that a certain route is providing needed conditions. In line with Gibson's way to describe environments, it is possible to argue that paths or routes that lack benches are not walkable for certain, specific groups since they are not *restable*[1]. Or, as the municipality describes it; to walk one have to be able to sit (Lennartsson and Blomberg, 2019, building on Gustafsson, 2013). It means that local circumstances may have considerable global effects, if strategic paths lack a frequent interval of benches this implies that such routes are not part of the pedestrian network for those with mobility impairments.

In the municipal guidelines for benches (Lennartsson and Blomberg, 2019) conclude that benches need to be places with a distance of 100-200 meters, in proximity of important goal points. In neighborhoods with high density of elderly and disabled people, the distance should be reduced to 50 meters. The maximum distance between benches in recreation areas (green areas and parks) is suggested to be 250 meters. In this study with elaborations of the syntactic model exploring the effects of its modifications, the aim is to identify all routes that fulfil these goals. First, we analyze the spatial system and what street segments or paths are provided with benches; routes that are not only walkable for pedestrians but also *restable*. We identify what locations are found to have an impact on the global system and where the conditions have narrow effects on the local level. Second, we highlight areas where there is higher accessible density to elderly in the

[1] Gibson invented new concepts and words by adding 'able' as a suffix to a verb/phrase (Gibson, 1979).

municipality, people of the age over 70 years. Third, we study the effects of the distribution of benches in relation to on the one hand residential addresses and on the other hand, how health care centers are located in relation to the walkable-restable-network of Uppsala.

In the analyses with the aim to identify the *walkable-restable network* a method is applied where the distance between benches is analyzed. Each bench having another bench within a distance of 50, 100, 150, and 200 meters, measured as walking distance through the street network, is assigned. These paths equipped with benches build up the network for people with special needs, while routes that lack benches of such distance is argued to be inaccessible, or at least unattractive, for people with impaired mobility. The results reveal that only a third of the benches in the city of Uppsala has another bench within 50 meters. If increasing the radius to 100 meters, we find that 83% of all benches are connected with at least one other bench (Figure 3). As the distance increases a slightly larger share of the benches add up to the system and measuring 250 meters as much as 92% of the benches are connected.

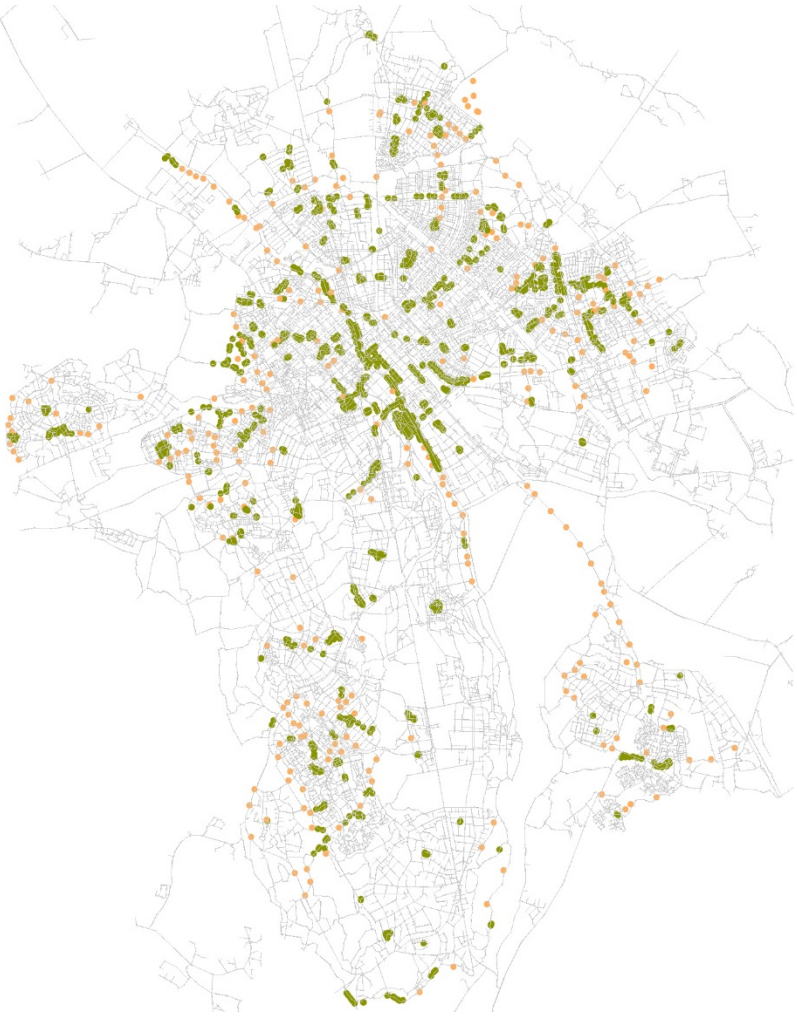

Figure 3. Benches with a distance of maximum 100 meters (green points).

Looking at the pattern that emerges it is possible to see that continuous lines are located in a north-south direction in proximity of the river Fyris as well as along streets characterized by high

centrality in a direction to the northeast from the city core. However, the analysis also reveals that benches are not equally distributed throughout the city, large areas lack benches completely and may be seen as a kind of 'bench deserts'. As an illustration, we have highlighted the segments that are in proximity of benches of 100-meter-distance and what emerges is a scattered urban structure, covering a relatively large share of the central parts, however, at the same time large areas extinguish, in total as much as 42% (Figure 4). When highlighting where there is a concentration of elderly in the city of Uppsala we find two islands, both located in the city core or at the edge of the core. These two areas are rather well equipped with paths that allows resting along the route, indicating that at least these areas afford rather favorable conditions.

Figure 4. Street segments provided with benches placed within 100 meters of a neighboring bench highlighted in black, superimposed on a background of buildings, areas that may be described as 'bench deserts'.

Studying the relation between residential addresses and the walkable-restable-network we find that a considerable share, 43%, of the residential address points lack access to benches in the 200-metric system. The pedestrian routes are important for access to various amenities.

The lack of benches along a path may imply that services and goal points in their proximity becomes inaccessible for people with special needs. To demonstrate we have chosen a public service, namely health clinics, and studying whether they are in proximity of benches placed with a 300-meter distance. The result shows that twenty out of twenty-five health clinics (80%) are located with contact to paths having benches within 300 meters (which is far from what the municipality argues is a satisfying standard). Since health clinics constitute a key service function, it is of significant importance that the environment in their proximity is designed in a way that takes into account special needs, especially impaired movement but also hearing impairment or visual impairment. Therefore, we also study the location of the health clinics in relation to the system where benches are placed within 100 meters from each other. The result reveals that only six out of twenty-five of the health clinics (24%) are connected to paths where benches are placed within 100 meters from another bench.

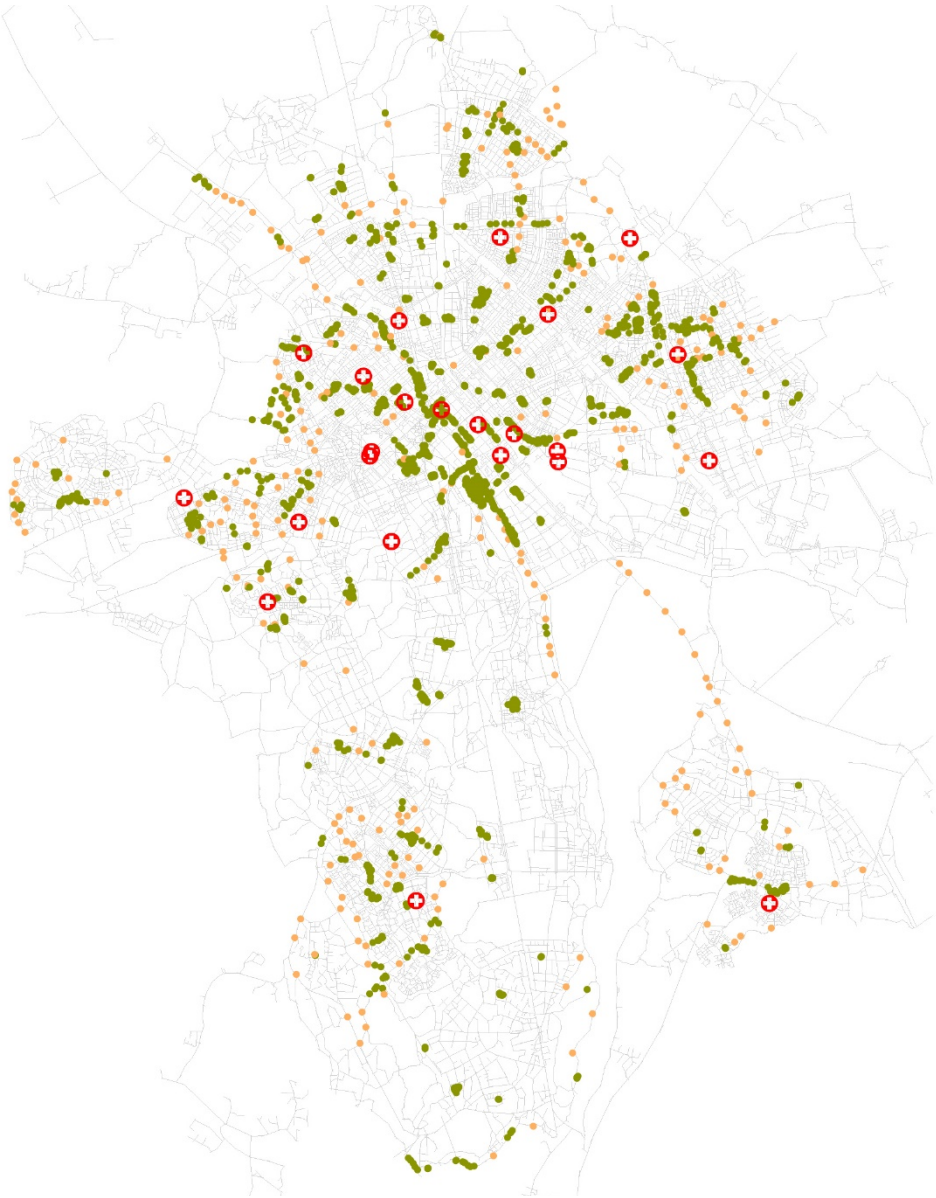

Figure 5. In the city of Uppsala, six health care clinics out of twenty-five connect to paths that have benches with a maximum of 100-metres distance.

The example with the benches illustrates one aspect of what constitute accessible environments and demonstrated in the Uppsala example as this is prioritized by the municipality and has been highlighted by the two Disability Rights Organizations, on the municipal level as well as on the county level. In the municipal rhetoric, the policy focuses strongly on elderly, but we see that the possibility to rest and stay in public space has relevance for other age groups as well. Apart from enabling a person to rest, it also offers opportunities to experience a specific environment, for example a park or a street with urban life, it may be used to observe, or, for sharing the bench with others and for social purposes. Hence, it expands the reach where one may reach amenities and it enables opportunities for participation in urban life.

3.3 Barriers

Barriers—that, is where some people are hindered by the environment—may be the more conventional understanding of Universal design challenges. For analysis, this can follow a rather simple procedure similar to the one by Heitor et al (2013): we simply remove the lines or portions of lines which are reported as inaccessible or avoided. This allows to analyze whether ostensibly small or large differences have small or large effects from a systemic perspective. That the amount and character of change is difficult to predict has been shown in for instance research regarding resilience (Abshirini and Koch, 2017), but while difficult to predict, changes definitely follow patterns based on both morphological context and character of change (Peponis et al., 2015).

We will base the analyses of barriers on a questionnaire conducted together with the disability rights organization of Uppsala municipality (Funktionsrätt Uppsala kommun), with 44 respondents in total from a range of different disability rights member organizations. The questionnaire asked basic information of how the respondents would describe their disability, use of particular types of services (including public transport), particular streets and other locations, and more open questions regarding types of locations (hospitals, malls, public buildings, streets, squares). While the data is limited so individuals cannot be identified, it is important for integrity reasons to be careful with it. Therefore, when we present maps of 'individuals', they never represent *all* reported challenges from an individual. By and large, this is achieved by limiting the analytic area to central parts of the municipality, leaving it unknown whether the respondent provides answers on other areas. Since *all* respondents comment on the inner city, while how much and where they report in other parts of Uppsala varies greatly, the data in the inner city can then be considered anonymous. For the same reason, we will limit the analysis to the city. Lastly, one should be careful to assume that the questionnaire provides *all* locations any respondent finds difficult, why as we analyze the configuration for different respondents, the analyses are of the affordance for 'fictive' individuals rather than real.

Individual perception 1

The first respondent is quite specific, both in responses to questions of particular locations, and in the way the more open questions are answered, almost always pointing to specific streets or

intersections, and providing clear details when questions have a more general character. This may be a character of the respondent, but allows for analyzing the effects of removing these specific spaces from the analysis. We interpret a response that a public square is inaccessible as that it also is a barrier to pass through, and that if a street (or portion of a street) is inaccessible, that it is also a barrier to cross. This may exaggerate some of the effects, but as we are here working to demonstrate potential, we believe the risk of some exaggeration is a smaller problem than the minimizing of problems that could come from the opposite assumptions. In this case, it is a few specific streets and squares, and one bridge.

Individual perception 2

The other respondent, in addition to a few specific locations, rather says they avoid the area "from the cathedral to Svandammen", an area of roughly 500*200m, because "many of the sidewalks are narrow and difficult to use". While it may be functionally possible to traverse the area (in both directions), and navigate in or through it along select streets, the whole area is avoided due to 'enough' presence of problematic elements. In addition, they mention a number of concrete squares, streets, and other locations such as the Botanical Garden. By combining 'areas' with some specific locations, the respondent provides a composite map where a portion of the city is 'blanket avoided', while specific street segments are also added to the mix.

Analytic results

The initial question is then whether these reported challenges are local, or have system effects. There are many different aspects of such a question, but we will look on a larger scale on global (here analyzed as radius 45) and local (here analyzed as radius 3) integration in an axial map (Figures 6 through 9). For the global measures, we can see that both the first and second respondent, there are noticeable changes to the pattern of centrality on a wider scale, also outside of the areas directly affected. However, some of the larger changes seem to not affect some parts of the very core of Uppsala that much, which is in line with the findings of Abshirini and Koch (2017), showing how two conditions seem to mitigate disruptive effects: in general, distributed systems, or distributed parts of systems, are more resilient to differences, if the difference are in the distributed part of the system.

We also note that there are two types of changes; absolute integration values, and relative integration values. In general, changes are more notable on absolute values, and, predictably, in absolute numbers integration turns lower. These changes spread far out in the city, meaning that the differences that are mostly in the very center of Uppsala 'pulls the whole municipality apart', making the more peripheral streets even more peripheral. However, as it comes to *relative* values, the changes are somewhat less predictable, and relative integration is more often *redistributed*. Uppsala is a more segregated city for the 'individuals' we have mapped, but not only that, which streets and areas are most central is partially different.

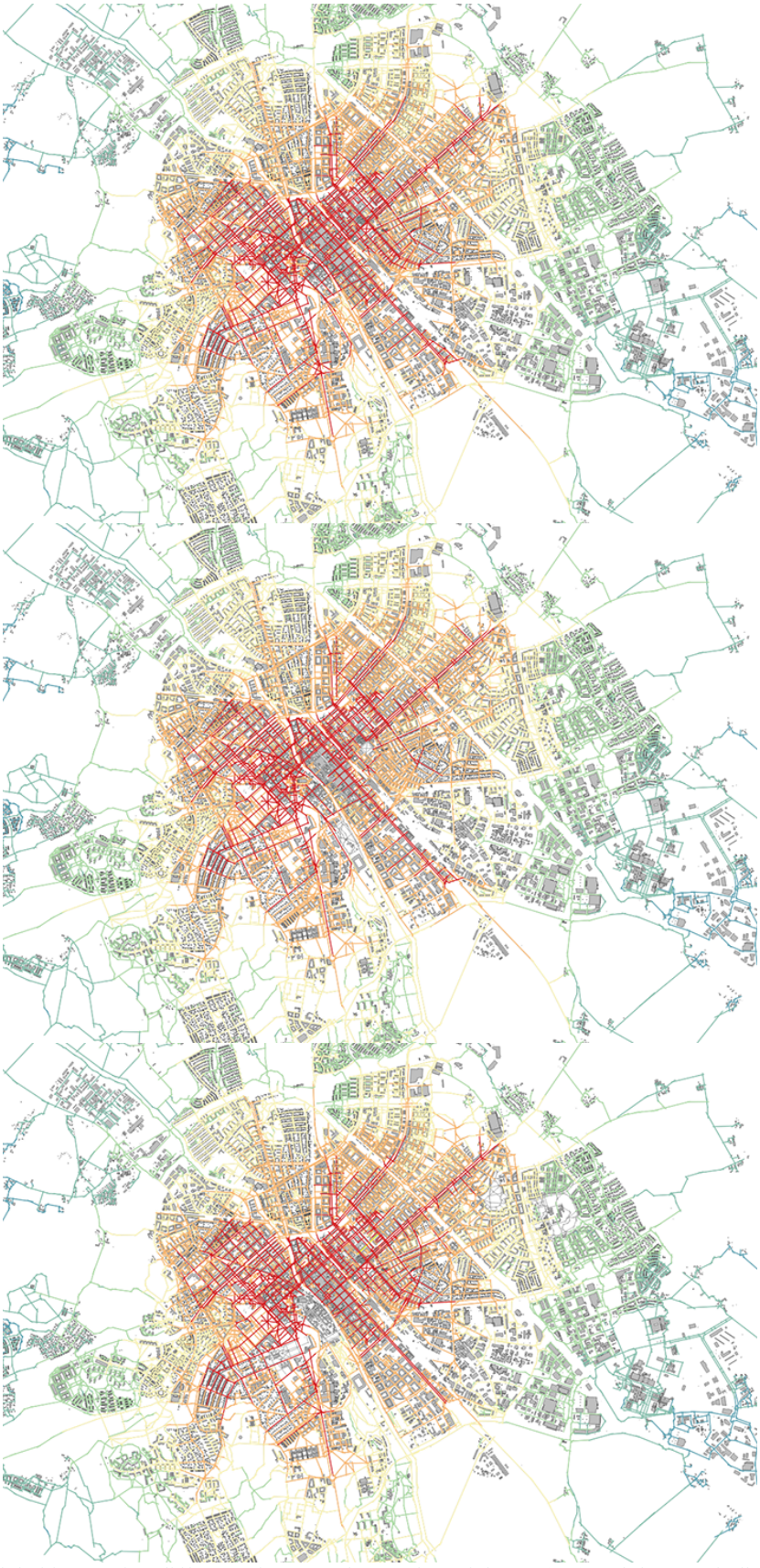

Figure 6: Global integration difference between the regular axial map (top) and the two 'individual' axial maps in a larger scale of Uppsala (in numbered order middle and bottom). Global scale as radius 45. The color scale is adjusted to be more sensitive at higher integration values, since the periphery of Uppsala (not in the figure) is noticeably more segregated than the studied area. The value ranges show the relative integration of each individual map.

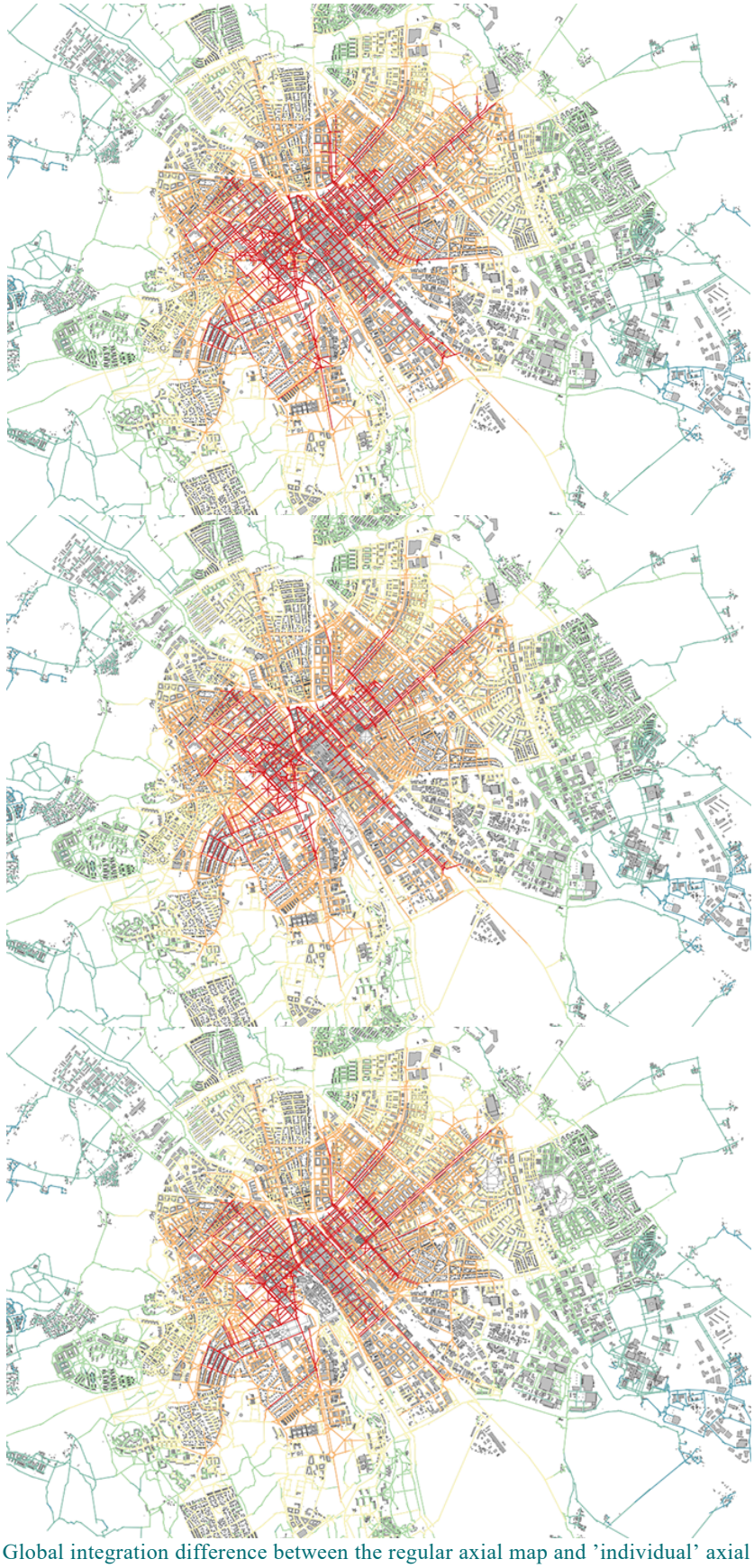

Figure 7: Global integration difference between the regular axial map and 'individual' axial maps in a larger scale of Uppsala. Global scale as radius 45. The color scale is adjusted to be more sensitive at higher integration values, since the periphery of Uppsala (not in the figure) is noticeably more segregated than the studied area. The value ranges are the same for all maps.

For instance, a south-eastern part next to the central core of Uppsala, which is an area where no changes to the map have been made, becomes relatively less central for the first individual, but relatively more central for the second (e.g., the 'continuous bend' of red lines in the latter), whereas in absolute integration it is less integrated in both cases. For both, the effect is largest in the east and south, while the northwest is largely unaffected.

On a local level, the change is also clearly visible in both cases, partially because it more obviously affects the very central core of Uppsala. Again, the difference between the 'standard' map and the individual maps is not uniform, and the changes also affect parts that are not directly related to the lines that are different. While one might intuitively understand the difference in relative integration for global integration—a location can be relatively more central in the system as a whole when another is made less central—just how to interpret the relative distribution of local integration is not quite as easy, although it would suggest that different places would be experienced as well-connected for different 'individuals'. What we can see is, further, that in absolute figures, the center of Uppsala is more heavily affected than in relative figures, and more affected in local than in global integration.

In both global and local integration, we can further see how, on an overall level, the southern part of Uppsala city and the network reaching out towards the southern suburbs—west of the river and south of the center—is more sensitive than other directions even whether directly affected or not. This seems to be linked to how the network connects across the river in this direction, with increasingly few and complex links to and from bridges. Thus, addressing some of the discovered patterns may also include efforts outside of the location of the reported problems: the network effects of the challenges to mobility would be smaller if a pair of simpler and more straight-forward connections were established across the river to the south.

Figure 8: Local integration difference between the regular axial map and ‘individual’ axial maps. Local scale as radius 3. The value ranges show the relative integration of each individual map.

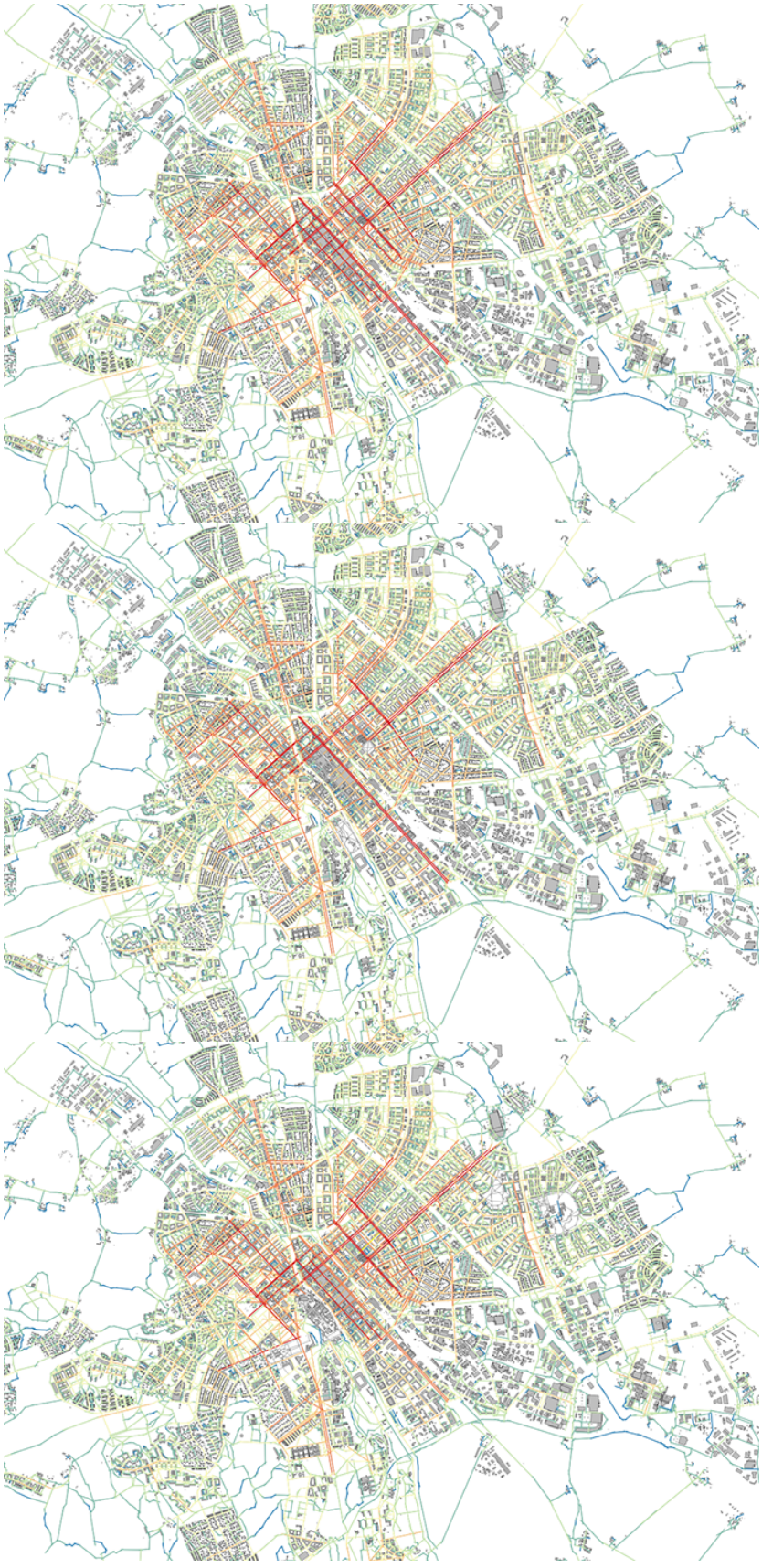

Figure 9: Local integration difference between the regular axial map and 'individual' axial maps. Local scale as radius 45. The value ranges are the same for all maps.

4 DISCUSSION

In many ways the reasoning of the research and of our analysis is in line with established ideas of differences in how people understand 'centrality', such as the difference between inhabitant and visitor perspectives in buildings (Hanson, 1998; Hillier and Hanson, 1984); that is, depending on *for whom* and *in what context* the analysis is performed, what spaces are included in the analysis is differentiated (e.g. including an exterior or not). However, while arguably implied in the works of Hillier and Hanson, the principles for 'included spaces' in our analyses is quite different. But what do these analyses show, and what do they in extension imply?

The analyses of 'system-world' factors demonstrate how the entire municipality can be radically different for different individuals, and that while some of this may be 'latent' since not all parts are experienced by everyone, the system level effects may be significant. They point to how, in addition to Universal design challenges being important for individual's rights and conditions, they may create layers of social segregation and inequality on the collective scale that go beyond reaching individual locations. The city may, quite literally, be more segregating for some than others—and may appear as archipelagos of disconnected islands where it for others works as continuity, with further effects on behavior and perception driving inequality and segregation not only in access but in who-meets-whom and who can experience what (kind of) environments. In extension, it may affect our understanding of 'who' is part of society.

The 'system-world' analysis also becomes important for urban planning and design work, since it helps understand which challenges are related to physical planning in particular, and what may relate to other factors, including the degrees to which it relates to different aspects of municipal work. It can further help to understand whether an effort is likely to, in short or long term, have larger scale benefits or if it operates more locally. Both types of efforts are valid and can be important, but precision in which is which, where, is also important—not only for the municipal planning 'in itself', but for dialogue and communication with citizens. An effort communicated as addressing 'system' challenges may even backfire if it does not, and a challenge treated as either on system or local scale may be addressed wrongly if understood in the wrong way. We argue that a better understanding of whether there are local or global effects as a result of different barriers supports the municipal decision-making process and in prioritization of when and where to work with addressing problems in the built environment.

The two 'life-world' analyses of individual affordances must be understood in the light of the previously mentioned respondent's comment: while there are environmental conditions that have generated their environmental perception and what locations they avoid, this is not a continuously updated understanding. Rather, they make use of their knowledge and choose to avoid locations they consider problematic, not returning to 'update' themselves particularly often. What locations and environments they avoid is therefore based on what one could term 'projection', or at least expectation—although built on real-life experience (Koch, 2017; Netto,

2008). However, as the second individual analysis demonstrates, it also builds on metonymic understanding: individual or collections of perceptions can come to characterize whole areas, whether 'correct' or not and whether individually experienced or not (Augoyard, 2007). This supports the approach of the research in that it confirms that there are 'system effects' of individual challenges, but creates additional layers to the analytic challenge in that in addition to system effects that emerge from bundles of factors (e.g., several stairs), the bundles may serve to create *new* challenges by generating perceptions of entire streets or areas.

This, of course, relates to the very character of 'avoidance' as extending beyond direct reactions to local conditions. The place is avoided before even being thought of going to, and/or at the point of being thought of going to, rather than upon being discovered. Navigation choses other paths and directions well before being challenged by the particular locational properties (Koch, 2016). This poses challenges for research as well as for caring for these problems in practice: effects of improvements are slow and difficult to communicate, and the data of avoided locations gathered from informants are likely to be a patchwork of information with various age and thereby various degrees of current material validity. Using informants' statements to *directly* judge which locations are difficult is therefore problematic, and needs to be complemented or confirmed by on-site visits and for instance 'walking interviews', although 'walking' might seem to be particularly strange term to use in this context. However, the reverse is also true: using current information on the material environment may be 'true', but cannot be directly translated to the affordances of individuals here and now.

This is also of general importance: while discovered relations between material world, cognition, and behavior may be strong *over time*, there can be significant 'lag' between changes of the environment and effects on behavior. While this may sound obvious, it suggests that validation of analyses through observed behavior—when not in controlled experiments of currently newly experienced environments—will always contain a patchwork of spatial cognition, where people act in part on the 'current' configuration, and in part on previous experience—and in part on projection and expectation. This patchwork of information may further distort gathering of spatial information, or spatial learning (Montello, 2007; Marcus, 2018), where arguably, the less frequented spaces are, the slower the information will be updated. While the analyses of, for instance, benches are likely to provide an important and informative result concerning affordances, the step in-between environmental conditions and individual affordances needs to be taken into account. The analyses can thereby help the municipality understand where there are significant challenges with the environment, but must be complemented by understanding perceived challenges, as well as with dialogue and information efforts on what is done so that efforts to improve also land with those the improvements are meant to help.

There are remaining questions of how to work with such analyses as we do in a productive way, which are embedded in the very core of the research project. Some regular explanations or

interpretations of how and why correlations occur in syntactic research become more complex: the importance of memory and projection as parts of spatial cognition and navigating our environments becomes clear (Koch, 2017; Augoyard, 2007), as does the 'allocentric' aspects of cognition (Hillier, 2003; Piaget and Inhelder, 1956; Portugali, 2011). But it also asks to what extent spatial cognition revolves around the individual or the shared, collective understanding and use of a city. That is, whether a 'cognitive map' is built on the direct environmental experiences of the individual, or on a collective shared understanding of the environment. The questionnaire suggests that it is a combination, suggesting that explaining effects of syntax through cognition should more clearly include communication of spatial knowledge between people. Arguably connected to this, but also through the analyses of the 'individual' maps, the research suggests that rather than a plethora of individual affordances, certain ranges of understanding would be likely to *converge* whereas others might *diverge.* The regular axial map based on mobile walking individuals is likely to be one such converging cognitive map, but the implications reposition it in two ways: as a particular map of relevance for many, but not universally 'human', and while built on a spatial analysis that captures cognitive aspects of material arrangements of space, as fundamentally *social*.

There are of course many challenges remaining. Further in-depth work around specific environments where 'system-world', 'life-world' and 'material-world' can be scrutinized and brought to align with one another is central. In such work, a challenge is to understand when specific challenges, or collections of specific challenges, translate into perception of whole areas, such as how respondents say they do not go to the inner city because of difficulties to navigate a number of streets and blocks—while might be possible for them to navigate fair portions of the area. This is important both in terms of how to work with analysis, and how to work with data gathering and digitalization, which affects how municipalities need to build their geographic information to allow these kinds of analyses with precision and relevance. But with this said, the approach can help to understand whether an effort to address universal design challenges is likely to, in short or long term, have larger scale benefits or if it operates more locally. While ideally such understanding is supported by accurate and systematically gathered information, the experiments made in this project suggests a lot can be learned also through targeted efforts.

5 CONCLUSION

While the implications and questions raised through the research and analyses are important, we will conclude by refocusing on the more concrete results of the research and their implications for spatial analysis, municipal planning, and digitalized geographic information, as well as some concrete challenges. While Uppsala municipality have well-developed policies and programs with the aim to increase accessibility and foster participation, especially addressing people with special needs and disabilities, it has been illustrated how different 'molecular' challenges, local barriers and constraints, in some cases may aggregate and affect accessibility in a larger 'molar' scale. The paper describes three different situations may be captured and what such analyses may

contribute with but also the complexity in terms of data gathering, data quality, constructing an adequate model on the one hand, and, on the other hand, the difficulty to capture how different users perceive environments, either in their minds or as a result of embodied experience.

The analyses clearly demonstrate how small, local, differences in accessibility can have large-scale effects. They show how small 'objects' such as public benches can manipulate systemic accessibility and make or break urban continuities, and how for instance street surface can redistribute accessibility and centrality between individuals. They further demonstrate how the city may look quite different, both in terms of what is, in particular, accessible or not, far away or close by, but also in patterns of navigational centrality. Both through or analyses and through our work together with the municipality and the disability rights organizations, the validity of the approach is confirmed, while the extent of their direct representativity needs further development and empirical corroboration. However, through the process of performing the analyses, an understanding of Uppsala grows forth in terms of what parts are generally—or more often—affected and which parts remain more stable. While doing analyses for every difference is impossible, we can further see how a few analyses lead to a better understanding of where the structure of Uppsala is sensitive even if they are 'particular' for select individuals. It also suggests that while there may be large differences to be found if one looks at the conditions for people with different disabilities, systemic patterns are likely to emerge, converging towards a smaller set of overall patterns. We also note that a more distributed system is more resilient to difference (i.e., the effect of removing links generally is smaller), but that this must be complemented by that the questionnaire suggests that differences are more often reported (and thereby possibly more often perceived) in central parts of the system.

Perhaps most importantly, the capacity for the analysis to bring universal design questions from the local, 'molecular', to the system scale, 'molar', also enables it to more easily be integrated in comprehensive planning and strategic urban design and development discussions—as well as in formulating strategies for accessibility work 'in itself'. Especially when it helps bringing 'life-world' problems into 'system-world' ways of operating, in a form that allows it to be understood on a structural urban scale. When building an understanding of what affects accessibility and affordance on a larger scale, efforts can be made on that scale, in addition to addressing the local situation—and some challenges can be mitigated by addressing problems by investments made ostensibly 'elsewhere', to make the structure less sensitive to individual differences if and when they occur.

REFERENCES

Abshirini E and Koch D (2017) Resilience, space syntax and spatial interfaces: The case of river cities. *A|Z ITU Journal of the Faculty of Architecture* 14(1): 25-41.

Augoyard J-F (2007) *Step by Step: Everyday walks in a French urban housing project.* Minneapolis: University of Minnesota Press.

Bafna S, Maitra KK, Kim Y, et al. (2021) Association between home layout connectivity and cognitive ability in community dwelling older adults: Implication for occupational therapy. *Journal of Design for Resilience in Architecture & Planning* 2(special issue): 18–33.

Berghauser Pont M, Ståhle A, Marcus L, et al. (2019) PST. Stockholm and Gothenburg: KTH and Chalmers.

Bricout JC and Gray DB (2006) Community Receptivity: The Ecology of Disabled Persons' Participation in the Physical, Political and Social Environments. *Scandinavian Journal of Disability Research* 8(1): 1-21.

Ceccato V (2017) Women's transit safety: making connections and defining future directions in research and practice. *Crime Prevention and Community Safety* 19(3-4): 276-287.

Conroy-Dalton R and Bafna S (2003) The syntactical image of the city:a reciprocal definition of spatial elements and spatial syntaxes. In: Hanson J (ed) *Proceedings of the 4th International Space Syntax Symposium*. London: Space Syntax Laboratory, pp.59.51-59.22.

Conroy-Dalton R and Kirsan C (2005) Graph Isomorphism and Genotypical Houses. In: van Nes A (ed) *Proceedings to the Fifth International Space Syntax Symposium*. Delft: Techne Press, pp.16-28.

Crenshaw K (1989) Demarginalizing the Intersection of Race and Sex: A black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics. *University of Chicago Legal Forum* 1989(1): 139-168.

Cutini V (2007) Accessibility and Exclusion: The Configurational Approach to the Inclusive Design

of Urban Spaces. In: Koch D, Marcus L and Steen J (eds) *Proceedings of the 7th International Space Syntax Symposium*. Stockholm: KTH, pp.21:21-21:13.

Cutini V, Farese D and Rabino G (2020) Configuration and resilience: some remarks from the cases of Florence and Milan. *Plurimondi* 18: 35-51.

Dalton RC (2005) Space Syntax and Spatial Cognition. *World Architecture* 11: 107-111.

Dalton S and Dalton RC (2009) Solutions for Visibility Accessibility and Signage Problems via Layered Graphs. In: Koch D, Marcus L and Steen J (eds) *Proceedings of the 7th International Space Syntax Symposium*. Stockholm: KTH, pp.1-8.

de Holanda F (2021) Brasília: Superblocks in perspective. *Journal of Design for Resilience in Architecture & Planning* 2(special issue): 34-55.

Emo B (2014) Seeing the axial line: Evidence from wayfinding experiments. *Behavioral Sciences* 4(3): 167-180.

Esposito A and Di Pinto V (2015) Calm after the storm: The configurational approach to manage flood risk in river cities. *Proceedings of the 10th International Space Syntax Symposium*. London, pp.70:71-70:16.

Feng C and Zhang W (2019) Algorithms for the parametric analysis of metric, directional, and intersection reach. *Environment and Planning B: Urban Analytics and City Science* 46(8): 1422-1438.

Gibson JJ (1977) The theory of affordances. In: Shaw R and Bransford J (eds) *Perceiving, Acting, and Knowing*. Hoboken: John Wiley and Sons, pp.67-82.

Gibson JJ (1979) *The Ecological Approach to Visual Perception.* Boston: Houghton Mifflin.

Grzeschik R, Hilton C, Dalton RC, et al. (2021) From repeating routes to planning novel routes: the impact of landmarks and ageing on route integration and cognitive mapping. *Psychological research* 85(6): 2164-2176.

Gustafsson S (2013) *Möjlighet att sitta för att kunna gå: En fältstudie kring tillgång och användbarhet av bänkar i Sala backe i Uppsala*. Swedish University of Agricultural Sciences, Uppsala.

Habermas J (1987) *The theory of communicative action Vol. 2 Lifeworld and system : a critique of functionalist reason.* Cambridge: Polity.

Hanson J (1996) The architecture of justice: Iconography and space configuration in the English law court building. *Architectural Research Quarterly* 1(4): 50-59.

Hanson J (1998) *Decoding homes and houses.* Cambridge, UK: Cambridge University Press.

Hanson J (2004) The inclusive city: delivering a more accessible urban environment through inclusive design. *RICS Cobra 2004 International Construction Conference: responding to change.* York, UK.

Heitor T, Nascimento R, Tomé A, et al. (2013) (In)accessiblte Campus: Space syntax for universal design. In: Kim YO, Park HT and Seo KW (eds) *Proceedings of the Ninth International Space Syntax Symposium*. Seoul: Seoul University, pp.84:81-84:17.

Hillier B (1996) *Space is the Machine: A Configurational Theory of Architecture.* Cambridge: Cambridge University Press.

Hillier B (2003) The architectures of seeing and going: Or, are cities shaped by bodies or minds? And is there a syntax of spatial cognition? In: Hanson J (ed) *Proceedings to the 4th International Space Syntax Symposium*. London: Space Syntax Laboratory, pp.6.1-6.34.

Hillier B and Hanson J (1984) *The Social Logic of Space.* Cambridge, UK: Cambridge University Press.

Hillier B and Iida S (2005) Network Psychological Effects in Urban Movement. *Lecture Notes in Computer Science* 3693: 475-490.

Hillier B, Yang T and Turner A (2012) Normalising least angle choice in Depthmap - and how it opens up new perspectives on the global and local analysis of city space. *Journal of Space Syntax* 3(2): 155-193.

Hölscher C, Meilinger T, Vrachliotis G, et al. (2006) Up the down staircase: wayfinding strategies in multi-level buildings. *Journal of Environmental Psychology* 26(4): 284-299.

Iwarsson S and Ståhl A (2003) Accessibility, usability and universal design—positioning and definition of concepts describing person-environment relationships. *Disability and Rehabilitation* 25(2): 57-66.

Kim YO and Penn A (2004) Linking the spatial syntax of cognitive maps to the spatial syntax of the environment. *Environment and Behavior* 36(4): 483-504.

Koch D (2005) Parallel spatial scales - discerning cognitive levels of space. In: van Nes A (ed) *Space Syntax 5th International Symposium: Proceedings*. Delft: Techne Press, pp.373-386.

Koch D (2012) Architectural Disjunctions: Morphological identity and Syntactic Contrast of Visibility and Permeability. In: Greene M, Reyes J and Castro A (eds) *Proceedings: Eight International Space Syntax Symposium*. Santiago de Chile: PUC, pp.8143:8141-8118.

Koch D (2016) On Avoidance: Reflections on Processes of Socio-spatial Structuring. *Civil Engineering and Architecture* 4(2): 67-78.

Koch D (2017) Memory, Projection, and Imagination: On Challenges for Observation and Statistics Based Research. *Contour 2: Agents/Agency of Urbanity* 2(1): 1-15.

Koch D and Miranda P (2013) Syntactic Resilience. In: Kim YO, Park HT and Seo KW (eds) *Proceedings of the Ninth International Space Syntax Symposium*. Seoul: Sejong University, pp.054:051-054:016.

Küller R (1991) Environmental assessment from a neuropsychological perspective. In: Gärling T and Evans G (eds) *Environment, cognition and action: An integrated approach*. New York: Oxford University Press, pp.111-147.

Law M, Cooper B, Strong S, et al. (2018) The Person-Environment-Occupation Model: A Transactive Approach to Occupational Performance. *Canadian Journal of Occupational Theory* 63(1): 9-23.

Legeby A (2013) *Patterns of Co-Presence: Spatial Configuration and Social Segregation.* Stockholm: KTH.

Lennartsson A and Blomberg Å (2019) Riktlinjer för sittplatser på allmän plats i Uppsala kommun. In: Stadsbyggnadsförvaltningen (ed). Uppsala.

Lid IM (2014) Universal Design and disability: an interdisciplinary perspective. *Disability and Rehabilitation* 36(16): 1344-1349.

Linder RJ, Eliasson J and Engström B (2017) *Linder, Rober, Jo., Eliasson, Jonny., & Engström, Bo. (2017). Äldrevänlig stad: om hur det är att åldras i Uppsala. Uppsala: Uppsala kommun.* Uppsala: Uppsala kommun.

Marcheschi E, Ståhl A, Almén M, et al. (2020) A Theoretical Model for Urban Walking Among People With Disabilities. *frontiers in Psychology* 11(156).

Marcus L (2018) Overcoming the Subject-Object Dichotomy in Urban Modeling: Axial maps as geometric representations of affordances in the built environment. *frontiers in Psychology* 9: 449.

Marcus L, Giusti M and Barthel S (2016) Cognitive affordances in sustainable urbanism: contributions of space syntax and spatial cognition. *Journal of Urban Design* 21(4): 439-452.

Marshall S, Gil J, Kropf K, et al. (2018) Street network studies: from networks to models and their representations. *Networks and Spatial Economics* 18(3): 735-749.

Montello DR (2007) The Contribution of Space Syntax to a Comprehensive Theory of Environmental Psychology. In: Kubat AS, Ertekin Ö, Güney Yİ, et al. (eds) *Proceedings of the Sixth International Space Syntax Symposium*. Istanbul: ITU Faculty of Architecture, pp.iv:1-iv:12.

Netto V (2008) Practice, space, and the duality of meaning. *Environment and Planning D: Society and Space* 26(2): 359-379.

Peponis J (2012) Building layouts as cognitive data: purview and purview interface. *Cognitive Critique* 6: 11-50.

Peponis J (2018) What Does the Syntax of Space Say? Understanding and Designing Buildings as Interfaces. *World Architecture* 179: 33-41.

Peponis J, Feng C, Green D, et al. (2015) Syntax and parametric analysis of superblock patterns. *Journal of Space Syntax* 6(1): 109-141.

Piaget J and Inhelder B (1956) *The Child's Conception of Space.* London: Routledge and Keegan Paul.

Portugali J (2011) *Complexity, Cognition and the City.* Dordrecth: Springer.

Psarra S (2018) *The Venice Variations: Tracing the Architectural Imagination.* London: UCL Press.

Uppsala kommun (2016) Program för full Delaktighet för personer med funktionsnedsättning. In: Kommunstyrelsen (ed). Uppsala.

Uppsala kommun (2020) Handlingsplan för äldrevänlig kommun. In: Äldrenämnden (ed). Uppsala.

Vanier C and d'Arbois de Jubainville H (2017) Feeling unsafe in public transportation: A profile analysis of female users in the Parisian region. *Crime Prevention and Community Safety* 19(3-4): 251-263.

Watchorn V, Hitch D, Grant C, et al. (2018) An integrated literature review of the current discourse around universal design in the built environment – is occupation the missing link? *Disability and Rehabilitation*.

Zhu J (2012) Seeing versus moving: A review of Julienne Hanson's 'The architecture of justice' (1996). *Journal of Space Syntax* 3(1): 55-61.

Zukin S (1995) *The Cultures of Cities.* Oxford: Blackwell.