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The challenges of teaching space syntax in urban design studio

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ABSTRACT

This paper discusses the challenges of integrating space syntax methods into urban design studio teaching, through the example of two teaching initiatives at different Swiss universities. The paper presents the aims, methods and case studies of each of the studios separately. Different forms of space syntax analyses were applied according to the topic of the studio, spanning network analysis, visibility graph analysis and plot accessibility analysis. A common aim across all semesters was to motivate students to explore the use of space syntax tools as a design tool. Students were encouraged to engage in an iterative design-analysis feedback loop, where findings from one analysis would inform a design intervention, which would then be analysed in turn, and so on. However, this proved challenging for a number of reasons. First, students require a minimum of theoretical training for the application of space syntax methods to make sense, and there is often no time in a design studio to teach enough of the theory. Second, the workflow pipeline between space syntax analysis and CAD is cumbersome. Third, space syntax researchers rely on a specific software or use a GIS plugin, all of which are new to students. The paper addresses the challenges faced in these teaching projects and discusses possible solutions.

KEYWORDS

Urban design studio, teaching, design-analysis feedback loop

1 INTRODUCTION

This paper reviews the challenges faced trying to integrate space syntax methods into urban design studio teaching. While many space syntax courses exist in architecture departments around the world, it remains challenging to introduce the methods in compulsory Bachelor and/or Masters of Architecture design studio teaching. This is because a design studio is a complex pedagogical environment that often engages in wicked problems (Rowe, 1994; Buchanan, 1992) and because, ideally, students would already have some space syntax knowledge before using the methods in a design studio.

1.1 Previous work

Several design studios use or have used space syntax methods in the past. Behbahani and colleagues review pedagogical efforts that are based in regular B-Arch and M-Arch courses and report the findings from an initiative that introduced space syntax into a year three Bachelors studio (2017). The authors comment that the breadth of material (theoretical and practical) to cover for entirely novice students is quite large, and that this impacted the extent to which students were able to get to grips with space syntax as a design tool. Reveron presents an interesting paper in which one test group of first year architecture students in Merida, Venezuela briefly engaged with space syntax methods in their design projects (2009). The work of those students was compared against a control group of students who were not exposed to space syntax. The author reports that the average depth of the projects (calculated as Total Depth, Mean Depth, Relative Asymmetry and Integration Value) in the experimental group's work was greater, suggesting that they processed spatial information differently than the control group. Schneider and colleagues describe a design studio in which architectural and spatial cognition elements were brought together to help students understand their projects from the users' perspective (2013). Having been introduced to space syntax methods and theory in lectures and through introductory workshops, students had to design a university building. The authors report that the students paid attention to the sequence of rooms (relating to spatial configuration) and on the geometry of the plan so that spaces with similar levels of privacy were clustered. Although not part of a B-Arch or M-Arch programme, and instead a unit in the MSc "Spatial Design: Architecture & Cities", Psarra, Kostourou and Krenz analyze how students combined different forms of knowledge in the E-merging Design Research studio course unit at University College London (2018). At the hand of four example projects from the Venice studio, the authors explain how "multiple convergent or divergent bisociations between the 'form-' and the 'syntax-of-classes'" were used (ibid, p.240). The authors also acknowledge that analytic processes can only go so far in the design process and that ultimately students will activate the type of knowledge (creative, analytic or otherwise) that they require in order to hand in the best possible design project. Our paper extends previous work by showing examples of teaching space syntax in compulsory B-Arch and M-Arch urban design studios.

1.2 Space syntax methods

Space syntax is a set of methods and techniques that can predict how people will behave in a space by analyzing the layout of the space (Hillier and Hanson, 1984; Hillier 1996). The methods can be applied at building or urban scale[1]; for an introduction to both scales see Bafna (2003) and Karimi (2012) respectively. Different methods exist to examine different types of behavior; in

[1] This paper discusses urban-scale design studio teaching only.

this paper, we discuss network analysis, visibility graph analysis (VGA), and plot accessibility analysis. The power of space syntax is the ability to predict behavior based on relatively sparse input information: either a floorplan or the street network, depending on the type of analysis. What ties the various techniques together is the fundamental tenet that the use of space is a function of how spaces connect with one another.

In space syntax, network analysis transforms the street network into a dual graph, whereby the streets are the nodes and the connections between streets are the links in the graph. Graph-theoretic measures of centrality have been shown to relate to different types of movement through the network (Hillier et al., 1993) (mainly at aggregate, but also evidence for individual wayfinding decisions); it has been shown that predicted movement through a network correlates to between 60% - 80% when compared to observed movement (Penn, 2003). The analysis is done at street segment level as this allows for the inclusion of a weighting system for the angular deviation from the straight line, which has been shown to correlate to observed movement patterns better (Hillier and Iida, 2005). Streets that are more central are said to be more integrated in the network, and would expect to have higher flow through the street.

Visibility graph analysis (VGA) examines the mutual intervisibility between locations on a floorplan (Turner et al., 2001). Spaces that are highly visible are likely hotspots for social interaction are said to be more integrated. The floorplan is modelled as a graph, upon which various parameters can be calculated, which have been shown to relate to observed movement patterns. As for network analysis, VGA can be applied to building and urban scales.

Another type of analysis, plot accessibility analysis, was used to gain a better understanding of the spatial properties of the morphological structure of the city over time. Plot accessibility analysis is a parameter that stems from the Place Syntax Tool (PST) developed by space syntax researchers in Sweden (Ståhle et al., 2005)

1.3 Two teaching initiatives

The paper reviews two teaching initiatives at different Swiss universities spanning 2015 – 2021. The first initiative discusses one aspect of the project "Evidence-based design thinking: an interdisciplinary teaching approach for architecture students" which was a collaboration between the Chair of Cognitive Science and the Chair of Architecture and Urban Design at ETH Zurich between 2015 and 2017. This paper discusses the space syntax methods used over two semesters in that collaboration (named Studio 1 and Studio 2 below), which was just one method used as part of a larger project (Emo and Hölscher, 2020). The second initiative was the 'Zurich Gebaut' design studio (named Studio 3 below) held at Zurich University of Applied Sciences (ZHAW), taught by Urs Primas and Andri Gerber in autumn 2020. Both initiatives taught space syntax methods with the aim of exposing students to a design-analysis feedback loop, as discussed below.

2 DESIGN-ANALYSIS FEEDBACK LOOP

The essence of the design-analysis feedback loop is to provide a mechanism whereby design solutions are informed by findings from some form of analysis. A design-analysis feedback loop can be relevant for any type of analysis (such as energy, environmental data). In this paper we consider one type of analysis which focusses on how users perceive the built environment. In this user-centred workflow, the user of a space is considered on equal terms with the architect and the space itself (see figure 1). In this case, the steps that accompany the design process are analytic or relating to the actual use of the finished space (labelled in the diagram as "post occupancy evaluation"). Different types of analysis enter into the user-centred design toolkit, including space syntax, behavioural observations and behavioural experiments (Emo, 2019). The aim of the studios reported in this paper was to apply space syntax analysis as part of a user-centred design-analysis feedback loop directly in the teaching of three urban design studios.

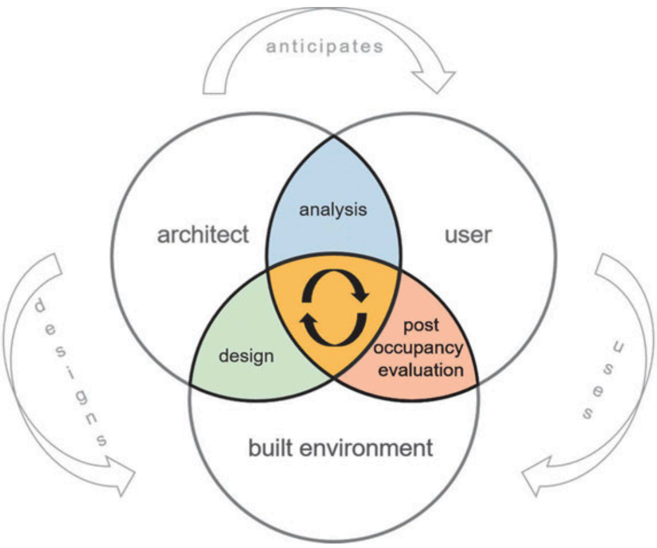

Figure 1: The design-analysis feedback loop, indicated at the centre of this diagram, is at the heart of the evidence-based design toolkit (image from Emo, 2019, after Dalton and Hölscher, 2017)

The challenges of being able to implement a design-analysis feedback loop, so that students experience this iterative process, are discussed in this paper. What is missing however is a theoretical framework whereby the value, and limitations, of using data-based methods in the design process are established.

3 STUDIO 1

The aim of this studio was to design a new urban neighborhood to house 100,000 people in Paya Lebar, an abandoned air base in Singapore (figure 2). The studio was tied with the Vertical Cities Asia 2015 design competition with the overarching theme "Everyone Contributes"[2]. Alongside a

[2] https://nuspress.nus.edu.sg/products/vertical-cities-asia-international-design-competition-and-symposium-2015-volume-5-everyone-contributes

holistic design that supports and sustains the wellbeing of the ecological system, the residential component of the intervention needed to be up to 50% of the total floor space. Students had to submit two main documents: a Design Report and a Research Report. Space syntax methods were introduced into the design studio as an addition to the regular pedagogical input of the studio to see if they could i) improve the quality of the overall proposal, and ii) make a significant contribution to the scientific quality of the Research Report.

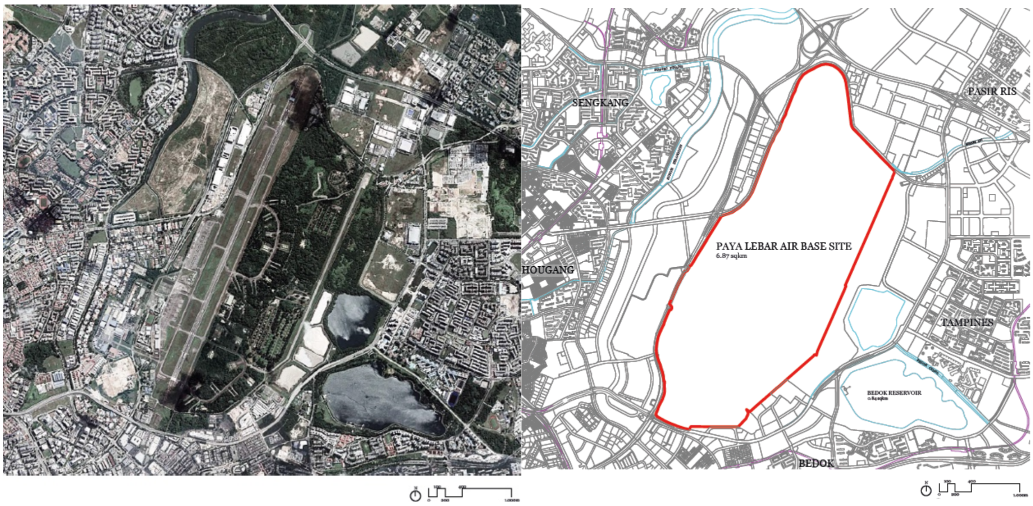

Figure 2. Arial view of the case study area (left) and demarcation of its perimeter with the existing street network (right).

3.1 Network Analysis

The main space syntax analysis taught in this studio was network analysis (figure 3). This is because the site had no existing infrastructure, no existing street network, and deciding on how to propose a layout for the street network for the future neighborhood was a major hurdle. The benefit of using space syntax network analysis was to be able to connect the proposed street network layout to expected flows through the network. Students were interested in both pedestrian and vehicular flows. Students wanted to find out how well their proposed street network fit with the existing network. The nature of the site meant that a newly-developed street network would in practice connect with the surrounding area in only a few places. The challenge was to be able to show that this connection was a fruitful one, mainly in terms of mobility.

Students were taught the basic principles of space syntax centrality-based network analysis and its predictive power for aggregate pedestrian flow. Given that students had no GIS knowledge, they were shown network analysis using Depthmap standalone software[3]. They were taught how to run Integration, Choice and Step Depth analyses. The base input file of road center line data was received from transport planners at the Future Cities Laboratory, Singapore. Students were supported in the preparation of the analysis, and in cases where the analysis would have taken too long, the course tutors ran the analysis on the students' behalf.

[3] https://github.com/SpaceGroupUCL/depthmapX

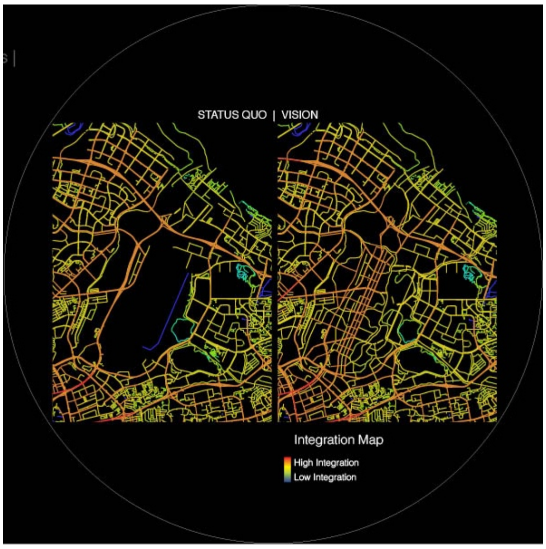

Figure 3. Network analysis, Integration, for the case study area.

Incorporating space syntax methods into the studio was challenging for a number of reasons. First, the layout of the street network was a crucial part of the design process, that was constantly being adapted and revised, and from which other crucial elements of the design, such as the placement of buildings etc., depended. Being able to motivate why the street network should follow any particular layout was a priority for the students. Space syntax tools had the potential to provide such motivation, however the students struggled to define the street layout precisely enough that a street network analysis was even conceivable. Thus a fruitful analysis could only be performed as validation, once the street layout had been more or less decided upon. This points to the fact that the space syntax method was used more as an evaluative tool.

A related issue was the cumbersome workflow pipeline between the design process, done in CAD, and the space syntax analysis, done in Depthmap. Students drew the masterplan in the usual urban design fashion, where each street is demarcated by two lines that indicate the boundary of the street to another surface. However the network analysis required road center-line data. This was problematic because students, who were novices in space syntax, could not embrace the deeper learning associated with producing a road center-line map, and instead wanted to be able to run the analysis quickly, without having to produce versions of their CAD drawing that were solely necessary for the analysis.

Another challenge was that students wanted to understand how both pedestrians and vehicles would move through the new neighborhood, and understanding both types of movement required different input files. The preparation of each type of input file could not be simply automated, and required making consistent decisions for each case.

Finally, the type of network analyses that were most meaningful for the studio involved placing the proposed street network into the surrounding street network, and the resultant analyses were large and took a long time to run. A workaround was to have the students share the input files that they wanted analyzed, and the course tutors would run the analyses for them (often on separate computers or on servers). This again pointed to the disconnection between the space syntax analysis and the design aims of the studio.

4 STUDIO 2

The aim of this studio was to propose a masterplan for the redevelopment of the former industrial harbor area of northern Amsterdam (figure 4). The studio focused on the development of a mixed-used neighborhood in northern Amsterdam, as well as how that neighborhood was connected with the rest of the city. The City of Amsterdam already had a number of developments planned, such as three new bridges over the river Ij, from which students' projects could benefit.

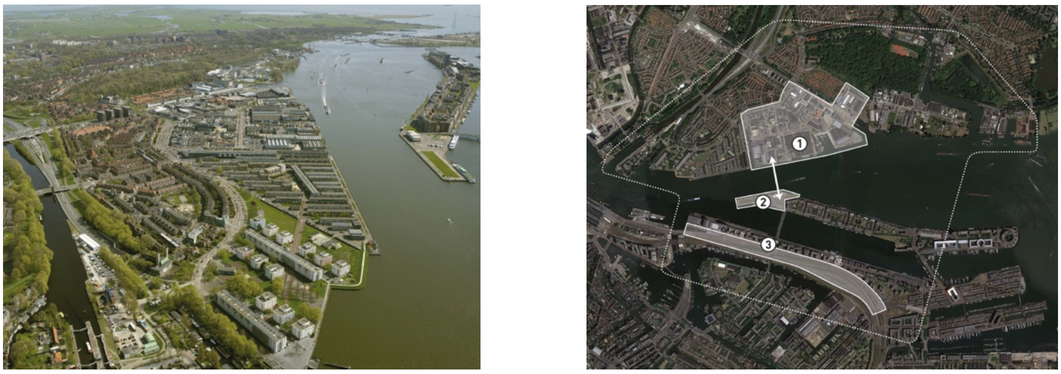

Figure 4. Arial photograph (left) and plan view (right) of the case study area: Hamerstraad neighborhood in north-easternern Amsterdam (1), the connection with the head of the Java island (2) and the area by the Central Station (3).

Space syntax methods were introduced in the studio to explore i) the social quality of the neighborhood and ii) how integrated that neighborhood is to the rest of the city. As in the previous studio, given that students had no GIS knowledge, the standalone software Depthmap was used. Different methods were used to tackle each topic.

4.1 Network Analysis

Network analysis was used to analyze how integrated the new neighborhood is to the rest of the city. This topic was especially exciting given that students were able to include in their analysis three new bridges already in planning by the City of Amsterdam. The base input file of the street network was based on Open Street Map data and needed polishing before being used to run the network analysis. Students were given an overview of what a network analysis can show, and were taught how to run Integration, Choice and Step Depth analyses in Depthmap.

Students struggled with gaining any real meaning from the network analyses. Many of the challenges from Studio 1 were also faced here. The workflow pipeline required input files to be generated from the CAD drawing that included road center lines, whereas students typically drew roads in the way that is usual at masterplan level, where each road has two lines (and not just the single line of the road center line). Second, students wanted to explore vehicular and non-vehicular flows, which required generating different input files. Third, the analyses took a long time to run and the software often crashed, which, as in Studio 1, led to the course tutors running the analyses on behalf of the students.

Figure 5. Black and white network analysis, Integration radius n, of the case study area.

A new challenge was that the usual color scheme often used in space syntax graphics was seen as confusing; the classic Depthmap color scheme was felt to detract from the information being shown. In the sole graphic that was seen as helpful, shown in figure 5, a greyscale color scheme was used. It was felt that the inclusion of this graphic was symbiotic with the other graphics shown in the presentation of the design project.

4.2 Visibility Graph Analysis

Visibility Graph Analysis (VGA) was used to explore the social quality of the neighborhood. Students were introduced to the concept of visibility analysis and its link to potential social and behavioral patterns. Students were taught how to perform a visibility graph analysis for area, through vision, and visibility step depth. Of these three measures, students were most comfortable with step depth: they understood how step depth is computed and were able to explain the graphic and its link to expected social behavior convincingly.

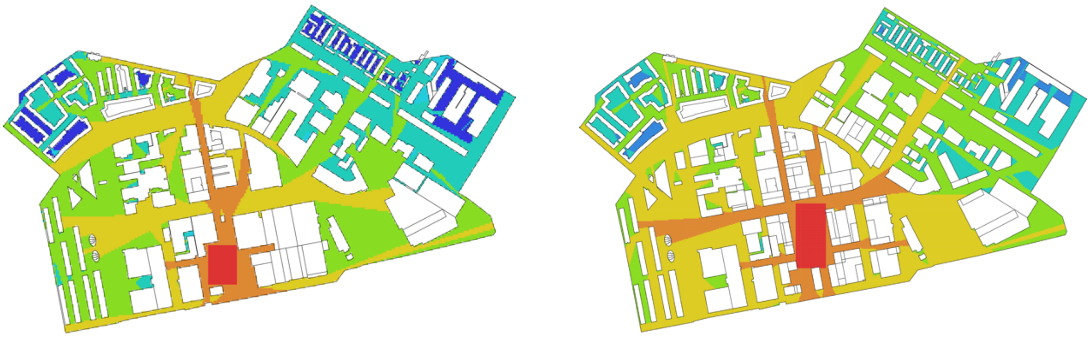

Figure 6. VGA analysis of the case study area showing Visibility Step Depth for status quo (left) and design proposal (right).

The application of visibility step depth as a means of analyzing the change in the social quality of the neighborhood between the status quo and the design proposal was successful for one group of students, who were able to show that the residential area in the design proposal was more integrated in the community than in the status quo. This is shown convincingly in figure 6, which shows that while the residential area remains in the same location, changes to the size of the central neighborhood square mean that residents are now better visually and spatially connected to the central square. The graphic output of this VGA analysis was very easy to present and easy to understand by people not involved in the studio (including the guest critics).

Not all students were able to use VGA to such a success. A major challenge was the fact that the input file for the VGA needed to be a revised version of the CAD file that students were working on that identified merely the walkable space. The process of producing a revised input file for running a VGA was time-consuming. Students also viewed this task as additional to their studio work, although it can be argued that creating such an input file forces the student to consider more in depth how their design proposal will be eventually used. Another challenge was that the parameters (Area, Through Vision and Step Depth) were new to the students and they were not always able to explain what they meant convincingly.

5 STUDIO 3

This studio aimed at providing master-level architecture students with a deeper understanding of the historical depth of cities. Acting inside the historical core of a city, it can nowadays be hard to consider the built environment as something historically grown which may evolve further, rather than as a static and immutable datum. Using the core area of Zurich as a case in point, a combination of morphological analysis, space syntax and scenario technique was applied in an open-ended way to discover threads from the past that could be picked up and woven further to write stories for the future (figure 7). The theoretical basis for this setup was a combination of the study of the diachronic evolution of street networks through Space Syntax with a process-oriented approach to urban morphology (Primas 2021).

Figure 7. Perimeter of case study area shown in white.

In the first phase of the studio the students were asked to analyse the structural evolution of the city core over a period of 1100 years, focusing on morphological changes happening between nine moments in time (figure 8). The first step involved the mapping of a series of time sections (900, 1050, 1350, 1800, 1850, 1900, 1950, 1990, 2020) based on recently available, georeferenced historical maps. Working backwards from the present-day dataset, a base map for each time-section was compiled in QGIS. These maps showed water bodies, building footprints, plot patterns (if available) and road centrelines. Furthermore, a differentiation between basic and specialized buildings was introduced. The road centreline maps were then used to produce analyses of choice and integration values for each time section and on various radii. Where plot patterns were available (from 1800 onwards), also the overall plot surface accessible through the network was calculated for each plot. Both types of analysis were performed in QGIS using the PST plugin (Ståhle 2012).

The compilation of the maps was done in nine groups and took about three weeks. In parallel, the students received introductions into process-based urban morphology, and an introduction into Space syntax. The result was a thorough understanding of the dynamics of development, in particular concerning key elements of urban morphology such as roads, water bodies, gates, walls and other types of borders, and their influence on the evolution of centralities and functions. On this basis, the second phase of the studio was dedicated to the development of four scenarios for possible transformations in the next fifty years, thus adding new, hypothetical layers to the historical ones that had been studied. In order to allow enough space for the analytical and scenario phases, this last phase was much shorter than usual in design studios.

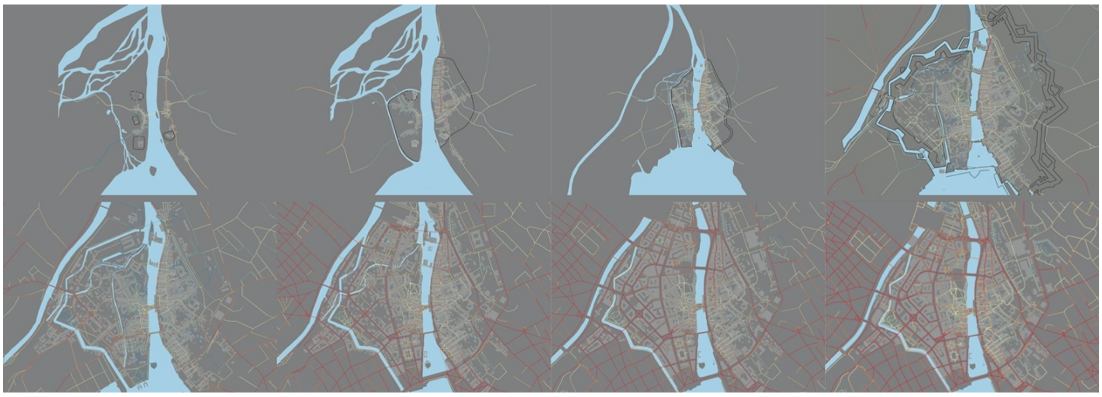

Figure 8. Historical evolution of street networks, building footprints and water bodies. Top left to right: 900, 1050. 1350, 1800. Bottom left to right: 1850, 1900, 1950, 1990

5.1 Network Analysis

The comparison of the network analyses of the different time sections led to surprising discoveries that not only inspired the scenarios in many ways, but also triggered the identification of topics for further research to be pursued outside the framework of the studio (figure 9). First of all, the visual comparison of centrality distributions over time highlighted a couple of crucial transitions in the evolution of the network such as the impact of the continuous reconfigurations of the western entrance to the city, the massive shifts in integration values around Central Station between 1870 and 1915 or the transition of river and lake from logistical backyards to stages for urban life. While urban historians have long identified the importance of these transitions, the space syntax analyses allowed to assess them in a systematic and traceable way. Furthermore, it became possible to evaluate the impact of individual interventions on the overall configuration, sometimes leading to a revisiting of received ideas. For instance, it turned out that the decisive association of central station with the highest global integration values was not yet achieved after the opening of Bahnhofstrasse in the late nineteenth century, but only after the opening up of a new east-western axis in 1913. As this connection does not directly link to the central station, its importance for the overall repositioning of the station within the network may have been underrated.

Figure 9. Normalized Angular Integration values for a 1000m radius around Central station in 1850 (left), 1900 (middle) and 1950 (right)

The challenges of this analytical phase were considerable. First of all, most of the students had no previous experience with GIS. A crash course provided them with some basic skills, and in the end at least one student per group mastered the software sufficiently to be able to perform the required analyses. However, the technical difficulties turned out to be more time consuming than expected. This was not least due to some fundamental misunderstandings of GIS typical for seasoned CAD users. Many students initially understood their GIS project not as a database, but as some kind of complex CAD file, leading to cumbersome workflows and in one case even to the loss of previously mapped data. Another set of problems concerned the mapping of historical networks. While the 2020 road centreline input had previously been prepared and tested, the students had to adapt this dataset for earlier time sections, erasing street segments that did not yet exist and adding those that no longer existed later on. A rather trivial, but complex problem was caused by the setup of this workflow. As each time-section was created by adapting the next newer one, students would inherit, and not correct, errors implemented by the previous group. In this way, minor errors would accumulate, leading to an inferior quality of the network maps for the time before 1800. On a more fundamental level, the students also encountered some basic – and to date largely unresolved – challenges of historical GIS. As many streets initially emerged on private grounds and were made public and eventually straightened out only later on, the decision when to keep a particular street segment and when to adapt or entirely erase it can require quite demanding considerations. A final challenge concerned the understanding of what is actually mapped in space syntax network analyses. Many students initially understood these maps as a kind of traffic modelling, probably because they were already familiar with similar-looking representations of traffic flows. It was necessary to insist on the fact that it is morphological information only that enters the model – no input about density, public transport access points or land use was considered – and that it is actually quite remarkable that such a model correlates, for instance, with observed pedestrian flows.

5.2 Plot accessibility analysis

Complementing the network analyses, the PST plugin was also used to calculate the plot surface accessible from each origin plot within different angular and metric radii for the time sections where plot patterns were available (figure 10). While the results of these analyses suffered from a series of shortcomings, they provided an extremely helpful alternative view on the evolution of centralities. The possibility of visualizing relative accessibility not only for street segments, but also for plots led to an understanding of shifts in relative location undergone by individual plots or buildings following adaptations that might have occurred in quite distant parts of the network. Such representations can play a key role in developing an understanding of the interactions between local potentials and the global properties of spatial networks.

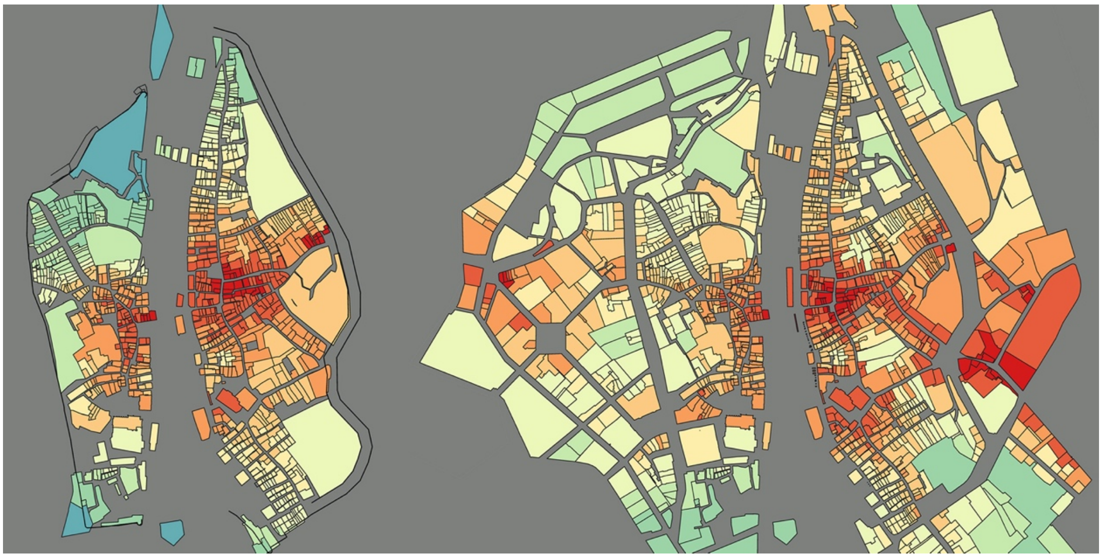

Figure 10. Accessible plot surface within a 1000m radius within the medieval walled city (1350, left) and after the demolition of the baroque fortifications (1850, right).

A major limitation for plot accessibility analysis was the fact that, as opposed to the road centreline maps, plot maps were only available for the study area itself. This caused significant distortions along the edges, because the accessible plot surface outside the study area was not considered. We also found that plot size tends to bias the results because the accessible surface on other plots is significantly smaller when measured from the centre of a very large plot than when measured from the centre of a small plot. This bias could be avoided by a time-consuming mapping of access points to each plot, something that was not possible within the framework of the studio. Finally, the diachronic comparison of plot accessibility faces a problem of calibration. As the number of plots and the number of streets continuously grows, the accessibility values generally augment in each time section as well. While the normalization procedures in network analysis allow to a certain extent for the comparison of networks of different sizes, the accessibility maps as they had been produced in the studio only permitted a relative assessment within individual time sections.

6 RESULTS

The two pedagogical initiatives reported above showed some common challenges which are discussed here.

First, the amount of material to cover in an urban design studio, even without trying to include space syntax methods, is already large. Urban designers tend to have to consider a large number of different aspects in their work, and learning how to do this is already challenging for students, even without the inclusion of space syntax. Having said this, to be able apply space syntax methods correctly requires some basic theoretical training. There is often little to no time in an urban design studio for such training. One way around this is to structure the entire studio around the space syntax methods (as shown in Studio 3), as opposed to trying to integrate a new method into an existing pedagogic program (this was the case in studios 1 and 2). Even then, the amount of space syntax theory that can be covered is small, with the result that students are not entirely comfortable with how the analysis works or explaining what the output graphics show.

Second, the workflow pipeline is cumbersome. This is off-putting for students who often need a solution quickly or even, if at all possible, instantly. We found that the cumbersome workflow was a deal breaker for students who wanted to test the methods for the first time, and for students who were willing to try the design-analysis feedback loop. The main issue was that the input file is not the same as CAD file, but needs reworking; and that the import/export process is cumbersome which leads to the separation of the analysis from the design process. Alongside the usual pressures of the studio deadlines, students simply did not have time to spend on these methods.

Third, there were numerous software issues. Space syntax network analysis works well using the Qgis Space Syntax Toolkit[4] (Gil et al., 2015). However, architecture students tend to have no prior knowledge of GIS (we have not ever had a student with GIS skills) and there is no time to teach students GIS in a regular design studio situation. One solution, as shown in Studio 3, is to provide students with a crash course in order to be able to complete the tasks at hand. However, there were numerous technical difficulties and troubleshooting issues. Another software issue in studio 3 was that PST prefers Mapinfo format for importing and exporting, which is doable but quite complicated in QGIS. Studios 1 and 2 taught Depthmap software instead, however students had several running and interface problems. It should be noted that many of the software issues that students of studios 1 and 2 encountered when performing VGA using Depthmap may have been resolved in newer versions, and/or be resolved in the newer Isovist software[5] which is an exciting alternative to Depthmap for visibility analysis.

7 CONCLUSIONS

In conclusion, it is not trivial to teach space syntax methods in an urban design studio. There are three main issues: 1) space syntax methods require a theoretical basis for which there is often no time within the constraints of a design studio; 2) the workflow pipeline between space syntax analysis and CAD is cumbersome; and 3) space syntax researchers rely on specific softwares or GIS plugins, all of which are typically new to students.

This paper argues that the value of integrating space syntax is to be able to improve the understanding of how users will end up behaving in the completed space. The vision of having students experience a design-analysis feedback loop was only partially fulfilled in the two teaching projects described in this paper given the effort required to get students to engage with

[4] https://plugins.qgis.org/plugins/esstoolkit/
[5] www.isovists.org

the methods in the first place. What we learnt is that students need to be clear of the potential benefits from applying such methods in their design project. Tutors should therefore clarify goals beforehand to make sure that students understand what can be expected from the application of space syntax.

Many space syntax courses worldwide are taught detached from regular design studio courses. This has the benefit that such courses can really focus on the theory behind the methods and students have time to explore what the parameters mean for a variety of case studies. In addition, in many cases students are taught GIS so that they are competent at using the various syntax tools for GIS. The disadvantage however is that space syntax methods are decoupled from the design process; emphasis is instead placed on space syntax's evaluative potential. This paper reported efforts to embed space syntax in design studio. The most promising approach is to plan the studio content around space syntax, as shown in studio 3; the combination of space syntax, morphological analysis and scenario technique allowed the students not only to understand past urban dynamics, but to also to build upon these insights for their own, creative and speculative projects and interventions. As more design studio teachers seek to implement space syntax seamlessly, the recently published textbook on *Space Syntax in Urban Studies* (Van Nes and Yamu, 2021) fills an important gap.

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